ISSN 1822-296 X (print)
ISSN 2351-7034 (on-line)

KAUNAS UNIVERSITY OF TECHNOLOGY
KLAIPĖDA UNIVERSITY
JSC LITHUANIAN RAILWAYS (AB "LIETUVOS GELEŽINKELIAI")
IFToMM NATIONAL COMMITTEE OF LITHUANIA
LITHUANIAN SOCIETY OF AUTOMOTIVE ENGINEERS
THE DIVISION OF TECHNICAL SCIENCES
OF LITHUANIAN ACADEMY OF SCIENCES
VILNIUS GEDIMINAS TECHNICAL UNIVERSITY
PUBLIC ENTERPRISE ROAD AND TRANSPORT RESEARCH INSTITUTE

TRANSPORT MEANS 2018

PROCEEDINGS OF THE 22nd INTERNATIONAL SCIENTIFIC CONFERENCE

PART II

October 03 – 05, 2018
Trakai, Lithuania

KAUNAS • 2018

CONFERENCE IS ORGANIZED BY
Kaunas University of Technology,
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Klaipeda University,
JSC Lithuanian railways (AB "Lietuvos geležinkeliai"),
IFToMM National Committee of Lithuania,
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PREFACE

22nd international scientific conference TRANSPORT MEANS 2018 will be held on 03-05 October, 2018 in „Trasalis – Trakai resort & SPA“, Trakai (Lithuania), Gedimino str. 26. It continues long tradition and reflects the most relevant scientific and practical problems of transport engineering.

The conference aims to provide a platform for discussion, interactions and exchange between researchers, scientists and engineers.

The reports cover a vide variety of topics related to the most pressing issues of today's transport systems development.

The main areas covered in plenary session and in the sections are: design development, maintenance and exploitation of transport means, implementation of advanced transport technologies, development of defense transport, environmental and social impact, advanced and intelligent transport systems, transport demand management, traffic control, specifics of transport infrastructure, safety and pollution problems, integrated and sustainable transport, modeling and simulation of transport systems and elements.

In the invitations to the conference, sent five months before the conference starts, the instructions how to prepare reports and how to model the manuscripts are provided as well as the deadlines for the reports are indicated.

Those who wish to participate in the conference should send the texts of the reports that meet relevant requirements under indicated deadlines. Each report must include: a short description of the idea or technique being presented, a brief introduction orienting to the importance an uniqueness of the submission, a thorough description of research course and comments on the results.

The submissions are matched to the expertise according to the interests and are forwarded to the selected reviewers.

Scientific Editorial Committee revises, groups the properly prepared reports according to the theme and design the conference programme.

The Proceedings are compendium of selected reports presented at the Conference.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Approach Procedures Optimization in Regard to Aviation-Related Noise Impact

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Abstract

This paper is focused on approach procedures and related noise impact on settlements close to airport. The objective is to evaluate four operational noise mitigation measures for Vaclav Havel Airport Prague runway 24, which is the most used runway at this airport. Evaluated mitigation measures are increased glide slope angle, curved approach, two-segment approach and displaced threshold. Based on MATLAB modelling, these measures are compared and the best one is chosen.
KEY WORDS: *approach, aviation, noise, mitigation measures, glide slope*

1. Introduction

Because air traffic is steadily increasing, it is necessary to manage and mitigate aviation noise more than ever before. In our research we focused on noise on Standard Terminal Arrival Routes (STAR) and especially on noise on approach.

Noise is one of the negative effects of air traffic, which is strongly perceived by the public and especially by people living in the immediate vicinity of the airport. Noise is perceived very subjectively, and it depends on many factors which are being influenced by our perception. These factors are e.g. the momentary psychic state or current emotions. Therefore, the tool for evaluating benefits of different noise mitigation measures was created.

The mitigation measures are various types from increased glide slope angles to curved approach [4]. In this paper these mitigation measures are described and the ones that could be used at Vaclav Havel airport Prague are evaluated.

2. Methodology

The aim of the work was to determine the possible noise savings caused by the implementation of methods reducing noise for runway 24 (RWY24) at Václav Havel Airport Prague. For determination of noise savings of individual methods, visualization tool was created in program MATLAB [7]. The output from MATLAB is the noise footprint for each method on map base. Based on our calculations and these visualizations, we determined which of these methods has the greatest noise savings (reducing the number of people affected by noise).

The mitigation measures are as follows:

1. Continuous Descent Approach (CDA) - CDA is operation where arriving aircraft descends without interruption by employing minimum engine thrust ideally (avoiding level flight) in low drag configuration. Generally it means that aircraft remains in a smooth descent profile instead of descending in a series of steps. The CDA procedure keeps an aircraft higher above the ground and therefore is quieter [3, 2].
2. Tailored arrivals - The tailored arrival profile is another procedure reducing noise on approach. TA is kind of continuous descent operation initiated from top-of-descent that takes advantage of aircraft automation to fly a specifically defined path. The path is “tailored” to current traffic conditions [3].
3. Low power/low drag operation (LP/LD) - This method is based on delayed deceleration approaches, where the aircraft is kept fast and in clean aerodynamic configuration for as long as possible during the approach phase of flight [1].
4. Increased glide slope angle - This kind of approach keeps the aircraft higher for as long as possible for reducing of perceived noise levels on the ground. Some airports such as London Heathrow or London City Airport are implementing this method of steeper approach [3].
5. Two-segment approach - This procedure is combinations of two different angles of glide slopes. First part of approach is angle of glide slope steeper than conventional 3° glide slope. This part of approach keeps arriving aircraft higher over nearby communities. Second part of this approach is conventional 3° glide slope [3].
6. Displaced threshold - This procedure permits an aircraft to land at a point further down the runway than the normal runway touchdown threshold. Displaced threshold is usually combined with method of steeper approach [3].
7. Runway preference - This procedure provides local communities living under the final approach parts of flight periods of relief from aircraft noise. The noise benefits arise due to runway alternation, it means that at certain time are

changed runways for arrival and departure. The affected area by noise is different in different time periods [6].

8. Arrival alternation - Arrival alternation is similar to runway preference, but instead of changing runways, arrival routes are changed during the day.

9. Curved approach – Curved approach is method, which needs to be supported by approach system, but with the development of GNSS, these will be used on the near future.

From all of these, the ones, which could be easily used at RWY24 are increased glide slope angle, two-segment approach, displaced threshold and curved approach.

Calculations and visualizations do not consider noise attenuation due to atmospheric conditions (fog, rain, wind, temperature gradients, etc.), ground-effect and barriers. We work with the model of the atmosphere where the noise spreads directly. Only noise attenuation due to increasing distance from the source is calculated. For the calculations are used data from the type certificate data sheets for noise (TCDSN) from EASA website [5].

Final step is calculation of number of citizens, who are impacted by increased level of noise. The mitigation measures are then compared between each other.

3. Results

The results of modelling are visualizations for selected mitigation measures. These can be seen in the figures below. First set is for increased glide slope angle. Visualizations are available for standard 3° glide slope, 3.5° glide slope and for 5.5° glide slope (extreme angle of glide slope which is used at London City Airport). These are in Figs. 1-3. In the Fig. 4, visualizations of displaced threshold and increased angle of glide slope can be seen. In the next two figures can be seen the visualization of two-segment approach. The first one (Fig. 5) shows glide slope 3.5° changing to standard 3° and the second one (Fig. 6) shows glide slope 5.5° changing to standard 3°.

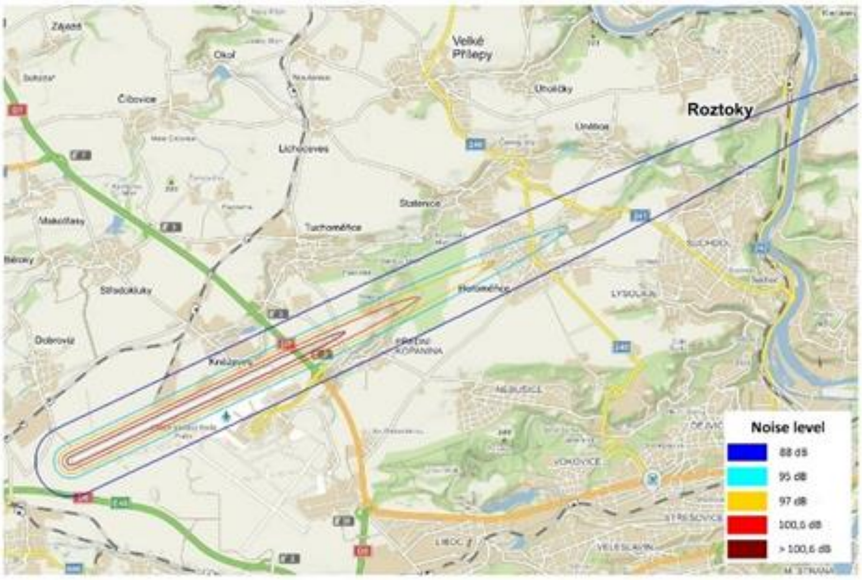

Fig. 1 Visualization of standard 3° glide slope and originated noise levels

Fig. 2 Visualization of 3.5° glide slope and originated noise levels

Fig. 3 Visualization of 5.5° glide slope and originated noise levels

Fig. 4 Visualizations of displaced threshold by 1000m and increased angle of glide slope to 5.5°

Fig. 5 Visualization of two-segment approach, where glide slope 3.5° changes to standard 3° and originated noise levels

Fig. 6 Visualization of two-segment approach, where glide slope 5.5° changes to standard 3° and originated noise levels

Fig. 7 Visualization of curved approach with 3.5° glide slope and originated noise levels

Fig. 8 Visualization of curved approach with 5.5° glide slope and originated noise levels

Method of curved approach is the last method which was visualized. In previous cases all of mentioned methods demonstrated that noise reduction is possible by implementation of them. There are some areas (Horomerice village), which are still affected by noise irrelevant of used method. That is why we were trying to use curved approach. Application of this method reroutes the approach from above these areas which are affected by noise during the standard approaches. Various angles of glide slope were used (3.5° and 5.5°) as can be seen in Figs. 7 and 8.

Comparison of implemented methods was done based on number of affected population. Results can be seen in the Table 1.

Table 1

Comparison of implemented methods

Rank	Implemented method	Population affected by noise
1.	Curved approach (glide slope 5.5°)	2 803
2.	Displaced threshold (glide slope 5.5°)	5 536
2.	Increased angle of glide slope (glide slope 5.5°)	5 536
3.	Curved approach (glide slope 3.5°)	6 477
3.	Curved approach (glide slope 5.5°)	6 477
4.	Displaced threshold (glide slope 3.5°)	11 379
4.	Increased angle of glide slope (glide slope 3.5°)	11 379
4.	Two-segmented approach (glide slopes 3° and 5.5°)	11 379
5.	Displaced threshold (glide slope 3°)	19 782
5.	Two-segmented approach (glide slopes 3° and 3.5°)	19 782
6.	Standard approach (glide slope 3°)	20 178

4. Conclusions

This paper is focused on visualization of noise mitigation measures for RWY24 Vaclav Havel Airport Prague. Based on visualizations and the calculation of number of people affected by air traffic noise for each method, comparison of these methods was done. Noise-mitigation method with the greatest noise savings (less population affected by noise) is method of curved approach combined with an increased angle of the glide slope (about 86% less population affected by noise). This method was designed only to find a noise benefit for the village of Horomerice, which is constantly exposed by air traffic noise. This method of curved approach is very difficult to apply in real traffic. That is why we ignore this method in next comparison. After curved approach method with the greatest noise savings is the method of displaced threshold in combination with increased angle of glide slope (about 72.5% less population affected by noise). A very similar noise benefit to this method is the method of implementing only increased angle of glide slope.

It can be stated, that applying even the simplest noise mitigation method can bring great benefits and the recommendation is to increase the glide slope to 3.5° for RWY24.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Analysis of Adaptive Gripper Effector

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Abstract

The aim of the paper is to perform finite element method analysis of the most stressed part of the adaptive gripper mechanism, which will serve for fast handling the products in an engineering company. The results of the analysis will help in selecting the appropriate material to ensure failure-free operation of the entire mechanism.
KEY WORDS: *manipulation, transport, material, robotisation, automation*

1. Introduction

The long development of mankind to the state we see today has its origins in the ages when the man had to fight for survival in the original living conditions. Repeating successful activities that have brought improved living conditions have also triggered brain activity, i.e., from simple logical operations to memorization and analysis. The result of this process was creations of man, whose improvement led to progress consisting of the construction of machines and heavy machinery. This process of developing technical systems that relieve man from repetitive physical work is called mechanization, and there is no need to talk too much about the importance of machinery for manipulating the material. If we want the material flow to function, it must be an essential part of it. The level of mechanization is fundamentally influenced by several factors. For example, if its high safety is not guaranteed, effective mechanization cannot be realized. Technical equipment with parts of mechanisms that allow for the perfect and reliable transmission of force effects is a crucial condition for successful mechanization [1, 2].

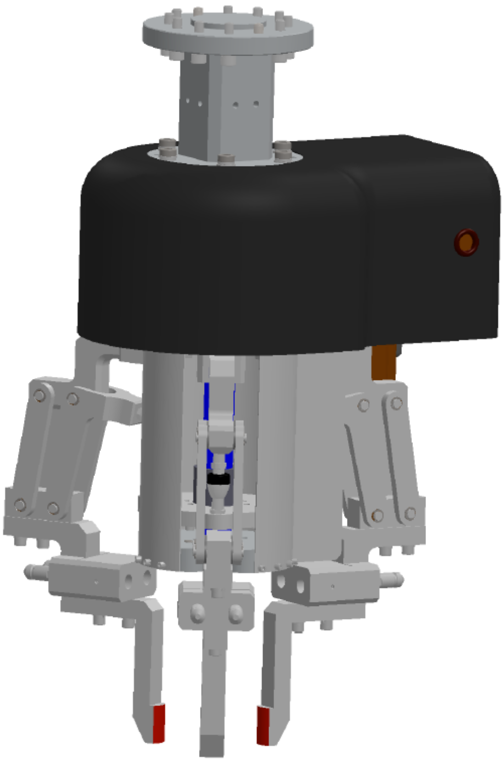

Fig. 1 3D model of the designed universal gripper for the robotic manipulator

Today's advanced production is characterized by automation, which is a highly complex process including very simple control operations, which are performed automatically at a relatively simple device, as well as very complicated control of big production units. Control is a purposeful action of valuation and processing of information about

controlled object or process, actions in the process (these may include measurement device data, signalling equipment states) and according to them related machines are controlled so that prescribed aim is reached - in this case, handling of piece loads with a maximum weight of m = 25 kg by industrial robot (Fig. 1).

2. Proposal of Rotating Fingers' Belt Drive

For the calculation of rotating fingers' belt drive of the gripping mechanism (Fig. 2), two methods were used, namely, the classical analytical method of the functional calculation and the GATES DesignFlex numerical solution. Both methods provided the same results.

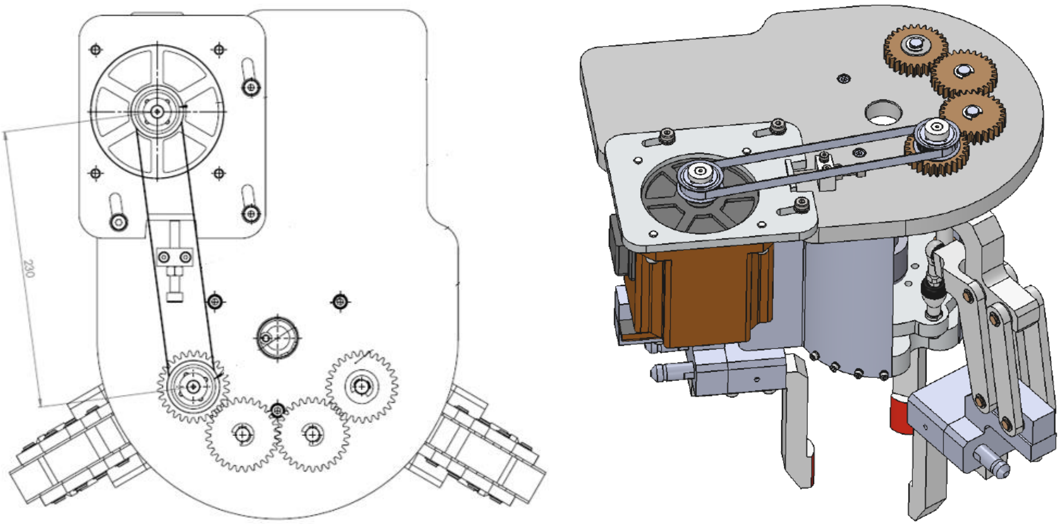

Fig. 2 Belt drive assembly

The calculations show that the ratio of the proposed belt gear is 1: 1. The detailed numerical calculation of the belt transmission is shown in Table 1. In the case of rotation of the fingers, it was not necessary to solve the mechanical motion stops due to the accuracy of the positioning of the AC servo-motor and the electromagnetic brake. The type of belt used was designed by SATI: PowerGrip HDT 550-5M-9. The drive and driven pulley was designed by SATI: HDT 26-5M-09. As the last component, it was necessary to design an extension adapter.

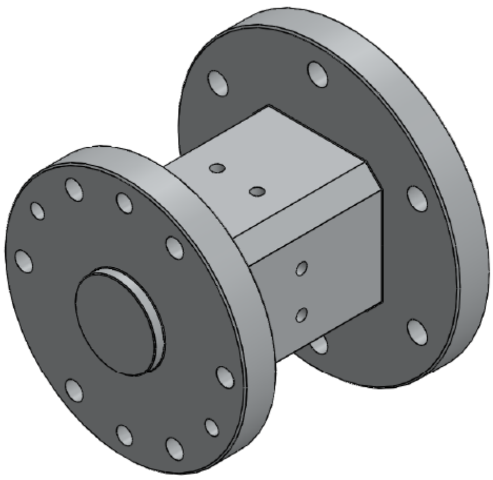

Fig. 3 Extension Adapter

The extension adapter (Figs. 3, 1) is a device that provides robot extension. Extension is important in order to define the possibility of collision and ensure the maximum possible gripping space during operations. The design was based on the attachment dimensions of the end of the robot head. The middle part of the adapter was designed square, and two M8 holes were placed in the center of each surface. The holes will be used to attach cable harnesses or air-conditioning as required. The material chosen for the production of the adapter is EN-AW 5182 based on the characteristics of this material, which has a good corrosion resistance, very good thermal conductivity, good anodicity (ability to be eloxal coated) and very good weldability even though it is an aluminum alloy. For connecting the adapter with the robot, standard galvanized connecting material, M8x35 DIN 912 bolts, pins Ø10x30 DIN 7979D were used [3]. There are also two M10 threaded holes that will be used to extrude the adapter from the pins when dismantling it.

Table 1

Specification of toothed belt gear

				drive	driven
Input data					
Speed ratio	1		Revolutions per minute	2000	2000 +/-4%
Engine power	0.12 kW		Max. peripheral speed	33 m/s	33 m/s
Engine efficiency	92 %		Shaft diameter	14 mm	12 mm
Operating factor	1.6				
Design power	0.19 kW				
Center distance	209 – 251 mm				
engine	Electric motor				
Selected drive					
Belt type	PowerGrip HTD – 5M		Belt 550-5M-9	26 teeth	26 teeth
Speed ratio	1				
Driven speed	2000		Peripheral speed	4.2 m/s	4.2 m/s
Nominal power	0.5 kW		Revolutions per minute	2000	2000
On shaft	36 N		Pitch diameter	41.38 mm	41.38 mm
Center distance	231 mm				
Installation tolerance	209 – 251 mm				
Loading					
	New belt		**Used belt**		
Static force (on groove)	34 – 38 N		24 – 27 N		
Static belt pull	68 – 75 N		48 – 55 N		
Deflection (on groove)	3 mm		3 mm		
Force in deflection (on groove)	0.38 – 0.4 kg		0.31 – 0.34 kg		
Sonic - measurement	34 – 38 N		24 – 27 N		
Belt frequency	74 – 78 Hz		62 – 66 Hz		

3. FEM Analysis of the Most Loaded Part of the Effector

At configuration of the fingers grabbing non-circular objects, the connecting plate will be loaded asymmetrically by moments from the individual finger movement mechanisms. For this reason, it has to be investigated what impact this loading will have on the required accuracy of the mechanism. For the calculation, two basic plate materials were selected: EN AW 6082 and steel STN 11 523. The plate was loaded by two forces F_{sp1} and the force F_{sp2} from the individual finger mechanisms at configuration of the non-circular object gripping and maximum finger opening, which corresponds to a 96.59°. In this configuration, the highest load forces will be applied to the plate. In order to achieve a higher accuracy of the calculation, a mesh size of 1.3 mm was used. When entering boundary conditions, the object cannot move in the direction of the x and y axes, z = free. For the correctness of the calculation it was necessary to achieve the equilibrium state of the investigated object. A Fixed Support was used on the surface of the plate connecting the ball screw nut [4-6].

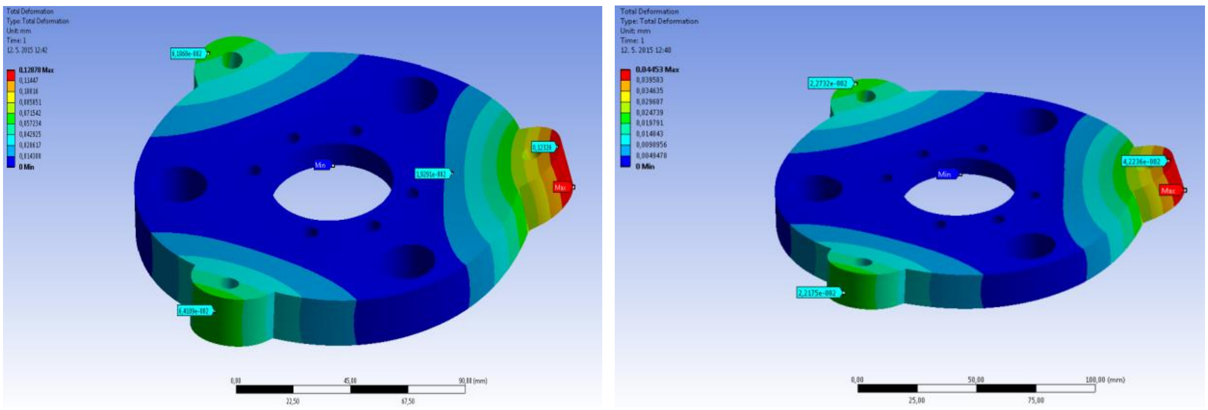

Fig. 4 Maximum displacement of the connecting plate, left EN AW 6082 material with max. displacement of 0.129 mm, right STN 11 523 material with max. displacement of 0.045 mm

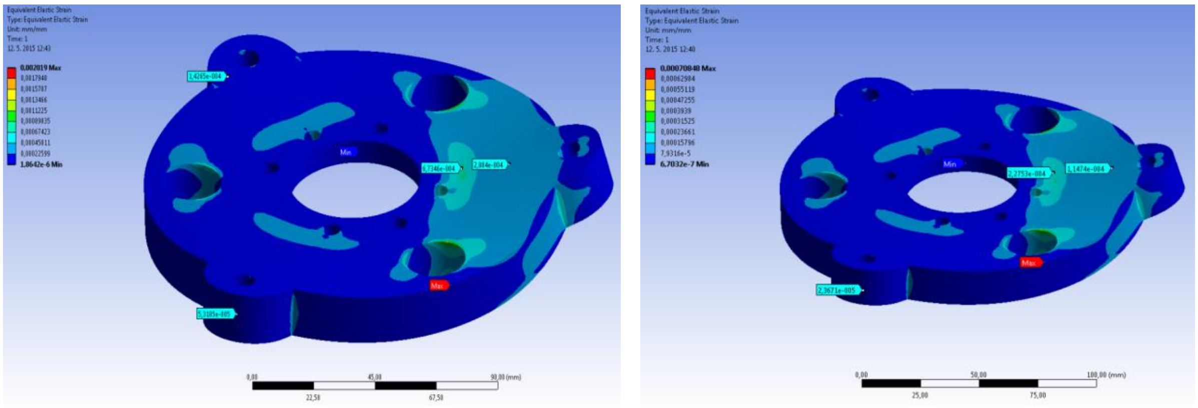

Fig. 5 Maximum deformation of the connecting plate, left EN AW 6082 material with max. deformation of ε = 0.0021 (-), right STN 11 523 material with max. deformation of ε = 0.00071 (-)

Calculated stress values in the connection plate do not exceed the permissible values (Fig. 6), so both materials can be used in the production [7]. Maximum deformation can be seen in Fig. 5. However, the resulting displacement in EN AW 6082 (Fig. 4 left) reaches a maximum of 0.129 [mm], which could affect the positioning accuracy of the gripper. The resulting displacement in the 11 523.1 steel (Fig. 4 right) reaches 0.045 [mm], which is a much smaller value because of the greater stiffness of this material [8]. Therefore, a plate of STN 11 523 is chosen for the production and the resulting maximum displacements do not significantly affect the positioning accuracy.

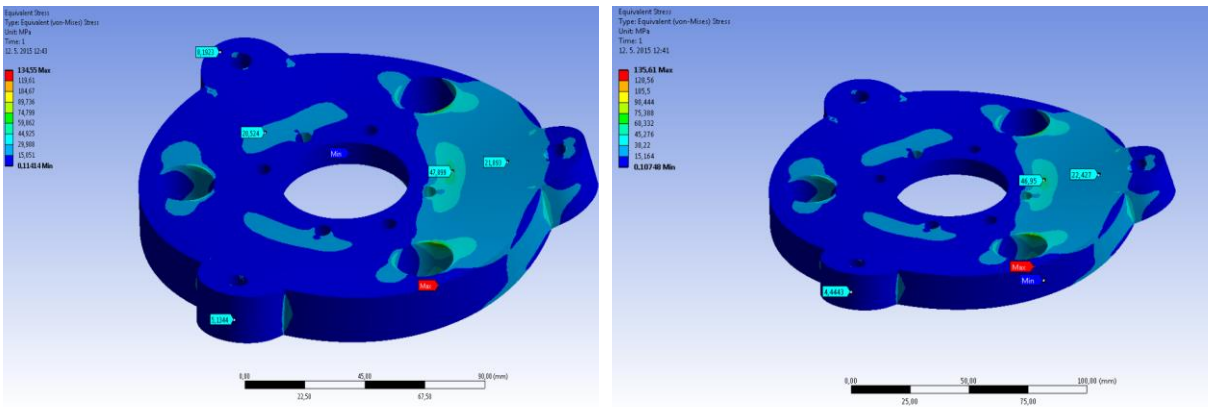

Fig. 6 Maximum von Mises stress in the connecting plate, left the EN AW 6082 material with max. stress σ = 0.0021 (-), right STN 11 523 with max. stress σ = 136 MPa

Table 2

Technical parameters of the gripper

Parameter	Value
Number of fingers	3
Grip range for given configuration 1	10 [mm] – 80 [mm]
Grip range for given configuration 2	Ø 10 [mm] – Ø 120 [mm]
Maximum effector loading	25 [kg]
Mass of the device	56 [kg]
Mounting dimensions from the base	440 [mm]
Effector mounting dimensions	10 × M10 – Ø 125 [mm]
Number of effector configurations	2

4. Conclusion

At present, there are a large number of single-purpose effectors on the market. The use of such devices is limited. For complex applications, it is necessary to use a larger number of single-purpose grippers, which increases cost growth. The use of single-purpose effectors has several disadvantages, such as their cost, idle at gripper change and limited use [9, 10]. The designed universal gripper (Figs. 1, 2) should eliminate the shortcomings of these single-purpose devices. The great advantage of the proposed device is the range of objects it can handle. Other benefits include removing the time required to replace the effector and replacing multiple single-purpose devices with one universal.

The device is theoretically functional at this time and ready for implementation into real production. The maximum gripping force induced by the ball screw on the finger gripping mechanism corresponds to 3,500 [N]. Other technical parameters can be seen in the Table 2. To maximize the gripping range, it is not necessary to change the entire gripper. An increase in grip diameter can be achieved by changing the finger construction.

Acknowledgement

This work has been supported by KEGA project No. 015ŽU-4/2017.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Safety of Pedestrian Crossings and Additional Lighting Using Green Energy

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Abstract

Additional safety and lighting of pedestrian crossings using green energy can be reached by using specially designed device for forced reduction of vehicle speed. Device performs two functions: during the movement of the vehicle above the device, it generates electrical energy, as well as works like a normal speed limiter (a thick plate that is attached to the road surface to slow down the velocity of vehicles). This paper takes a new look at the term of „sleeping policeman" - an element forcibly reducing the speed of vehicles, one of the measures to calm the traffic, in our case before the pedestrian crossing. "Sleeping policeman" offered in the frame of current research offers possibility also to generate green energy for additional lightening of pedestrian crossings. Both functions together, will bring pedestrian crossing to the new level of safety.
KEY WORDS: *transport infrastructure, sustainable transport system, green energy, lighting, pedestrian crossing, energy conversion, safety*

1. Introduction

The principal characteristic of safety pedestrian crossings is minimal number of accidents with pedestrian involved. Unfortunately, statistics shows, that number of accidents on the pedestrian crossings are still high. The main goal of current article is to offer solution for making pedestrian crossing safer. In ideal case, pedestrian crossings are responsible for pedestrians' safety, but in many cases drivers did not drop velocity of the vehicle good enough, crossing the area of pedestrian crossing.

Traditionally, the focus has always been on road marking and special signs to underline the location of pedestrian crossing. Sometimes it is enough, but sometimes it is needed to use additional equipment. Few researchers have addressed the problem of insufficient lighting of pedestrian crossings, but this problem is still actual, especially in darkest time or when weather is rainy, or in other weather condition, when pedestrian crossings are not seen well enough. Despite this interest, no one to the best of our knowledge, did not offer adequate, simple enough solution for problem solving.

The present paper aims to offer the solution, which can help make pedestrian crossings safer and in same time will produce "green" electricity.

This paper takes a new look at the term of „sleeping policeman" - an element forcibly reducing the speed of vehicles, one of the measures to calm the traffic, in our case before the pedestrian crossing. "Sleeping policeman" offered in the frame of current research offers possibility also to generate green energy for additional lightening of pedestrian crossings. Both functions together, will bring pedestrian crossing to the new level of safety.

2. The Problem of Unlighted Pedestrian Crossings

As it was mentioned above - the principal characteristic of safety pedestrian crossings is minimal number of accidents with pedestrian involved. Unfortunately, statistics shows, that number of accidents on the pedestrian crossings are still high.

The safety of all traffic participants depends not only on drivers and pedestrians, but also on the conditions of traffic, transport infrastructure, weather conditions, etc. More than 30% of traffic accidents to some extent concern pedestrians. The pedestrian can be the reason of road accident or/and a victim.

Unfortunately, pedestrian crossings cannot guarantee safety. The main causes of accidents at pedestrian crossings are poor lighting or its complete absence, long pedestrian crossings, high speed of moving vehicles through pedestrian crossings (i.e., the absence of speed limits) [1].

Of course, one cannot fail to mention the importance of a culture of driving and mutual respect for drivers and pedestrians as participants in road traffic. The society and the state must work together on this problem. In countries where this is given more attention, the number of accidents is much less than in countries with a more loyal attitude to violators of traffic rules.

In many countries, a lot of researches of the causes and factors that affect accidents are being done [2-7]. To conduct research, various technical devices are used to collect statistical data.

For example, in Israel, it was studied how the removal of marking pedestrian crossings could affect the safety of pedestrians [2]. The study confirmed that road marking is one of the factors of increasing safety, and its removal increases the risk for pedestrians.

Swedish scientists studied the factors that affect the speed of the car, the relationship between speed and traffic safety, as well as the way to influence the driver to change the speed [3]. They proposed a system that limits the maximum speed of the vehicle to improve the safety of all traffic participants.

In Belgium, they have made a study of the reasons for the violation of the rules for crossing the road by pedestrians [5]. It is determined that both traffic conditions and technical characteristics of pedestrian crossings have a significant effect on the frequency of violations. Because pedestrian crossings are part of the transport infrastructure, the most important task is to improve them.

The authors [6] analyzed data from the USA and Germany with the aim of studying the change in the number of pedestrians and cyclists per capita lost. The results showed that there are large differences in age groups in the lethality and serious injuries. Elderly people have the highest rates.

Ukraine also has serious problems with the safety of pedestrians who are road users. This is their fault, and the fault of the drivers. For clarity on fig.1, the causes of accidents are ranked by the number of victims in Ukraine in 2017 [8].

As can be seen from fig.1, one of the main causes of road accidents is speeding. But it is important to note that absolutely all the indicated reasons can lead to the tragedy of any of the road users, including pedestrians. In addition, in Ukraine a large number of pedestrian crossings have neither traffic lights nor normal marking. And some of them have very little coverage in the dark or are not illuminated at all.

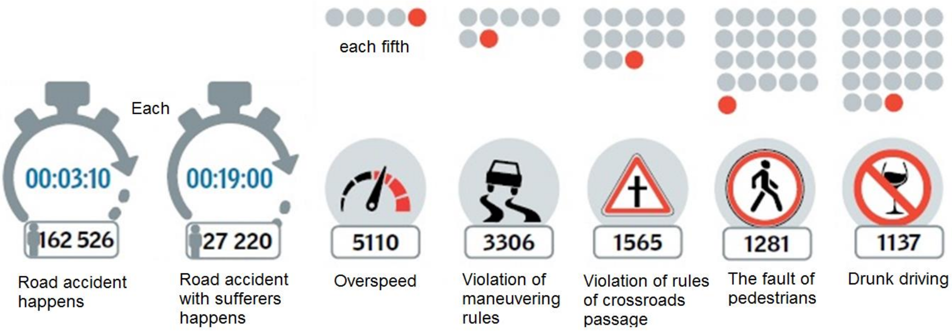

Fig. 1 Main causes of road traffic accidents with victims in Ukraine (Year 2017) [8]

Therefore, improving the safety of pedestrians can be divided into two components: reducing the speed of vehicles in front of pedestrian crossings and equipping pedestrian crossings themselves with additional technical means that promote observance of traffic rules by both pedestrians and drivers.

The question is – how to make pedestrian crossings safer? One of the possible solutions, offered by authors is described below.

3. Safety and Lighting of Pedestrian Crossings Using Green Energy

Additional safety and lighting of pedestrian crossings using green energy can be reached by using specially designed device for forced reduction of vehicle speed. Device performs two functions: during the movement of the vehicle above the device, it generates electrical energy, as well as works like a normal speed limiter (a thick plate that is attached to the road surface to slow down the velocity of vehicles).

At the same time, the process of conversion of kinetic energy into electrical energy will be more effective than in the above-mentioned devices due to the use of a cylindrical multiplier and a larger path of the drive strip of an electric generator. The essence of the proposed utility model is explained by schematic drawings - (Figs. 2-6) shows the construction and operation of the device for generating electric power and forced speed reduction with a multiplier.

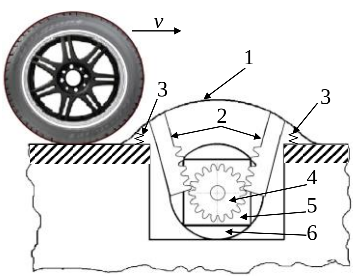

Fig. 2 Construction of the device for forced reduction of vehicle speed and generation of green energy.

The proposed device for generating electric power and forced speed reduction with a multiplier has the following structural elements (see Figs. 2, 3, 5): -a thick plate *1*; -the rails of the electric generator drive *2*; -springs *3*; -drive gear of electric generator *4*; -multiplier *5*; -electric machine (electric generator) *6*.

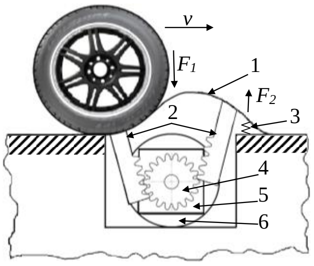

Fig. 3 Operation of the device for forced reduction of vehicle speed and generation of green energy. Step 1. F_1 - force of pressing; F_2 - force of action of a spring; υ - vehicle speed.

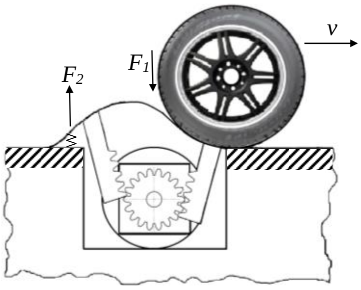

Fig. 4 Operation of the device for forced reduction of vehicle speed and generation of green energy. Step 2.

The device works as follows: when the vehicle wheel at a speed υ hits the plate *1* which is attached to the road surface to slow down the passage of vehicles that is connected to the electric generator drive rails *2* and the springs *3*, the thick plate 1 starts to move downward under the weight of the vehicle - under the action of pressing force F_1 (Figs. 2-4), thereby moving one of the electric generator drive rails *2*, which with its teeth is coupled to the drive gear of the generator *6*. The power driver's drive rail *2* moves down to the full compression of the spring *3*, and thereby rotates the drive gear of the electric generator *4*, which is rigidly fixed to the shaft of the multiplier *5*, which increases the rotational speed of the rotor of the electric machine (electric generator) *6*.

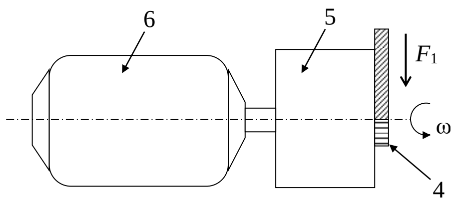

Fig. 5 The multiplier increases the rotational speed of the rotor of the electric generator

Where ω - angular speed of rotation.

When the wheel moves to the second half of the thick plate *1*, the process is repeated, but the second power strip of the electric generator *2* starts to work. At the same time, the spring *3*, which was compressed by the wheel, is straightened by the force F_2, and the second spring, on the contrary, by the action of the force F_1 and the rotor of the electric generator, under the action of the second power strip of the electric generator *2* through the drive gear of the electric generator *4*, it starts to rotate in the opposite direction and leads the EMF in the stator windings with a negative value. The stator windings of the generator are connected to the electric rectifier *7* (Fig. 6).

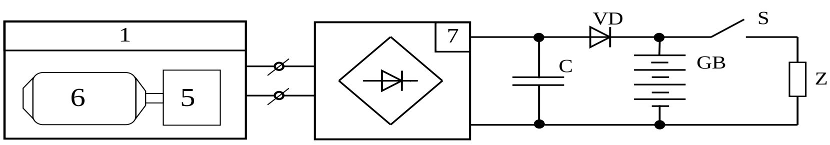

Fig. 6 The stator windings of the generator are connected to the electric rectifier

Where C - capacitive storage; VD - the diode; GB - rechargeable battery; S - switch; Z - the load.

When the EMF is guided along the windings, an alternating electric current begins to flow, and after it is rectified on the electric rectifier 7, it charges the capacitive storage C and through the diode VD - the battery GB. The

switch S turns on the power supply to the load Z.

Thus, the device for generating electric power and forced speed reduction with a multiplier makes it possible to increase the efficiency of energy conversion from pressing to electrical by using an electromechanical energy converter based on an electric machine, which is driven via a reducer, increase the speed of rotation-the multiplier, and also performs function of the speed limiter of vehicles.

The proposed electric power generation device can be used as a vehicle speed limiting device that simultaneously generates renewable electricity. Electricity produced by the device can be used for additional power supply to electricity consumers - households, schools, office buildings, shopping centers and the like.

The analysis of the causes of road accidents involving pedestrians (part 1) showed that the very first step in solving this problem is the development of devices that force both pedestrians and drivers to comply with the rules of the road. This can be achieved by applying non-standard ways of attracting the attention of all traffic participants to the signal of a traffic light at pedestrian crossings. The second part presents and describes in detail the operation of one of the possible devices, which not only reduces the speed of vehicles, but also allows the generation of some green energy. Based on the studies carried out and the developments presented, it is proposed to equip pedestrian crossings with the device described above, in conjunction with the signaling system described in [9, 10] (see Fig.7).

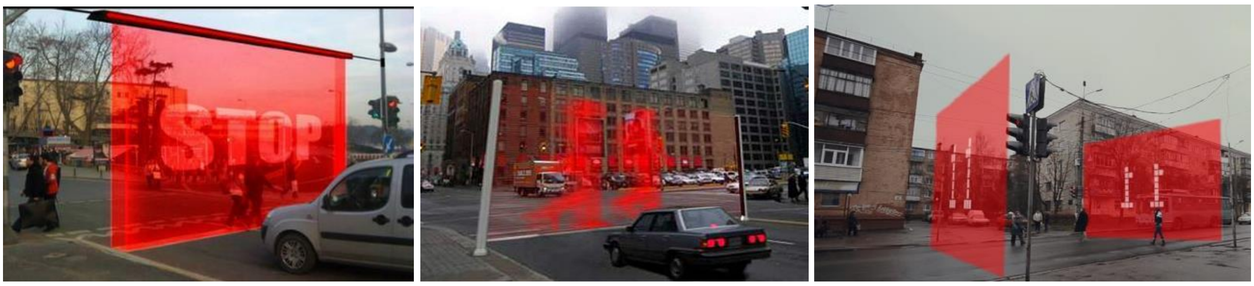

Fig. 7 Traffic light equipped with laser devices [9, 10]

These systems (see Fig. 7) need a constant power supply, and the proposed device (see Figs. 2-6) is able to generate the necessary amount of electricity for their operation. Such cooperation will, in the opinion of the authors, significantly reduce the accident rate on the road crossings and make them adjustable. At the same time, energy for traffic lights is generated by vehicles traveling along this section of the road. If the road section is sufficiently brisk, it is obvious that the generated green energy will be more than necessary for the functioning of this system. Consequently, surplus energy can be transferred to other (third-party) consumers. That is to say, this device (technical system) is an alternative and decentralized source of electricity. And here, in our opinion, we are already talking about energy-efficient and energy-saving technologies. And this topic is one of the most urgent in the modern world [11, 12].

After the offering current solution – the question will be – how to perform energy flow measurement? Introduction to that problem solving will be given in next section.

4. Energy Flow Measurement

Current solution of "sleeping policeman", able to produce green electricity needs an adequate energy flow measurements. There are some researches below, which in good way describe the possibilities to perform this action in different ways.

Because some consumers of electric energy work on direct current, they in their composition have converters of alternating current to constant and vice versa. This allows them to work with AC sources.

Often, the energy produced cannot be consumed at once, and even the generation of energy can be unstable. Therefore, in order to conserve excess energy and then use it, various types of energy storage devices are used: batteries, super capacitors, fuel cells, superconducting inductive storage, etc.

Such devices are connected to the micro-networks of direct current through bi-directional converters AC-DC-AC. Monitoring of the energy flow near consumers / sources of the DC chip and AC network allows determining the efficiency of the system, as well as the vulnerability of the system in terms of energy flow. This makes it possible to make changes to the workflow of devices to improve efficiency [18].

If the consumer generates a non-sinusoidal current form, then the calculation of energy consumption is based on instantaneous power values. To calculate instantaneous power, average power or consumed energy, instantaneous values of current and voltage are read [8], [14].

There is another method in which the values of voltage and current are averaged over multi-order delta-sigma modulation and multiplied. But installing devices for measuring / monitoring electricity near each consumer or generator is very expensive [18]. The authors of [15], [16] proposed several methods to reduce these costs. The main drawback is the need to use a separate low power source to measure the power supply IC and, as a consequence, increase the own consumption of the measuring device. Measurements of the energy of alternating and direct current are the difference due to the difference in the environment of AC and DC, especially if a bi-directional energy flow occurs. To solve this problem, a method was proposed for measuring the energy consumption of a fuzzy sample [17].

5. Conclusions

There is presented the analysis of the main causes of road accidents with pedestrians involved. The analysis addresses the main causes of such accidents in different countries. Main methods for eliminating these causes are given, which should lead to reduce number of road accidents.

Presented studies are not exhaustive, but clearly formulate and describe one of the possible ways to improve safety at pedestrian crossings.

The technical solution of the device for compulsorily reducing the speed of vehicles before pedestrian crossings is given. This device can be considered as an alternative and decentralized source of green energy, which is able to provide electricity for own needs and transfer its surpluses to other consumers.

It is offered to combine into a single system both components - the device considered to reduce the speed of vehicles and traffic light equipped with laser. Such a system is sufficiently visible for all road users and is able to provide the required safety at pedestrian crossings, making them adjustable. Laser light illumination makes a pedestrian crossing noticeable at any time of the day and, in fact, under all weather conditions.

Issues of measuring and accounting of generated electricity by the proposed technical system are also considered.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Standardised Description of Illegal Railway Track Crossings to Support the Characterisation of Analysis Areas Used in Risk Management Processes

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Abstract

Pedestrians very often cross the railway tracks in places not allowed for this purpose. It causes the activation of hazards related to life and health of people, but also to significant material losses. The risk treatment of these hazards requires a systematic, process-based approach. They are adequately managed by risk management, to which all railway entities, including rail infrastructure managers, have been legally obliged. Unfortunately, in the methods used, there is a lack of procedures allowing to obtain the unified characteristics of areas subject to risk management, which would allow them to be compared with each other. As a result, it is difficult to conduct many risk management processes, such as risk treatment or using reference areas/systems during risk assessment. Thus, the purpose of this article is to provide a practical solution to the problem of a unified description of the places of unauthorised crossing the railway tracks, understood as the area of analysis in risk management. The goal of the article will be achieved by presenting an example of standardised description of such places. The description format proposed for places of unauthorised crossing of the railway tracks may contribute to the unification of standards of dealing with such places (applying the same risk reduction measures), which in turn should reduce the costs of such activities.
KEY WORDS: *level crossings; risk management*

1. Introduction

Pedestrians very often cross the railway tracks in places which are not allowed for this. In Poland in 2017, the number of accidents resulting from the collision of a railway vehicle with unauthorised person who crossed the railway track amounted to 137 [8]. This means that statistically almost every other day, one person passes through the railway tracks in a place not intended for this purpose. In 2016, the number of such accidents amounted to 196, which accounted for 29.9% of all registered accidents in the railway system in Poland [6].

The effects of activating hazards related to railway tracks trespassing events concern both loss of health or life of people (161 people were injured in Poland in 2016, of which 116 are fatalities and 45 are seriously injured) as well as damage to railway infrastructure and railway vehicles. In 2016, the costs of damage to railway vehicles due to the collisions with unauthorised persons and suicides were estimated at over 45,000 EUR[1]. What is more, delays in railway traffic should also be considered as an important negative effect. In 2016, delays in passenger and cargo trains as a result of incidents involving pedestrians amounted to 113,451 minutes, i.e. almost 80 days [1].

Many factors affect the undesirable behaviour of pedestrians. This is primarily a tendency to reckless people "supported" by the conditions of the railway line environment – a long time/way to reach bus stops or non-collision crossings(aboveground and underground). An important factor is also the poor condition of railway infrastructure elements (including footbridges and aboveground and underground crossings), as indicated by the reports of the Polish Supreme Audit Office of 2016 [4]. Such conclusions can also be drawn from the analyses carried out by the Polish National Safety Authority – Office of Rail Transport [1].

The solution of the problem outlined before requires a systematic, process-based approach as shown, among others, in works [1, 2, 7]. This can be properly provided by risk management, to which all railway entities, including rail infrastructure managers, are legally obliged. Unfortunately, in the methods used, there is a lack of procedures allowing to obtain the unified characteristics of areas subject to risk management, which would allow them to be compared with each other. As a result, it is difficult to conduct many risk management processes, such as risk treatment or using reference areas/systems during risk assessment.

The purpose of this article is to provide a practical solution to the problem of a unified description of the places of unauthorised crossing of the railway tracks, understood as the area of analysis in risk management. The goal of the article will be achieved by presenting an example of standardised description of such places.

The standardisation of the description was based on analyses carried out on one of the main railway lines in Poland (No. 271 Wrocław Główny – Poznań Główny), which was characterized in the section 2. A set of appropriate

classification criteria was developed to implement a standardised description of places unauthorised crossing of the railway tracks. On this basis, an example of the description is presented for a place located in the city of Leszno.

2. Research Material

As the source of the necessary research data, the railway line number 271 Wrocław Główny – Poznań Główny was chosen. It is a fully electrified, two-track line with a length of 164,454 km. It is one of the most important communication routes in western Poland. Passenger and cargo trains move on it, also in very long relations (e.g. Przemyśl – Szczecin Główny, about 930 km).

The selected railway line runs through a densely populated, urbanised area and connects important urban centres. It is part of the Trans-European Transport Network (TEN-T) - main line E 59 Świnoujście – Chałupki included in the European Agreement on major international railway lines (AGC).

Railway line number 271, managed by PKP Polskie Linie Kolejowe S.A, is currently one of the most intensively used sections of railway infrastructure, which results in progressive degradation of its technical condition. Therefore, since 2008 the line has undergone a modernisation aimed at increasing the operating speed to 160 km/h for passenger trains and 120 km/h for cargo trains. This investment has been co-financed by the European Union.

In addition to the reconstruction of the track and subsoil with drainage, the project provides for the construction of new bridges, culverts and reconstruction of existing passages to facilitate the migration of animals. In order to improve safety, the layout of railway line crossings with pavements and roads is changed. Part of level crossings with high traffic volume is replaced by viaducts. The project also includes the reduction of noise generated by rail vehicles in form of the construction of acoustic screens, and the planned anti-vibration matting, modernisation of the catenary, power supply systems, reconstruction of railway equipment, telecommunications networks, and in particular the establishment of the Local Dispatcher Centrein Leszno. The bridge, station and platform constructions are also undergoing major reconstruction. They are equipped with new shelters, benches, better lighting, clear marking, modern passenger information system, platform edges are raised, and elevators for disabled people are installed in underground passages. All this in order to shorten travel time, increase passenger comfort, improve the technical parameters of the line and the largest possible adaptation of the railway infrastructure for people with reduced mobility [5].

3. Results

In order to obtain a standardised description of the places of unauthorised crossing of the railway tracks, the following nine classification criteria were developed:

1. Localisation of the unauthorised crossing of the railway tracks (K1).
2. Surroundings of the unauthorised crossing of the railway tracks (K2).
3. Distance between the place of unauthorised crossing of the railway tracks and ‘legal’ level crossings (K3).
4. Users of place of the unauthorised crossing of the railway tracks (K4).
5. Genesis of unauthorised crossing of the railway tracks (K5).
6. Signs used in place of unauthorised crossing of the railway tracks (K6).
7. Intersection angle with the track axis (K7).
8. Damages to the track in the place of unauthorised crossing of the railway tracks (K8).
9. Number and type of tracks (K9).

According to the criterion K1 (Localisation), the number and name of the section of the railway network or a station on which the unauthorised crossing of the railway tracks is located should be indicated. For ease of use, the relative location of the place by the distance from the nearest stations can be added.

Criterion K2 (Surroundings) concerns information about the spatial development of the area around the place of unauthorised crossing of the railway tracks. The indicative and brief characteristics of buildings located in this area are particularly important. In creating the appropriate record, it may be helpful to answer the following questions: Does the area cover a single housing development? Is this the area between the railway station and the car park, school, workplace of a large number of people, such as an industrial plant?

According to criterion K3 (Distance), it should be indicated which is the distance (in meters) of the location of unauthorised crossing of railway tracks from ‘legal’ level crossings or viaduct.

Criterion K4 (Users) is the answer to the question of who probably uses unauthorised crossing of the railway tracks. The criterion is related to the criterion K2, therefore, an appropriate analysis of the entries obtained in the framework of the other may enable the identification of a group of possible users.

Criterion K5 (Genesis) requires the introduction of factors that contributed to the creation of an unauthorised crossing of the railway tracks. Usually, these are the habits of the local population associated with the legally existing passage through the track or level crossing. These may, however, be more prosaic reasons, such as the possibility of leaving the car in a convenient (especially free) place on the other side of the railway line.

The criterion K6 (Signs) indicates the risk reduction measures applied by the infrastructure manager. Most often these are information-type means (signs, pictograms). Examples include the following signs: ‘Crossing tracks forbidden!’, ‘Beware of trains!’, ‘Railway area, no entry!’, etc. Exemplary signs of this type used by the railway infrastructure manager in Poland are shown in Fig. 1. Under this criterion, it is acceptable to use graphics or photos (see example in Table 2).

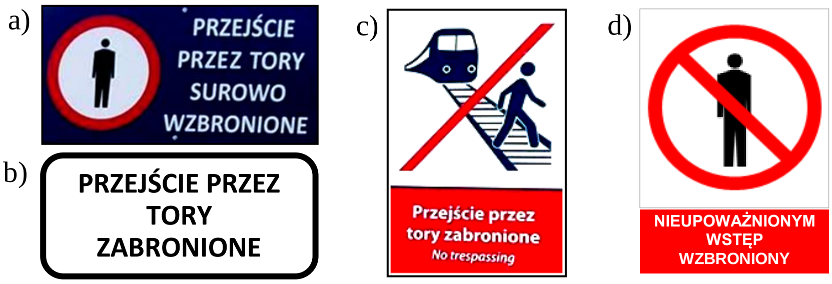

Fig. 1 Examples of restrictive signs used by the railway infrastructure manager in Poland on unauthorised crossing of the railway tracks

According to the criterion K7(Intersection angle), the angle of intersection of the road/path used by unauthorised persons crossing the railway tracks should be determined and recorded. If there are no traces of this directly on the railway tracks, an approximate value of the angle should be given, based on the nearest possible destination points located in the vicinity of the place.

Criterion K8 (Damages) indicates visible damage to the track caused by crossing the tracks by unauthorised persons. Most often they are damage in the form of a spilled or distorted heap of crushed stone. It is also proposed to give the scale of these damages.

According to the criterion K9 (Number and type of tracks), the number and type of tracks (station, mainline) through which pedestrians pass unauthorised should be given. Additionally, this criterion specifies the permissible speed on a given section of the railway line and/or currently applicable restrictions. It may also be important to indicate the reason for introducing these restrictions, since it is often one of the reasons for the creation of an place of unauthorised crossing of the railway track.

When creating a standardised description of the places of unauthorised crossing of the railway tracks, a significant amount of data is used. Table 1 presents selected sources of information that can be used for this purpose.

Table 1

Examples of sources of information predicted for the implementation of a standardised description of places of unauthorised crossing of the railway tracks

Criterion ID	**Short name of the classification criterion**	**Source of information**
K1	Localisation	Satellite maps, spatial development plans of city offices, photos (e.g. from CCTV) and other graphical images
K2	Surroundings	Area analysis and characteristic points determined using satellite maps; interviews with local inhabitants; own observations
K3	Distance	Satellite maps; manual measurements
K4	Users	Area analysis and characteristic points determined using satellite maps; interviews with local inhabitants; own observation sand analysis of records obtained under the criterion K2
K5	Genesis	Area analysis and characteristic points determined using satellite maps; interviews with local inhabitants; own observation sand analysis of records obtained under the criteriaK1 and K2
K6	Signs	Own observations
K7	Intersection angle	Satellite maps; manual measurements
K8	Damages	Own observations
K9	Number and type of tracks	Satellite maps, railway line schemes; own observations

An example of a standardised description of the place of unauthorised crossing of the railway tracks was prepared for a selected crossing located within the city of Leszno. The preparation of a standardised description should therefore begin with the preparation of data on the area (city) where the place is located. Below is its sample content.

Leszno was one of 49 Polish regional capital cities until 1999, inhabited by 64,722 people (31.12.2012), located in the western part of Poland. The closest important urban centres are: Poznań (approximately 70 km) and Wrocław (approximately 100 km). The area of the city is 32 km^2. Two main(‘national’) roads run through the city:

– national road No. 5, leading from Świecie on the Vistula (node with national road No. 91) through Bydgoszcz, Gniezno, Poznań and Wrocław to the border crossing in Lubawka;

– national road No. 12, leading from Łęknica (border with Germany) through Żary, Głogów, Kalisz, Piotrków Trybunalski, Radom and Lublin to Dorohusk (border with Ukraine);

The annual check-in for passengers at the main railway station in Leszno in recent years has been in the range of

1-2 million. Due to its geographical location, it is a natural hub for residents of the whole Leszno region.

The places of unauthorised railway crossings are located in two sub-areas: the station (five unauthorised crossings) and the Zaborowo district (one unauthorised crossing). Railway lines passing through the city divide them into the following three subareas: the Zatorze district, the zone between railway lines (with family gardens) and the inner city zone.

An example of standardised description of unauthorised crossing of the railway tracks is presented in tabular form (Table 2). The view of the crossing has been presented in Fig. 2.

Table 2

An example of standardised description of unauthorised crossing of the railway tracks in the Zaborowo district of the city of Leszno located on the 271 Wrocław Główny – Poznań Główny railway line

Criterion ID	Description of the unauthorised crossing of the railway track according to the criterion
K1	Railway line number: 271 Name: Wrocław Główny – Poznań Główny Locality: Leszno (Zaborowo) Railway line/station: Rydzyna – Leszno Relative position: 93,1 km
K2	Surroundings: Single family housing estates located on the north-west side of the railway line, and on the south-eastern side there are numerous production plants. The functioning crossing connects the residential district of Zaborowo with the investment zone of Leszno
K3	Distance: 650 m to the northern level crossing and 950 m to the eastern level crossing
K4	Users: Residents of Zaborowo who work in the investment zone of I.D.E.A.
K5	Genesis: The unauthorised crossing is probably located at the place of former level crossing on a road connecting Zaborowo (separate town until 1977) and Leszno, which has been closed many years ago (abt. 1952) 
K6	Signs:
K7	Intersection angle with the track axis : 90º
K8	Damages to the track: not found
K9	Number and type of tracks: 2-line Speed limit: 80-100 km/h (currently the limit is set up to 60 km/h due to track work)

Fig. 2 Unauthorised level crossing characterised in Table 2

4. Conclusions

The description format proposed for places of unauthorised crossing of the railway tracks may contribute to the unification of standards of dealing with such places (applying the same risk reduction measures – e.g. fences, signs), which in turn should reduce the costs of such activities. On the other hand, the extended criterion K5 also allows for a better understanding of the local conditions of using a given crossing and may suggest a non-standard solution leading to an increased level of safety. In the presented example it could be, for example, legalising the crossing in the form of so-called category F, normally closed, which would be opened by the designated employee of the economic zone I.D.E.A. during the beginning and ending of work shifts in the enterprises located there.

Acknowledgements

The research work financed with the means of statutory activities of Faculty of Machines and Transport, Poznan University of Technology.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

The Development of the Modular Forwarder Superstructure for the Dendromass Transport

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Abstract

This paper deals with the concept of development and strength analysis of the compression equipment for the forest forwarders. The design of the compression superstructure is based on the requirements of the specification, where there is modular equipment with an attachable hydraulic circuit. The equipment is designed for the compression of the dendromass and the transport for further use. The design of the superstructure must meet the strength requirements for the expected load from compressed dendromass.
KEY WORDS: *compression, dendromass, modular superstructure, fixed frame, strength analysis*

1. Introduction

The compression side panel in the transport space of the forwarder machine allows the development of the dendromass technology. The combination of the transport technology of wood and dendromass, using just one machine with the compression side panels, is an improvement in reducing the cost of machinery for the company.

The concept of the basic parameters of the compression equipment into the load space is a result of the analysis of the working environment. The dendromass from mining, for further processing of renewable resources, is transported to a temporary landfill. The parameters are determined by the basis of the forestry machine, the conditions of use and the possibility of modification of the structure [1].

2. Concept of the Compression Superstructure

The purpose of the superstructure is the interchangeability of the compression superstructure with standard fixed stakes. Another requirement is to empty the load area and unload it without using a crane. Due to the unpredictable load condition (moisture of the dendromass, presence of wood remnants [1]), an ideal angle of inclination was designed for the unloading of the load in the range of 45° to 60°. This very inclined slope of the load space must ensure that the dendromass slips from the load space. Due to the large angle of the inclined slope two alternatives were proposed [1].

The first option was a telescopic hydraulic motor with a height of 2500 mm. This telescopic hydraulic motor has two designed restrictions for the superstructure. The working lift height is limited by the capacity of the hydraulic motors from the catalog. The mounting space of the telescopic hydraulic motor is disposed in the machine frame. It is necessary to cut the holes in the supporting parts of the rear frame. Intervention into the supporting structure has been rejected.

The second variant was the use of an specific lifting kinematics powered by commonly available hydraulics motors. This lifting solution has design constraints for the superstructure. The original space is narrow and the height is limited. Therefore, a two-member lift kinematics was chosen [3, 5].

The concept of the compression side panel superstructure is shown in Fig. 1. The fixed frame (Fig. 1, position 1) forms an attachment that is fixed to the rear frame of the machine. The frame is fastened with screwed clamps at several places to the rear frame of the machine [3].

The height of the superstructure to the rear frame of the original machine depends on the attachment of the hydraulic lifting motors (Fig. 1, position 2) and the attachment of the kinematics (Fig. 1, position 3). The kinematics can not be placed outside the machine chassis. It is necessary to maintain a safe space for the movement of the wheel or the track unit of the forwarder (Fig. 2) [3].

The fixed frame (Fig. 1, position 1) is a welder from the steel profiles and is placed on the chassis of the rear frame to which it is fixed by bolts. Compression superstructure can be disassembled by loosening the bolts. At the rear of the fixed frame the spherical joint is for the tilting in a sloping position. The load space consists of a haul bed bottom (Fig. 1, position 5) and two compressions side panels (Fig. 1, position 6). Each side panel is powered by two hydraulic motors. The left and right side panels move independently of each other (Fig. 1, position 6). Moving the side panels creates the compression of the dendromass.

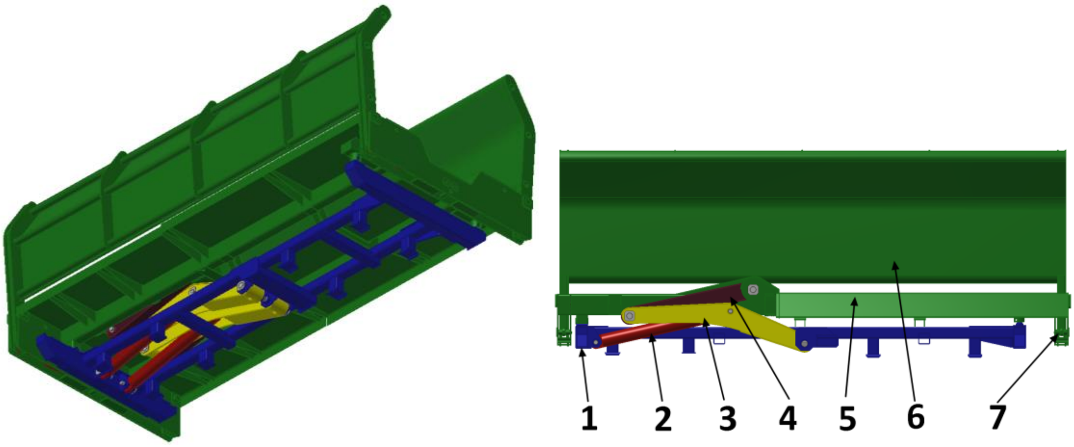

Fig. 1 Concept of the compression superstructure. Total assembly bottom view (left), cross section of the compression superstructure (right) = *1* - fixed frame, *2* – hydraulic lifting pistons, *3* - first kinematic lifting member, *4* - second kinematic lifting member, *5* – haul bed, *6* - compression side panel, *7* - hydraulic pistons of the compressions.

The tilt of the haul bed is provided by a hydraulic-mechanical mechanism (see Fig. 1, position 2-4) with two linear hydraulic motors [3]. The technical parameters for the design of the compression side panels are given in Table 1.

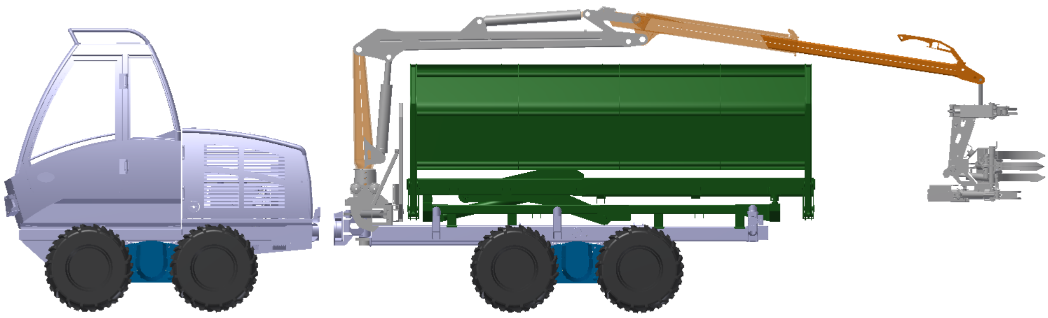

Fig. 2 Virtual model of the forwarder with the superstructure of the compression side panels and the accumulating energy wood head

Table 1

Parameters of the virtual prototype model of the compression superstructure

Parameter	Value
Total weight of the superstructure	1850 kg
Superstructure weight without a fixed frame	1320 kg
Length of the haul bed	4020 mm
Total height of the superstructure	1570 mm
Width of the superstructure	1870 mm
Maximum width after opening the side panels	2817 mm
Volume of the haul bed	4,4 m^3
Angle of inclination of the haul bed	57°
Working angle of the compression side panels	84°

3. Strength Analysis of the Fixed Frame of a Superstructure

Together with the concepts of the superstructure, an strength analysis of the fixed frame for the tilting the of the haul bed was performed. First, a dynamic simulation of the superstructure was performed to identify the load forces. Subsequently, the strength analysis of the individual parts of the mechanism was performed, and specially the fixed frame. The strength analysis was performed for the three positions of the haul bed tilting at 0°, 30°, 57°, and for the load weights of 2 tons and 3 tons. The load weight of 3 tons is the maximum weight of the transported load. A load weight of 2 tons is the estimated working weight of the transported load. This weight is considered in relation to the volume of the haul bed and the nature of the load being transported. This weight of 2 tons has to be verified when testing the real machine [1].

4. Dynamic Simulation of the Tilting Superstructure

The dynamic simulation of the superstructure was performed in MSC Adams 2012. The premise is the tilting with a load only when the machine is stationary and a tilting time shall not be less than 13 seconds. The dynamic simulation model was in total of 50 moving parts, 52 joints, 12 independent programmed movements and a total of 37 degrees of freedom (see Fig. 3). The values of the force effects were written down in the table 2 for the load conditions of the strength analysis of the fixed frame at defining the tilting angles [2].

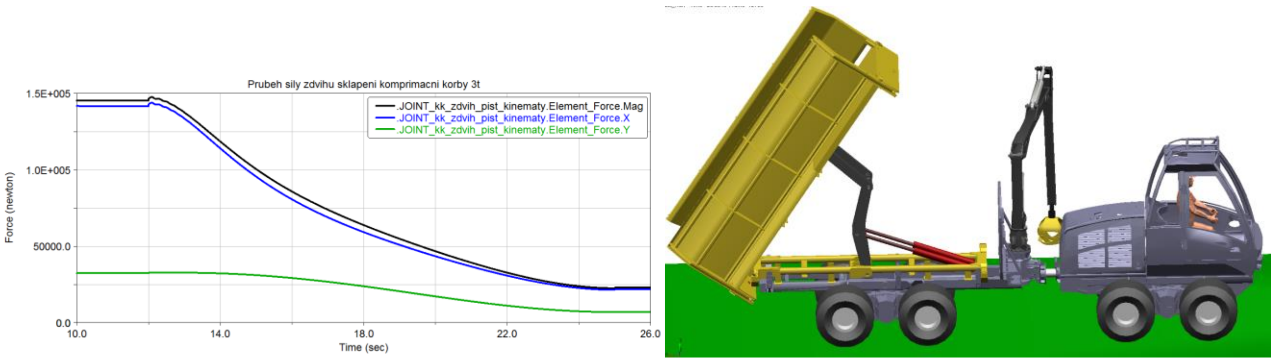

Fig. 3 The dynamic simulation model of the forwarder compression side panels, the force course of the hydraulic system (left), the animation in MSC Adams 2012 (right)

Table 2

The axial forces of the load cases for the maximum weight of 3 tons

Load cases Description of the axial forces		Forces for the load case		
		0° slope	30° slope	57° slope
Force in the hydraulic motor	F_{1X} [N]	-35930	-14190	-5357
	F_{1Y} [N]	-8210	-5718	-1718
Force in the first kinematic lifting member	F_{2X} [N]	9000	7547	3315
	F_{2Y} [N]	-2185	-2525	2030
Force in the joint of a haul bed	F_{3X} [N]	55400	13540	4466
	F_{3Y} [N]	-10600	-16044	-17801

5. Strength analysis of the fixed frame for the tilting

The strength analysis was performed on the superstructure fixed frame. This analysis was performed on a similar principle and a similar approach as used in the papers [4, 6]. The computational model of the fixed frame was created from a 3D model and it contained shell elements and solid elements (see Fig. 4). In this computational model was generated FE mesh by the number of elements 155 795 and the number of nodes 229 878 (see Fig. 4). Load cases for strength FEM analysis were loaded at defined locations according to the results of the dynamic simulation (Table 2).

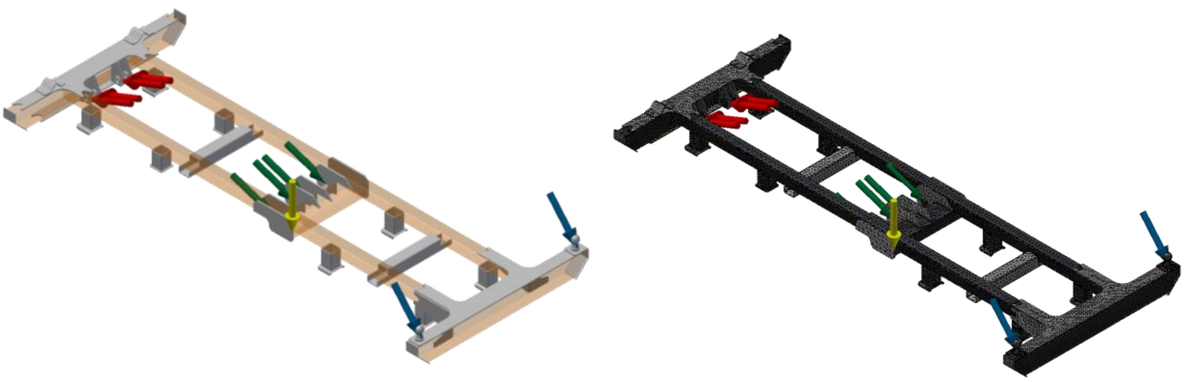

Fig. 4 The computational model of the fixed frame. The shell model and the solid model with the forces load cases (left), mesh FEM model (right).

6. Results of the FEM Analysis

The simulated load cases were calculated for the working tilts of the haul bed when the compressed dendromass was emptied. The resulting stress states of the strength analysis are shown in Fig. 5-7 for the load of 3 tons and for three positions of the haul bed 0°, 30° and 57°. The legend color spectrum used shows the reduced stress distribution according to the H-M-H theory. The color range corresponds to values of 0 to 235 MPa. This is the maximum permissible value of the steel material S355. This is a material of metallurgical semi-finished products with a safety of 1.5 times.

Fig. 5 is a load case at the beginning of the haul bed tilting. The construction has great forces and the inclination of the hydraulic motors is very small. The force begins to fall sharply as expected from the dynamic analysis (see Fig. 3). Fig. 6 shows the reduced stress distribution for a 30° tilt angle and a haul bed with a load of 3 tons. Fig. 7 illustrates the reduced stress distribution for the 57° full tilt angle and the 3 tons of a load.

Fig. 5 show a high stressed state at the beginning of the tilting. This fact was anticipated in the design of the superstructure as a disadvantage of this concept. The slope of the hydraulic motors at the beginning of the tilting was set to a minimum of 13° relative to the flat surface of the haul bed due to the initial force of the hydraulic motor. The resulting stress values are high but there is still a reserve due to the strength of the material. In the previous chapter it was stated that the weight of the real load must be verified during the testing of the real superstructure [1]. Other tilting load cases are subject to reduced stress in the range of up to 100 MPa.

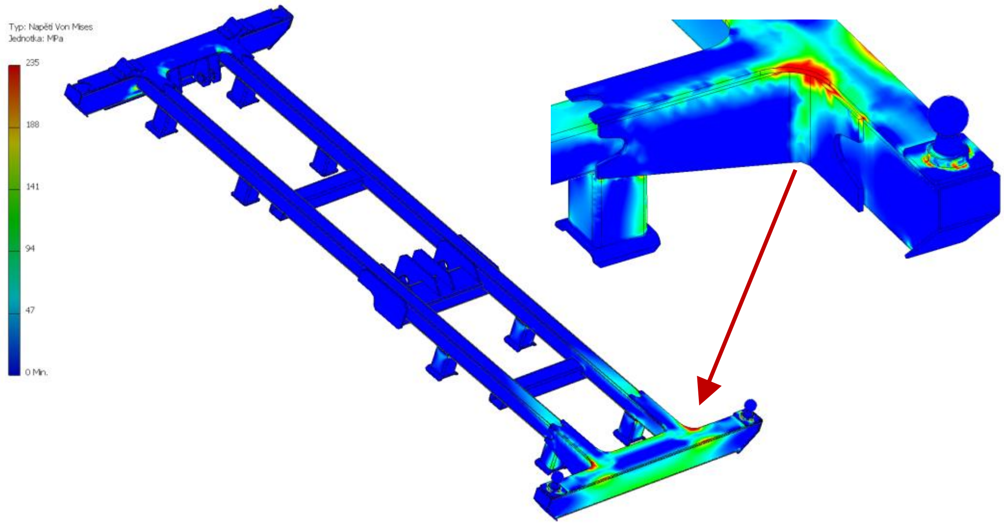

Fig. 5 Fixed frame - load 3tons, HMH reduced stress, legend stress range 0-235 MPa, load case-slope angle 0°

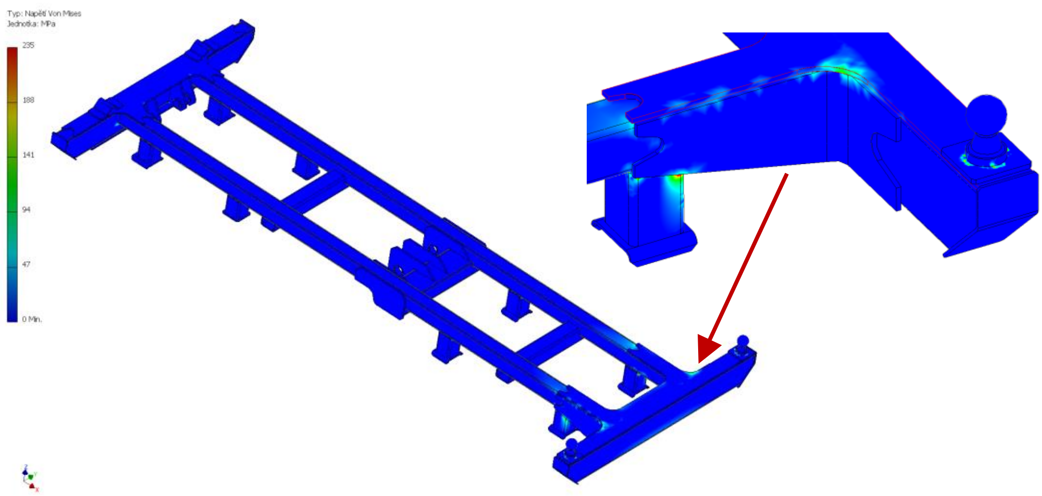

Fig. 6 Fixed frame - load 3tons, HMH reduced stress, legend stress range 0-235 MPa, load case-slope angle 30°

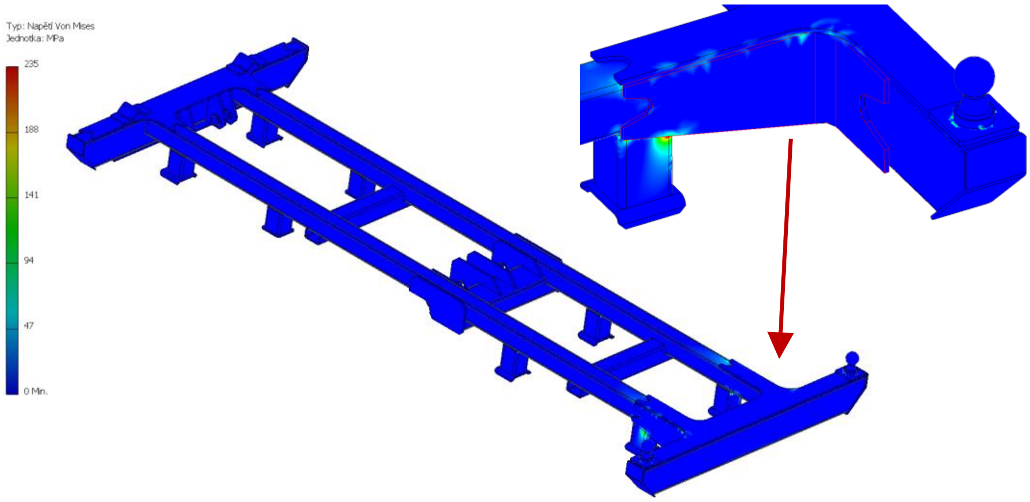

Fig. 7 Fixed frame - load 3tons, HMH reduced stress, legend stress range 0-235 MPa, load case-slope angle 57°

7. Conclusion

The paper deals with the design of a forestry forwarder. The task of the facility is to transport dendromass from the harvesting site to the landfill site in the maximum capacity of the load. The design meets the requirements for the versatility of the superstructure with a modular connection to the forwarder. After the final design of the equipment, kinematic and dynamic simulation of the mechanisms, were performed. The results were used as a boundary condition to the strength analysis. Strength analysis was performed on the fixed frame of the superstructure during the landfilling for the assumed loading cases of a compacted dendromass. The resulting values meet the strength requirements of the structure. The capacity of the load is limited by the required kinematics.

Acknowledgement

This work is an output of research project “Development and manufacture of forwarder with a special emphasis on environmental cleanliness of works and efficient biomass processing in forestry “, Reg. No. TA04020087, Program to support applied research and experimental development "ALFA" by financial means from the Technology Agency of the Czech Republic.

The research leading to these results has received funding from Specific research project “Research on computational and experimental methods in mobile systems” of the Faculty of Mechanical Engineering, Brno University of Technology (FSI-S-17-4104).

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Research of the Efficiency of Use of Second-Generation Biodiesel and Diesel Blends in Compression Ignition Engines Assessing Exhaust Gas Recirculation

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Abstract

The Article presents the research of energy indicators of compression ignition engines fuelled on different conventional diesel and second-generation biodiesel blends with biodiesel volume concentration of 0%, 30%, 50%, 70% and 100%. NESTE biodiesel NExBTL (BTL – Biomass to Liquid) was used for the research. Tests of physico - chemical properties of these fuel blends were carried out. In the course of the engine bench testing, exhaust gas recirculation (EGR) of the engine was changed from 0 to 0.3 – 0.35. Hourly and brake specific fuel consumption of fuel mass and fuel volume was determined by increasing second-generation biodiesel concentration in the fuel blend and changing EGR. NExBTL biodiesel was calculated to have a trend of improving the engine efficiency coefficient. Low EGR (up to 0.05) has a low impact on engine efficiency, but when increasing EGR, adverse effect on engine efficiency increases more intensively.
KEY WORDS: *compression ignition engine, biomass to liquid, engine efficiency, exhaust gas recirculation*

1. Introduction

So far, biofuels account for a small share of the total fuel market in today's world. Countries have assumed obligations to expand biofuel production. In order to reduce greenhouse gas emissions, countries have to use cleaner energy, search for alternative fuels and try to replace fossil fuels. Production of second-generation biofuels and biofuels of other generations (from waste and non-food raw materials) will be supported in solving energy and ecological problems in the EU and Lithuania. The EU calls for a significant reduction in greenhouse gas emissions and assuring that emissions in the transport sector are reduced by up to 60% by 2050, compared to 1990, and CO_2 emissions are reduced by 20% by 2030 compared to 2008. This can be achieved through a wider use of liquid and gaseous biofuels [6].

The purpose of this Article is to assess the efficiency of the use of second-generation biodiesel and diesel blends in compression ignition engines, taking into account the composition of the fuel blend and exhaust gas recirculation.

The following tasks have been set to achieve this purpose:

- To analyze scientific literature related to the use of second-generation biodiesel and diesel blends.
- To examine the efficiency of use of second-generation NExBTL biodiesel and diesel blends in compression ignition engines, taking into account the composition of the fuel blend and exhaust gas recirculation.

The methodologies used in the Article include literature analysis and stand tests.

2. Analysis of Theoretical Aspects of the Use of Second-Generation Biodiesel and Diesel Blends

The European transport fleet mainly consists of diesel-fuelled vehicles (cargo trucks, buses, inland ships, construction site and agriculture machinery, trains and part of passenger cars) that use EN 590 diesel fuel containing only 5–10% of fatty acid methyl esters (FAME) (depending on country) [7, 10]. Engine and vehicle manufacturers are in negotiation with EU pollution control and prevention bodies about increasing bio-share in fossil fuels [4, 17], and they have strong opinion, which is one of the reasons slowing down this "bioprocess". For this reason, advanced diesels are very important for the European transport fleet. One of the most promising diesels is pure hydro carbon made from renewable source and fuels known as Biomass-to-Liquid (BTL) and Hydrotreated Vegetable Oil (HVO). They are clean hydrocarbons and have similar properties to those of fossil fuels, their combustion is cleaner than of conventional diesel fuel [5, 18, 21] and offers a number of benefits over FAME, such as reduced nitrogen oxides emissions, better storage stability and better cold properties [1, 15]. Advanced biodiesels are straight chain paraffinic hydrocarbons that are free of aromatics and sulphur and have high cetane number [1].

The main reasons that promote the development of biofuels not only throughout the world but in Lithuania as well include [13]:

- environmental requirements relating to the reduction of greenhouse gas emissions becoming more stringent each year;
- increasing environmental pollution related to the use of fossil mineral resources;

- continuously increasing demand for diesel compared to petrol;
- energy dependence on imported mineral resources;
- complicated agricultural production market, which forces searching for new fields of utilization of agricultural production;
- social issues related to the employment of population.

The assessment of these reasons allows stating that biofuels are the future of the transport sector, because to this day, we already have first, second, third and fourth generation biofuels. This Article will focus more on second-generation biofuels the production of which does not use raw materials suitable for food production, also analyzing blends of these fuels with mineral diesel.

Second-generation biodiesel (HVO), which NESTE calls NExBTL, is a component of ProDiesel. Diesel made of renewable energy sources in application of the patented NExBTL technology is stated to comprise at least 15% of ProDiesel. The conducted tests showed that the consumption of this diesel is up to 5% lower than that of traditional diesel, but a specific decrease in consumption depends on many factors, such as the type of the engine used, technologies of fuel feed or emissions systems, environmental conditions, driving style, etc. [15].

Biodiesel and mineral diesel are very different in their origin. However, biodiesel produced by way of NExBTL is similar to mineral fuels in its chemical composition, thus this biodiesel can be used in diesel engines without any blending constraints, which means that this biodiesel must be of high quality and meet the set quality requirements. The quality of biodiesel can be characterized by its operational (flowability, evaporation level, flammability, corrosion, stability), physico - chemical (density, colour, acidity) and environmental (toxicity, environmental pollution) properties. The table below (see Table 1) presents the quality requirements for the second-generation biodiesel NExBTL and mineral diesel.

Table 1

Quality requirements for the second-generation biodiesel and mineral diesel [15]

Property		**Neste Renewable Diesel**	**EN 590:2013**
Appearance at +25°C		Clear & bright	
Cetane number		> 70.0	≥ 51.0
Density at +15°C	kg/m^3	770.0...790.0	820.0...845.0 ≥800.0*
Total aromatics	% (m/m)	< 1.0	
Polyaromatics	% (m/m)	< 0.1	≤ 8.0
Sulphur	mg/kg	< 5.0	≤ 10.0
FAME-content	% (V/V)	0	≤ 7.0
Flash point	°C	> 61	> 55
Carbon residue on 10% distilation	% (m/m)	< 0.10	≤ 0.30
Ash	% (m/m)	< 0.001	≤ 0.010
Water	mg/kg	< 200	≤ 200
Total contamination	mg/kg	< 10	≤ 24
Water and sediment	% (V/V)	≤ 0.02	
Cooper corrosion		Class 1	Class 1
Oxidation stability	g/m^3 h	<2 5	≤ 25 ≥ 20**
Lubricity HFRR at +60°C	µm	≤ 460*** ~ 650****	≤ 460
Viscosity at +40°C	mm^2/s	2.00...4.00	2.000...4.500 ≥ 1.200*
Distillation 95% (V/V) 90% (V/V)	°C °C	< 320 282...338	≤ 360
Final boiling point	°C	< 330	
Cloud point and CFPP	°C	As needed -5...-34	Down to -34
Antistatic additive		Added	
Conductivity	pS/m	≥ 50	

In order to comply with exhaust emissions requirements that have been getting more stringent, automotive engine manufacturers examined various technologies, with one of them being exhaust gas recirculation (EGR) system. The principle of operation of this system is based on the supply of a portion of the already burnt gas to the intake tract, thus reducing the burning temperature in the engine cylinder and the formation of NO_x. The use of EGR reduces environmental pollution, but more fuel is used with this system. NExBTL fuel has a significantly higher cetane number, is virtually free of sulphur and aromatic hydrocarbons, and also reduces exhaust gas emissions - the engine emits less smoke. High content of NExBTL can be assumed to shorten the ignition delay of the combustible blend leading to reduced NO_x emissions and

engine noise. The analysis of engine indicators [2] showed that standardly programmed EGR and the use of BTL allow reducing NO_x levels. This result was achieved without the increase in smoke, the decrease in thermal efficiency of the engine and increase in fuel content. A similar conclusion can be found in the work of Schaberg et al., 2005, which noted that lower emissions of soot when using the BTL biodiesel and its blends with diesel can significantly reduce NO_x emissions exploiting all EGR potential [20]. Researchers [8] state that properly programmed EGR allows achieving significantly lower exhaust emissions without reducing operating efficiency of the engine. Studies show that different fuel blends can be used effectively [3, 9, 11, 12, 14, 16, 19]. The purpose of this research is to analyse the efficiency of use of blends of second-generation biodiesel NExBTL and diesel in compression ignition engines, taking into account the composition of the fuel blend and the recirculation of combustion gases.

3. Research Methodology

Direct injection Audi 1.9 TDI engine tests were performed at the Internal Combustion Engines laboratory of Automobile Transport Department, Faculty of Transport Engineering of Vilnius Gediminas Technical University (VGTU). Diesel engine 1.9 TDI (1Z type) with electronically controlled BOSCH VP37 distribution type fuel pump and turbocharger was used for the tests. Table 2 lists the main parameters of the diesel engine Audi 1.9 TDI.

Table 2

Main parameters of the diesel engine VW-Audi 1Z 1.9 TDI

Parameter	**Value**
Displacement, cm^3	1896
Number of cylinders, -	4
Compression ratio, -	19.5
Bore, mm	79.5
Stroke, mm	95.5
Power, kW	66 (at 4000 rpm)
Torque, Nm	180 (at 2000 – 2500 rpm)

Tests were carried out at the engine speed of n = 2000 rpm. Brake torque (M_B) load was 60 Nm. The research was carried out with different diesel and NExBTL blends: diesel 100% / NExBTL 100% – D100; diesel 70% / NExBTL 30% – BTL30; diesel 50% / NExBTL 50% – BTL50; diesel 30% / NExBTL 70% – BTL70; diesel 0% / NExBTL 100% – BTL100.

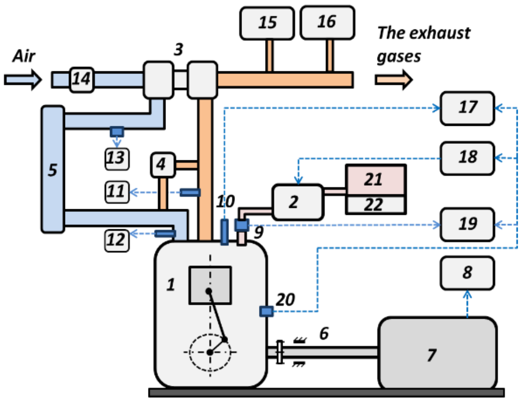

Fig. 1 The scheme of engine testing equipment: *1* – 1.9 TDI engine; *2* – high pressure fuel pump; *3* – turbocharger; *4* – EGR valve; *5* – air cooler; *6* – connecting shaft; *7* – engine load plate; *8* – engine torque and rotational speed recording equipment; *9* – fuel injection timing sensor; *10* – cylinder pressure sensor; *11* – exhaust gas temperature meter; *12* – intake gas temperature meter; *13* – air pressure meter; *14* – air mass meter; *15* – exhaust gas analyser; *16* – opacity analyser; *17* – cylinder pressure recording equipment; *18* – fuel injection timing control equipment; *19* – fuel injection timing recording equipment; *20* – crankshaft position sensor; *21* – fuel tank; *22* – fuel consumption measure equipment

Fig. 1 presents the scheme of laboratory equipment. Engine brake stand KI-5543 was used to determine the load M_B and the crankshaft speed. Torque measurement error was ±1.23 Nm. Hourly fuel consumption B_f was measured by electronic scales SK-5000 and a stopwatch, accuracy of B_f determination was 0.5%. Pollutants in exhaust gas were measured using gas analysers AVL DICOM 4000 (for CO, CO_2, HC, and NO_x) and AVL DiSmoke (for smoke opacity).

BOSCH HFM 5 meter was used to measure intake air mass flow with the accuracy of 2%. Intake manifold pressure was measured using a pressure gauge Delta OHM HD 2304.0. Sensor of device TP704-2BAI mounted ahead of intake manifold with an error of ±0.0002 MPa was used also using the exhaust and intake gas temperature meter K-type thermocouple (accuracy ± 1.5°C) was used. (Pulse Width Modulation) TESTER – TMW1 controller was used for the

control of EGR valve. Control ranged from 0% to 100%, with an error of ≤ 1%.

The permeability of the EGR valve was determined according to the formula:

$$EGR = \frac{m_{EGR}}{m_{EGR} + m_{oro(EGR)}}, \tag{1}$$

where m_{EGR} - exhaust gas mass returning to the cylinder through the opened EGR valve; $m_{oro(EGR)}$ - air mass sucked into the cylinder (under EGR).

$$m_{EGR} = m_{oro} - m_{oro(EGR)}, \tag{2}$$

were m_{oro} – air mass sucked into the cylinder (without EGR).

4. Result of Research

4.1. Result of the Research of Fuel Blends

The research of the physico - chemical properties of the tested fuels was conducted at the Marine Chemistry Laboratory. Physico - chemical properties of fuel were researched in order to assess the possible impact on 1.9 TDI engine performance parameters. Table 3 presents the values of the main properties of tested fuels (and blends).

Table 3

Main parameters of tested fuels

Properties		**Fuel**				
		D100	**BTL30**	**BTL50**	**BTL70**	**BTL100**
Dynamic viscosity	mPa × s	3.271	2.550	2.365	2.478	2.262
Kinematic viscosity	mm^2/s	3.947	3.149	3.000	3.163	2.959
Density at 15°C	g/ml	0.8441	0.822	0.8093	0.7978	0.7779
Water content acc. CF	%	0.0033	0.0025	0.0021	0.002	0.002
Oxidative stability	min	70.31	75.21	73.78	105	126.43
CFPP	°C	-10	-27	-33	-34	-40
Cetane number		50.9	58.1	59.9	68.5	74.5
Poor point	°C	-39	-40	-45	-40	-58
Gross heating value	MJ/kg	45.876	46.272	46.411	46.761	47.218
Net heating value	MJ/kg	42.570	42.827	42.873	43.131	43.449
Net heating value	MJ/l	35.93	35.20	34.70	34.41	33.80

The scatter of the determined values of the main physico - chemical properties shows a relatively strong dependence on the share of NexBTL in the fuel blends. A brief description of the researched physico - chemical properties can be started with a positive fact that all these parameters have a smooth change when the ratio of NexBTL and diesel fuel is changing. It goes without saying that NexBTL with lower viscosity, density and water content values makes these parameters lower in blends with diesel fuels. Lower water content in fuels is a positive sign due to its negative impact on for the combustion process and the fuel system parts' surface. Net heating value of pure NExBTL is by about 2.1% higher than that of mineral diesel. Such difference may affect test results. The greatest impact is likely in examining the efficiency ratio of the engine. Another significant difference is the density of fuel blends. The density of pure NExBTL is by about 7.8% lower than that of mineral fuels. The assessment of the net heating value and density of fuel allowed determining that net heating value of 1 litre of D100 is 35.93 MJ/l, while net heating value of 1 litre of BTL100 is 33.80 MJ/l (~5.9% lower). Such a difference in energy density of NExBTL fuel is likely to lead to higher fuel volume consumption, which is very important to vehicle owners. There may also be an effect from the difference in cetane in fuel blends, because cetane number of pure NExBTL is about 60% higher than that of mineral fuels, which will have an impact on the combustions process.

4.2. Results of the Research of Energy Indicators of the Engine

The lowest hourly fuel mass consumption of the engine B_{f_m} (kg/h) was determined with the engine fuelled on BTL100 fuel and it was by ~ 2.6% lower than D100 fuel consumption (Fig. 2). This came as a result of the net heating value of NExBTL being ~ 2.1% higher. Hourly fuel mass consumption of all fuel blends was determined to increase when increasing exhaust gas recirculation (EGR), and after EGR reaches 0.3 - 0.35, fuel consumption increased by 3.2 – 4.5%. Fuel consumption was increased by worse combustion process as a result of decreased oxygen content in the cylinder.

Brake Specific Fuel mass Consumption ($BSFC_m$) (g/kWh) was also determined to be the lowest with the engine fuelled on BTL100, and it was by ~2.6% lower than D100. When increasing EGR, $BSFC_m$ increased in the same manner

as the hourly fuel mass consumption (Fig. 3).

The highest hourly fuel volume consumption of the engine B_{f_V} (kg/h) (l/h) was determined with the engine operating on BTL100 fuel and was by ~5.7% higher than D100 fuel volume consumption (Fig. 4). With the engine operating on the tested diesel and NExBTL blends, when increasing biodiesel concentration, the fuel volume consumption increased proportionately, because net heating value of volume of this biofuel (MJ/l) was by about 5.9% lower than the net heating value of diesel.

Brake Specific Fuel volume Consumption ($BSFC_V$) (ml/kWh) was also the highest with the engine operating on BTL100 fuel and was by ~5.7% higher than that of D100 (Fig. 5). Due to its worse combustion, EGR was determined to have a negative impact, namely, to increase fuel volume consumption, and after EGR reached 0.3 – 0.35, fuel consumption increased by 3.2% – 4.5%.

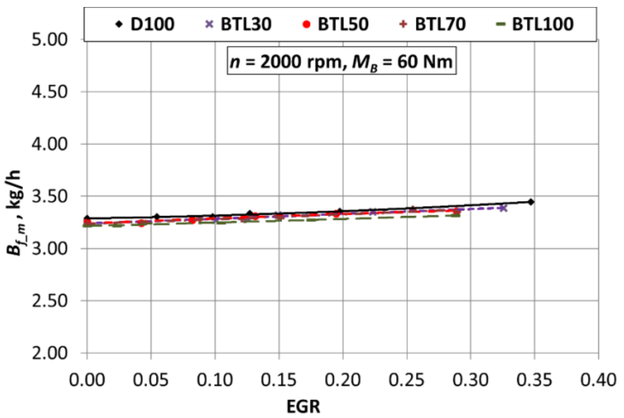

Fig. 2 Dependence of hourly fuel mass consumption on blend composition and EGR

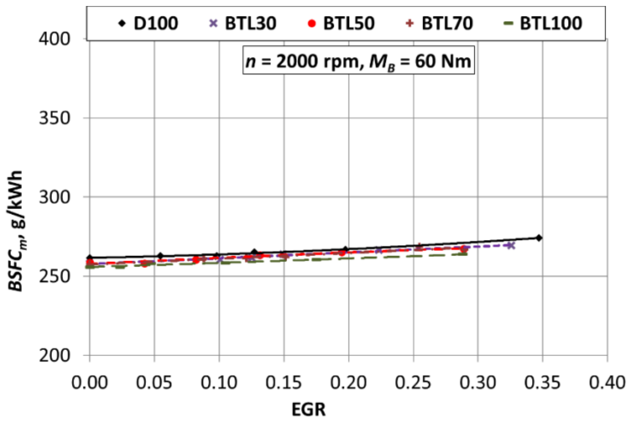

Fig. 3 Dependence of comparative fuel mass consumption on EGR

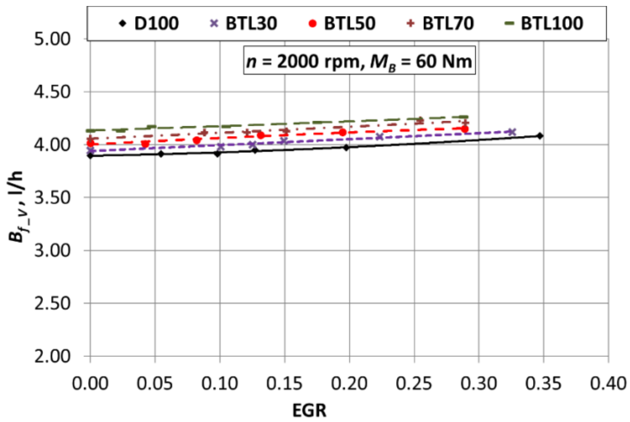

Fig. 4 Dependence of hourly fuel volume consumption on blend composition and EGR

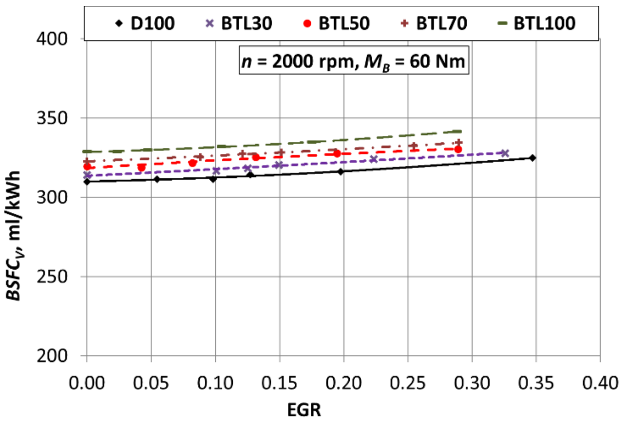

Fig. 5 Dependence of comparative fuel volume consumption on blend composition and EGR

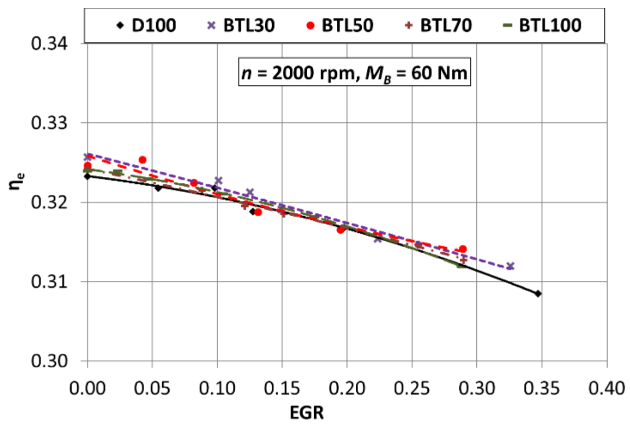

Fig. 6 Dependence of the efficiency coefficient on blend composition and EGR mass ratio

Engine efficiency coefficient η_e presents a comprehensive assessment of the efficiency of fuel energy use. It was determined that when engine operates on D100 fuel and various NExBTL blends, the difference in engine efficiency does

not exceed 0.6% (BTL30), which is below the measurement error (Fig. 6). This allows stating that when increasing NExBTL fuel concentration from 0% to 100%, engine efficiency remains unchanged, because the change in net heating value of fuel compensates the difference in fuel consumption.

When increasing EGR to 0.05, the engine efficiency changes slightly but with EGR growing to 0.3 – 0.35, the engine efficiency gradually decreases to 3.4% – 4.8%. When feeding back exhaust gas into the cylinder, EGR reduces the amount of air (oxygen) getting into the cylinder, which deteriorates the quality of combustion and the efficiency of use of thermal energy of fuel.

5. Conclusions

The following conclusions having made having carried out a research of efficiency of second-generation biodiesel and diesel blends in compression ignition engines and analysed the obtained test results:

1.The opportunities for application of NExBTL are viable due to large production resources and better physico-chemical properties of second-generation biofuel.

2.When replacing diesel with NExBTL fuel (up to 100%), hourly fuel mass consumption and Brake Specific Fuel mass Consumption (in proportion to the NExBTL concentration) decrease by up to ~2.6%, because NExBTL fuel mass unit contains more energy, i.e. net heating value of biofuel (MJ/kg) is ~5.1% higher than that of conventional diesel fuel.

3.When replacing diesel with NExBTL fuel (up to 100%), hourly fuel mass consumption and Brake Specific Fuel volume Consumption (in proportion to the NExBTL concentration) increase by up to ~5.7%, because NExBTL fuel volume unit contains more energy, i.e. its net heating value (MJ/l) is ~5.9% lower than that of conventional mineral diesel fuel.

4.When increasing the concentration of biofuels from 0% to 100%, engine efficiency in NExBTL blend with conventional mineral diesel fuel has a tendency to grow to 0.6% (BTL30) due to a simple molecular structure of biofuel and more efficient combustion, but the difference in energy efficiency results is within the limits of errors.

5.When gradually increasing EGR from 0 to 0.3 – 0.35, low EGR (up to 0.05) has a low influence on engine efficiency, but when increasing EGR more intensively, all diesel and NExBTL blend fuel consumption gradually increases by 3.2 – 4.5% and engine efficiency decreases by 3.4% – 4.8%. EGR reduces the amount of oxygen getting into the cylinder and the combustion temperature, which deteriorates the combustion quality and efficiency.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Stress of the Steering Mechanism of Combat Tracked Vehicles

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Abstract

The track lines are one of the great benefit of tracked vehicles - enable to achieve much better movement capability on the heavy terrain than the wheeled vehicles. On the other side the track lines are source of the vibrations and additive dynamic stress of the propulsion mechanism. This mechanism is also source of additive internal resistance and external resistances, which means the higher values of the power loses. Principle of tracked vehicles turning is very different from principle of the wheeled vehicles and it is the source of additional resistance, too. This paper focuses on directional devices of the tracked vehicles.
KEY WORDS: *tracked vehicles, turning, directional device, power*

1. Introduction

Combat tracked vehicles proved their position in the nowadays military operations, yet the tactic and utilization of weapons have changed. Current tank´s construction was set up almost 70 year ago, after the 2nd World War. Nowadays tank programs are focus on modernization of current vehicles. We can see difference in the Russia tank´s conception, which is different from the western countries. Nowadays upgrades bring vehicles weight increasing, which means increasing of the track propulsion mechanism stress. Weight increasing of nowadays MBTs in selected countries shows the Fig. 1.

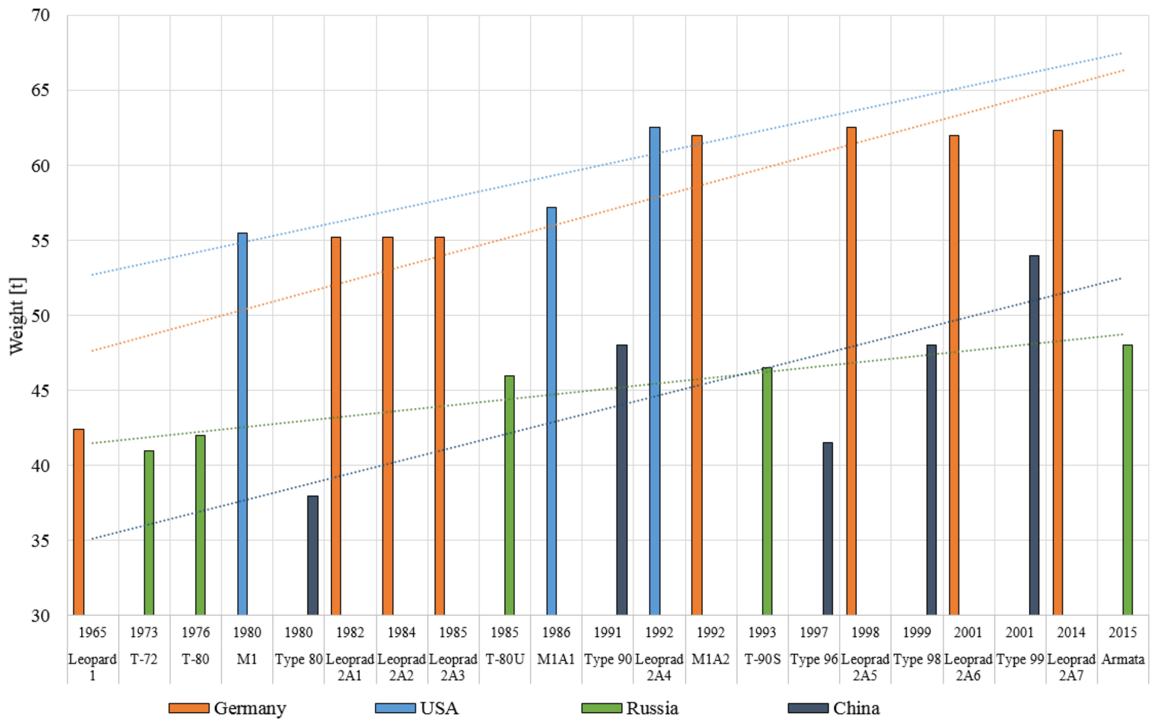

Fig. 1 Weight development of MBT in selected countries [1]

The construction of the movement mechanism and the resistance against the movement of tracked vehicles are very different from wheeled vehicles. The track lines are not only the additive source of vibrations and stress of the propulsion mechanism but also they are source of additive resistance, which means the higher values of the power loses. Principle of tracked vehicles turning is very different from principle of the wheeled vehicles. For turning of the tracked vehicle, it is necessary to change the speed between the inner and outer track lines. As a result of this change, the contact surfaces of the belts are laterally shifted on the ground and cause considerable resistances. The frictional forces between the track line and the ground and the forces that arise from the cutting and plating of the ribs of the cells generate these additive resistances. This means a high increase in total drive resistors at the turn of the Combat Tracked Vehicles (CTV), which leads to increasing of the engine and transmission load [1].

2. Theory of Combat Tracked Vehicles Turning

Steering mechanism of tracked vehicles is incorporated into the transmission. This directional device can be a separate construction part - a two-stage planetary directional device, or it may be part of the unit which are also used for the direct driving - the combined directional device or the directional gearbox. Directional device which utilize the two-stage planetary directional device or the directional gearbox is called clutch type. Directional device which utilize the combined directional device is called differential type. Magnitude of a vehicle speed v_0 during the vehicle turning is the main difference between the clutch and differential directional device [2].

Clutch directional device: speed of outer track v_2 is the same as during the direct ride, speed of the inner track v_1 is smaller, Fig. 2. The steering vehicle speed v_T is smaller than the initial vehicle speed v_0.

Differential directional device: speed of outer track v_2 is larger than the initial speed, speed of the inner track v_1 is smaller, Fig. 3. The steering vehicle speed v_T is the same as the initial vehicle speed v_0 [3].

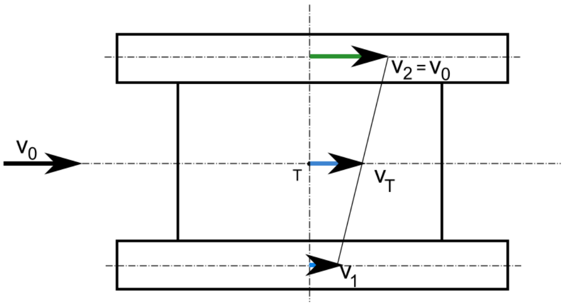

Fig. 2 Clutch directional device

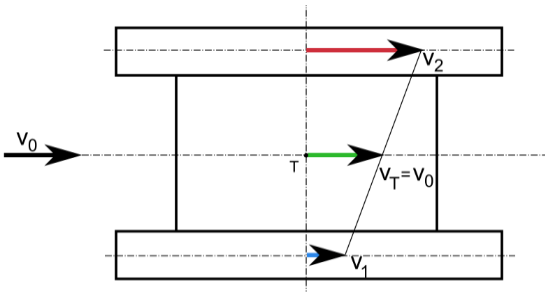

Fig. 3 Differential directional device

We can see that the vehicle steering speed of the vehicle with differential directional device is higher that speed of the vehicle with the clutch directional device, yet we can also compare the magnitude of the power required to overcome external resistances.

The general forces and torques which affect the track vehicle during the turning are presented in the Fig. 4.

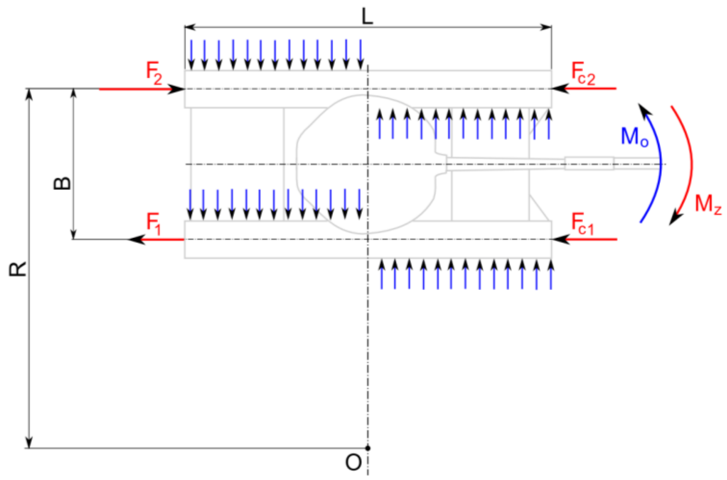

Fig. 4 The general forces and torques, where: B - track gauge; L - length of the contact surface of the tracks with the ground; O - center of rotation; R - radius of rotation; F_1 - force of the inner track; F_2 - driving force of the outer track; F_{c1} - resistance against movement of the inner track; F_{c2} - resistance against movement of the outer track; M_o - torque resistance; M_Z – turning torque

We can express the resistances against movement by next formula:

$$F_{c1} = F_{c2} = f \cdot \frac{m \cdot g}{2}, \tag{1}$$

where f - rolling resistance; m – vehicle weight; g – gravitational acceleration.

We can also express the forces F_1 and F_2 by the next equations. We expect the braking force F_1 in the next expressions:

$$F_1 = -\frac{f \cdot m \cdot g}{2} + \frac{M_o}{B}; \tag{2}$$

$$F_2 = \frac{f \cdot m \cdot g}{2} + \frac{M_o}{B}, \tag{3}$$

where M_o - torque resistance; B - track gauge.

Torque resistance is determined by the experiment and its magnitude is dependent on the ground quality, shape of the track elements and radius of rotation. Coefficient of the turning resistance μ express mentioned dependence. The torque calculation is based on the Fig. 5.

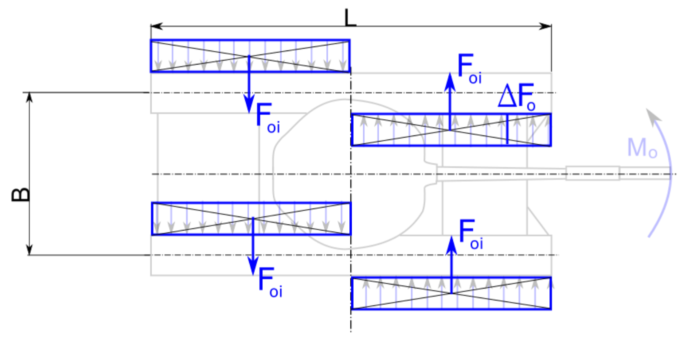

Fig. 5 Dependence of the lateral forces during the turning of the track vehicle, where: ΔF_o – element of the weight force; F_{oi} – lateral force of the selected track part

$$\Delta F_o = \frac{m \cdot g}{2 \cdot L}, \tag{4}$$

$$F_{oi} = \mu \cdot \Delta F_o \cdot \frac{L}{2} = \frac{\mu \cdot m \cdot g}{4}. \tag{5}$$

The magnitude of the torque resistance can be expressed by the next formula:

$$M_o = 4 \cdot F_{oi} \cdot \frac{L}{4} = \frac{\mu \cdot m \cdot g \cdot L}{4}. \tag{6}$$

From the magnitude of the torque resistance we can express the longitudinal force which affects the tracks in the longitudinal direction. Than we can express the forces F_1 and F_2 by next formulas:

$$F_1 = -\frac{f \cdot m \cdot g}{2} + \frac{\mu \cdot m \cdot g \cdot L}{4 \cdot B}; \tag{7}$$

$$F_2 = \frac{f \cdot m \cdot g}{2} + \frac{\mu \cdot m \cdot g \cdot L}{4 \cdot B}. \tag{8}$$

The Eqs. 7 and 8 are valid for the state where we do not consider centrifugal force F_o, because the centrifugal force will change the position of the vehicle turning center. The difference is shown in the Fig. 6.

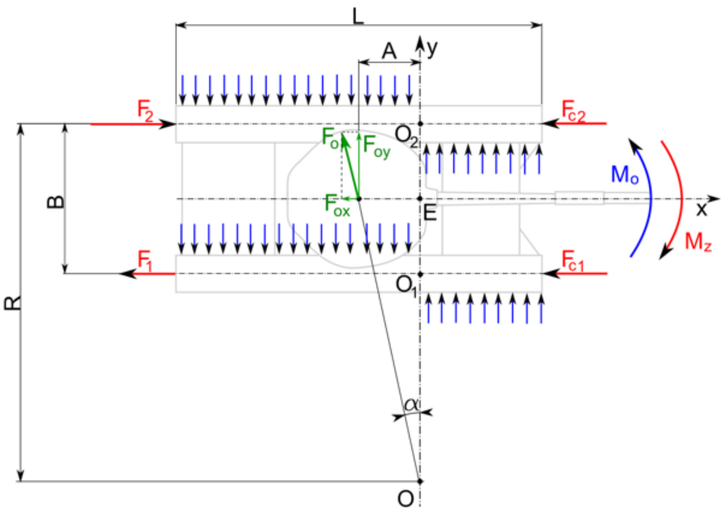

Fig. 6 Effect of the centrifugal force, where: F_o – centrifugal force; F_{ox} – centrifugal force in the longitudinal direction; F_{oy} - centrifugal force in the longitudinal direction; A - moving of the rotation center

The centrifugal force components and the moving of the rotation center we can express by next equations:

$$F_{oy} = \frac{m \cdot v^2}{R - \frac{B}{2}}; \tag{9}$$

$$F_{ox} = \frac{A \cdot F_{oy}}{R - \frac{B}{2}}; \tag{10}$$

$$A = F_{oy} \cdot \frac{L}{2 \cdot \mu \cdot G}. \tag{11}$$

The overall magnitudes of the forces F_1 and F_2 including the centrifugal force are given by next formulas:

$$F_{c1} = -f \cdot \left(\frac{G}{2} + \frac{F_{oy} \cdot h}{B} \right) + \frac{\mu \cdot G \cdot L}{4 \cdot B} \cdot \left[1 + \left(\frac{2 \cdot A}{L} \right)^2 \right] - \frac{F_{oy} \cdot A}{B} - \frac{F_{ox}}{2}; \tag{12}$$

$$F_{c2} = f \cdot \left(\frac{G}{2} + \frac{F_{oy} \cdot h}{B} \right) + \frac{\mu \cdot G \cdot L}{4 \cdot B} \cdot \left[1 + \left(\frac{2 \cdot A}{L} \right)^2 \right] - \frac{F_{oy} \cdot A}{B} + \frac{F_{ox}}{2}. \tag{13}$$

In the Eqs. (12) and (13) we can see that the overall forces against the vehicle movement depend on vehicle undercarriage geometry, vehicle speed (expressed by the centrifugal force) and terrain characteristics – which are characterized by the rolling resistance f and turning coefficient μ. The magnitudes of these forces are necessary for the analysis of the track lines stress during the vehicle turning.

3. The Power Required to Overcome External Resistances

The power to overcome external resistances during the vehicle turning consists of the parts: resistances of the straight movement P_{od}; resistances of the vehicle turning P_{ot}. Magnitudes of these powers can be expressed by next formulas:

$$P_{os} = F_{c2} \cdot v_2 + F_{c1} \cdot v_1; \tag{14}$$

$$P_{ot} = M_o \cdot \omega_t = \frac{M_o \cdot (v_2 - v_1)}{B}, \tag{15}$$

where v_1 – velocity of the inner track; v_2 – velocity the outer track; ω_t - angular speed of the vehicle turning.

We can express the necessary power by application of the Eqs. (14) and (15) and dependencies form the Fig. 2 and Fig. 3. Necessary power of the clutch directional device P_{oc} and differential directional device P_{od} are expressed by next formulas:

$$P_{oc} = \frac{F_2 \cdot R - F_1 (R - B)}{R} \cdot v_0; \tag{16}$$

$$P_{od} = \frac{F_2 \cdot R - F_1 (R - B)}{R - \frac{B}{2}} \cdot v_0, \tag{17}$$

where v_0 – initial velocity of the vehicle.

We can see that the vehicles with the differential directional devices need higher power for the turning maneuver.

4. Next Advantages of the Directional Devices of the Track Vehicles

Possibility of power recuperation during the vehicle turning is the benefit of the combined turning mechanisms. The recuperation principle is shown is the Fig. 7. The mechanical bond between the inner and outer track line is a condition for recuperation securing. This mechanical bond provides planetary reducers. During the vehicle turning is power from the outer track (green highlighted) through the terrain is returned to the transmission (orange highlighted)

by the inner track line, inner sprocket wheel, inner final gear, inner planetary gear – in this mechanism is divided into two ways (1st direction to the secondary control branch – grey highlighted; 2nd to the transmission – light blue highlighted) and to the transmission, which decreases the load of the main branch [1].

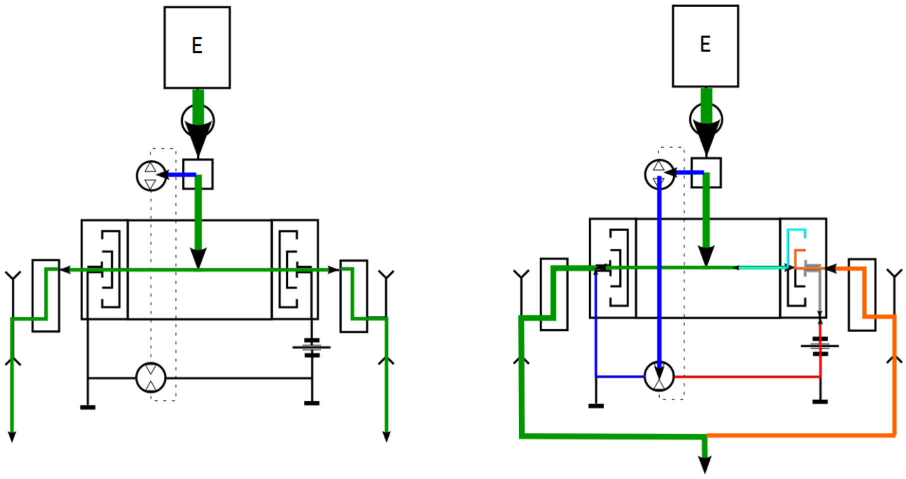

Fig. 7 Principle of the power recuperation, straight movement in the left, turning in the right [1]

The benefit of the recuperation also offers the two-stage planetary directional device, but only in one running stage – during the operation of the operating brake. Principle of the two-stage planetary directional device recuperation you can see in the Fig. 8. The red operating elements (SB1, SS2) are closed. The green line shows the path of the main stream of the power. The orange line shows the external power of the inner track, which is divided into red stream of the brake power and blue stream of the recuperation power – Kinematics linkage of the inner and outer track (through the planetary gear of the inner track) enables the power recuperation.

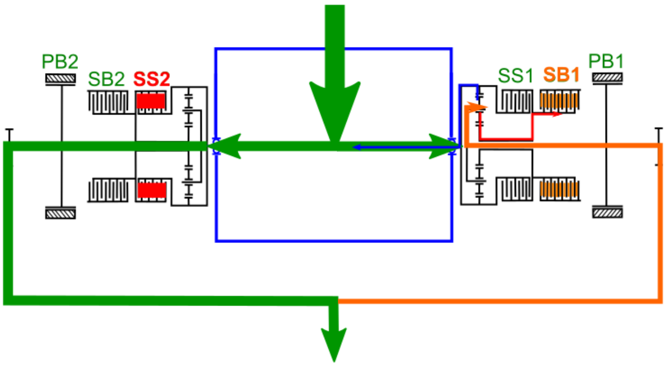

Fig. 8 Principle of the power two-stage planetary directional device recuperation, where: PB1 – operating brake of the inner track; SB1 – turning brake of the inner track; SS1 – blocking clutch of the inner track; PB2 – operating brake of the outer track; SB2 – turning brake of the outer track; SS2 – blocking clutch of the outer track

5. Conclusions

Velocity change of the inner and outer track is necessary process for the turning of the tracked vehicle. During the vehicle turning the tracks also laterally slide on the terrain – friction between the tracks, spreading of the soil are the sources of additive resistances during the vehicle turning. The lateral forces in the track line arise and increasing the friction loses in the track line movement. All these resistances negatively affect the stress of the propulsion mechanism (mainly: track lines, sprocket wheels, transmission, engine).

Most vehicles exclusively use combined directional mechanism – differential direction device. Reducing the friction losses in the directional device during the turning is huge advantage (in the hydro-mechanical transmissions are different loses, mainly in the hydraulics part). Combined directional mechanism enables (with the steady initial velocity) to pass the turn at a higher speed than the two-stage planetary directional device (clutch directional device). The power recuperation during the vehicle turning is the next advantage of this device. The two-stage planetary directional device also offers the power recuperation, but only in some operational states.

Significant complexity, higher weight and higher production costs are the basic disadvantages of these devices. Higher power is needed for the turning of the vehicle with combined directional mechanism. This means that the vehicles with differential directional device have higher engine power - this is obvious when comparing the Western (USA, UK, Germany, France…) and Russian design schools. Differential directional device is typical for the Western

design school and clutch directional device is typical for Russian construction school.

The overall forces against the vehicle movement and turning depend on vehicle undercarriage parameters (track line gauge B, length of contact area of track lines L), vehicle velocity and terrain parameters –characterized by the rolling resistance f and coefficient of the turning resistance μ. Turning coefficient depends on dependent on the ground quality, shape of the track elements and radius of vehicle turning.

The analysis of the stress of the track movement mechanism is really complex process, the next analysis will be focused on the utilization of the simulation technologies. Utilization of the simulation technologies can bring more detailed analysis of the stress of the tracked movement mechanism during the vehicle movement and its turning [4].

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Variation of Stiffness and Damping of the Laden hsfv1 Freight Car

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Abstract

This article presents the results of study on the influence of lateral and longitudinal stiffness and damping in primary suspension on dynamics of the hsfv1 laden freight car. The studies were performed for velocities below and above the critical one (v_n). The main scientific tool in these studies is numerical simulation. The results obtained will be used for comparison with the earlier results for 2-axle empty freight car of average parameters. This makes main part of the presented paper. The biggest difference is in the weight of the vehicle which has a direct impact on the non-linear behavior of the vehicle (vibrations). The laden freight car behaves more predictably and shows less non-linear behaviours.
KEY WORDS: *transition curve, critical velocity, numerical simulations*

1. Introduction

The article presents the results obtained for the lateral and longitudinal variation of the stiffness and damping of the 2-axle freight hsfv1 for velocities below and above critical velocity (v_n). The results were compared with the ones obtained earlier in an analogous way for an empty 2-axle freight car of average parameters. The biggest difference between the two vehicles is the weight of the body which obviously affects car body mass and inertial moments. Previous research has revealed that the vehicle body mass has a direct effect on the non-linear behaviour of the vehicle (vibrations). Freight hsfv1 car is a laden one and the weight of its body is 30000 kg. The freight car of average parameters is an empty one and its body weight is 10000 kg. The other nominal parameters of both vehicles are presented in Table 1. The authors focused on the following four parameters (longitudinal stiffness k_{zx}, lateral stiffness k_{zy}, longitudinal damping c_{zx}, lateral damping c_{zy}) whose significant influence was revealed in the publications on stability in the straight track (ST) and the circular curve (CC) [1-3, 7-12].

The research was carried out in a few steps. Both stiffness and damping longitudinally and laterally were varied below and above their basic values. The special case is longitudinal damping of laden car of the basic value c_{zx} = 0. In this case the value c_{zx} of freight car of average parameters was adopted instead and then it was also varied (see Table 1).

2. Description of Research Methodology

The article presents the results of numerical simulations received for two models: laden hsfv1 car and empty freight car of average parameters. Fig. 1 shows identical structure of both models. In addition, vehicle models have been supplemented with discrete models of vertically and laterally flexible track models which are shown in Figs. 1. a and 1, b, respectively. Models of systems are described in more detail in [12].

Description of the contact geometry is introduced into the model using the contact parameters table which was generated by ArgeCare RSGEO program [5]. Tangential contact forces were generated by the FASTSIM procedure [4]. In this study a pair of wheel and rail profiles S1002 and UIC60 was used and vehicles move on the track of 1435 mm gauge and 1:40 inclination of rails. Both the object and track models assume linear characteristics of elastic and damping elements. To simulate the motion the authors used the program that uses Lagrange second type equations adapted to describe the relative motion [6]. Both models have 18 degrees of freedom.

3. Results of the Studies

The article presents the results obtained for variation of the lateral and longitudinal values of the stiffness and damping of the primary suspension of freight hsfv1 car in comparison with the previously obtained results for the empty freight car of average parameters.

Simulations were started for the nominal (basic) parameters of the model (see Table 1) and radius R = 600 m, superelevation h = 0.15 m, velocity v = 45.3 m/s, non-zero initial conditions for wheelsets $y_i(0)$ = 0.0045 m and integration procedure relative error E = 0.01. The route consisted of three consecutive sections of a straight track (ST), a transition curve (TC) and a circular curve (CC). The lengths of ST (l = 300 m), TC (l = 142 m) and CC (l = 150 m) were adopted.

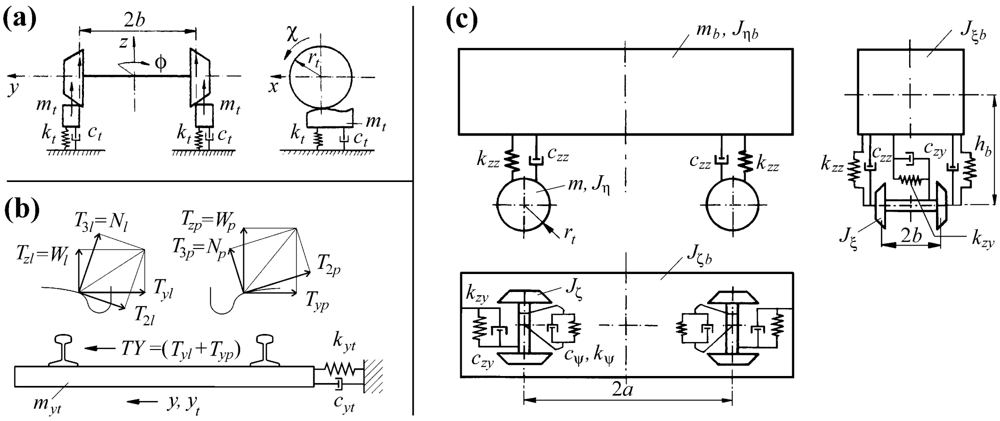

Fig. 1 Structure of the nominal model: a) track vertically; b) track laterally; c) vehicle

Table 1

Parameters of nominal models

Notation	Description	Measur. unit	Param. value of <u>empty</u> freight car of average param.	Param. value of hsfv1 <u>laden</u> freight car
m_b	vehicle body mass	kg	10000	30000
m	wheelset mass	kg	2400	2392
$J_{\xi b}$	vehicle body moment of inertia; longitudinal axis	kg*m^2	5830	51000
$J_{\mu b}$	vehicle body moment of inertia; lateral axis	kg*m^2	61700	240000
$J_{\zeta b}$	vehicle body moment of inertia; vertical axis	kg*m^2	61700	222000
J_ξ	wheelset moment of inertia; longitudinal axis	kg*m^2	1700	1662
J_μ	wheelset moment of inertia; lateral axis	kg*m^2	200	50
J_ζ	wheelset moment of inertia; vertical axis	kg*m^2	1700	1662
k_{zx}	longitudinal stiffness of the 1st level of suspension	kN/m	800	206.7
k_{zy}	lateral stiffness of the 1st level of suspension	kN/m	800	431
k_{zz}	vertical stiffness of the 1st level of suspension	kN/m	1000	4100
c_{zx}	longitudinal damping of the 1st level of suspension	kN*s/m	42	0
c_{zy}	lateral damping of the 1st level of suspension	kN*s/m	47	56
c_{zz}	vertical damping of the 1st level of suspension	kN*s/m	60	28
a	semi-wheel base	m	3.16	3.15
h_b	vertical distance between mass centres of wheelset and vehicle body	m	1.04	1.175
r_t	wheelset rolling radius	m	0.46	0.375

Results of the study were divided into eight groups.

In the first group longitudinal stiffness k_{zx} values were varied where k_{zx} values were lower than the basic value k_{zx} = 206700 N/m (see Figs. 2 and 3). In the second group longitudinal stiffness k_{zx} was varied where k_{zx} values were greater than the basic value (see Figs. 4 and 5).

In the third group lateral stiffness k_{zy} values were varied where the k_{zy} values were smaller than the basic value k_{zy} = 431000 N/m (see Fig. 6). In the fourth group lateral stiffness k_{zy} was varied where values were greater than the basic value (see Fig. 7).

In the fifth group lateral damping c_{zy} values were varied where c_{zy} values were lower than the basic value c_{zy} = 56000 N*s/m (see Fig. 8). In the sixth group lateral damping c_{zy} was varied where c_{zy} values were greater than the basic value.

In the seventh group longitudinal damping c_{zx} values were varied. The original basic value of c_{zx} = 0. Therefore, the value corresponding to the freight car of average parameters was substituted for the basic value of c_{zx} i.e. c_{zx} = 42000 N*s/m. In this group the values in the range between 42 to 42000 N*s/m were varied (see Fig. 9). In the eighth group c_{zx} values were varied where the values of c_{zx} were greater than the value of 42000 N*s/m (see Fig. 9).

Additionally, in each group of the already adopted stiffness and/or damping parameter variants, the radius R and velocity v were varied. The following radii of the arc are R = 300, 600, 900, 1200, 2000, 4000, 6000 and 10000 m

were taken (see Fig. 8). Where necessary the studies were extended with the R values equal to 450, 500, 550, 650, 700, 750 and 3000 m. The superelevation h was always selected in such a way that the balance of the component lateral forces took place. Variations of velocity v in the range from v = 25 m/s to the numerical derailment, i.e. to stop of the calculations, were made. The lengths of the ST and CC were also subject to change. The length of the TC always remained unchanged.

The figures illustrate selected lateral co-ordinates for the considered vehicles. These are lateral displacements y and yaw angles ψ. Indices *b, l* and *t* denote car body, leading wheelset and trailing wheelset, respectively. Additionally index */1x* is used for original graphs for basic lateral and longitudinal stiffness and velocity v = 45.3 m/s and R = 600 m. The study was conducted for the damping values 0 and 100 times the basic value which are indicated with /0x and /100x indices, respectively. There are also supplementary indices in use as /600, /1200 and/4000 corresponding to radius R in m. The exact parameters of the routes are specified in the figure captions.

Due to limitations in the article volume this paper contains only ten graphs (Figs. 2-11) but conclusions refer to whole results.

Figs. 2-5 show the results for longitudinal stiffness k_{zx} variants. Fig. 2 shows the result obtained for k_{zx} = 206700 N/m, i.e. the value is 10 times smaller than the basic value. Here, in both ST and CC, a limit cycle with a large amplitude was obtained. However, for the value k_{zx} = 0.2 times the basic value (k_{zx} = 413400 N/m), the trailing wheelset behaves similarly to the previous one, while the leading wheelset achieves the limit cycle in CC but with a very small amplitude (see Fig. 3). For the basic value, there is no vibration in ST, TC and CC (see Fig. 4). On the other hand, increase of value of k_{zx} 100 times (k_{zx} = 206700000 N/m) results in a solution of a different nature. Here the limit cycle in ST (with a different character) appears, while in the TC the vibrations gradually disappear and the lack of vibrations in CC exists (see Fig. 5).

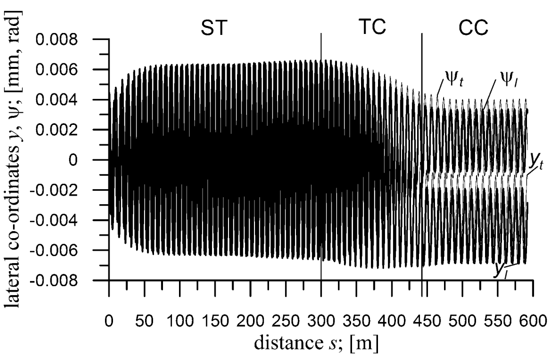

Fig. 2 Selected co-ordinates of hsfv1 car: R = 600 m, non zero i.c. $y_l(0)$ = 0.0045 m, h = 0,150 m, v = 45.3 m/s, k_{zy} = 431000 N/m, **k_{zx} = 206700 N/m (0.1x)**

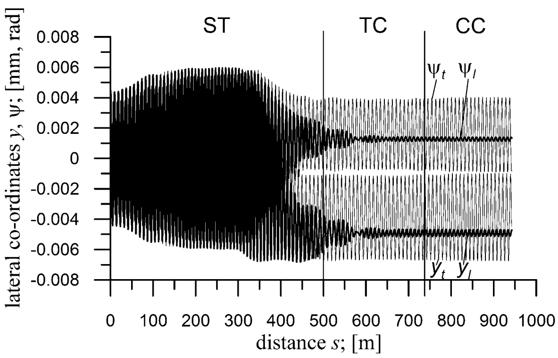

Fig. 3 Selected co-ordinates of of hsfv1 car: R = 600 m, non zero i.c. $y_l(0)$ = 0.0045 m, h = 0,150 m, v = 45.3 m/s, k_{zy} = 431000 N/m, **k_{zx} = 413400 N/m (0.2x)**

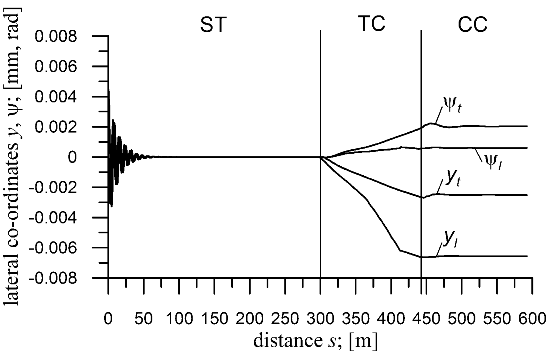

Fig. 4 Selected co-ordinates of hsfv1 car: R = 600 m, non zero i.c. $y_l(0)$ = 0.0045 m, h = 0,150 m, v = 45.3 m/s, k_{zy} = 431000 N/m, **k_{zx} = 2067000 N/m (1x)**

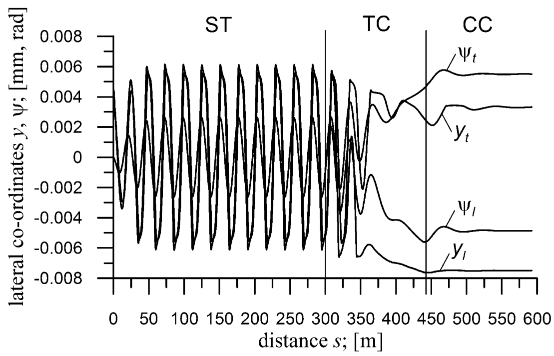

Fig. 5 Selected co-ordinates of of hsfv1 car: R = 600 m, non zero i.c. $y_l(0)$ = 0.0045 m, h = 0,150 m, v = 45.3 m/s, k_{zy} = 431000 N/m, **k_{zx} = 206700000 N/m (100x)**

Figs. 6 and 7 were obtained for varying lateral stiffness k_{zy}. Values of k_{zy} were smaller and bigger than the basic value. It was 0.8 of the basic value (see Fig. 6) and 8 times the basic value (see Fig. 7). However, for both cases k_{zx} was 10 times smaller. For a smaller value of the k_{zy} a limit cycle was obtained in ST and CC with quite a large amplitude (see Fig. 6). However, for a larger value of k_{zy}, there is no vibration in ST and TC, whereas in CC vibrations are generated and a limit cycle with quite large amplitude is fixed.

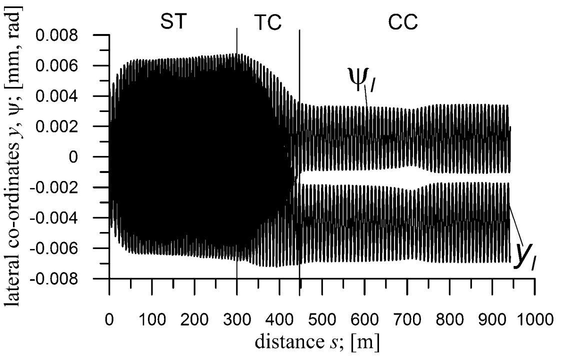

Fig. 6 Selected co-ordinates of hsfv1 car: R = 600 m, non zero i.c. $y_l(0)$ = 0.0045 m, h = 0,150 m, v = 45.3 m/s, **k_{zy} = 344800 N/m (0.8x), k_{zx}=206700 N/m (0.1x)**

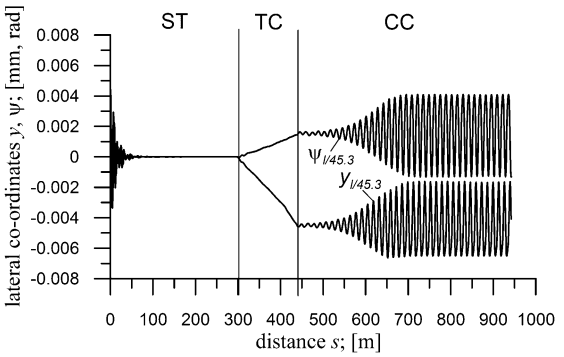

Fig. 7 Selected co-ordinates of of hsfv1 car: R = 600 m, non zero i.c. $y_l(0)$ = 0.0045 m, h = 0,150 m, v = 45.3 m/s, **k_{zy} = 3448000 N/m (8x), k_{zx} = 206700 N/m (0.1x)**

Fig. 8 presents the results obtained for lateral damping c_{zy} 1.5 times larger (c_{zy} = 84000 N/m) than the basic value. Here, one co-ordinate (lateral displacements of the leading wheelset) is provided for the three radius values R = 600, 1200 and 4000 m. The vehicle behaves in a traditional, expected way. As the radius of the arc increases the vibration amplitude values in CC increase.

Fig. 9 presents the results obtained for basic lateral damping c_{zy} = 56000 N*s/m. Here, one co-ordinate (yaw angles of the leading wheelset) is provided for the three values of longitudinal damping c_{zx} (c_{zx} = 0, c_{zx} = 42000 N*s/m (1x) and c_{zx} = 4200000 N*s/m (100x)). Each obtained result is different. For the smallest value c_{zx} = 0 a limit cycle in ST and CC with the large amplitude was obtained. For values c_{zx} = 42000 N*s/m (1x) the vibrations disappear in ST. No vibrations in TC and CC appear. For the highest value of c_{zx}, where c_{zx} = 4200000 N*s/m (100x) a limit cycle was again obtained in ST and CC but with the different frequency and amplitude than before (different character of the solution).

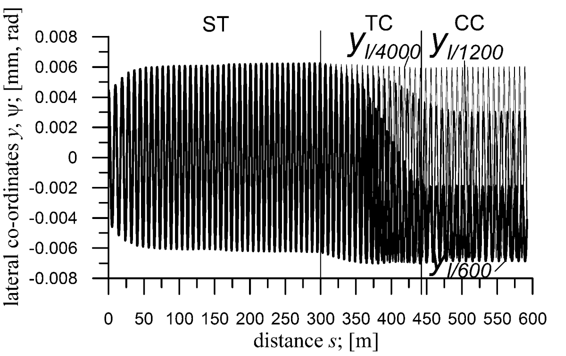

Fig. 8 Selected co-ordinates of hsfv1 car: ***R*-different**, non zero i.c. $y_l(0)$ = 0.0045 m, h-different, v = 45.3 m/s, **c_{zy} = 84000 N*s/m (1.5x),** c_{zx} = 0 N*s/m

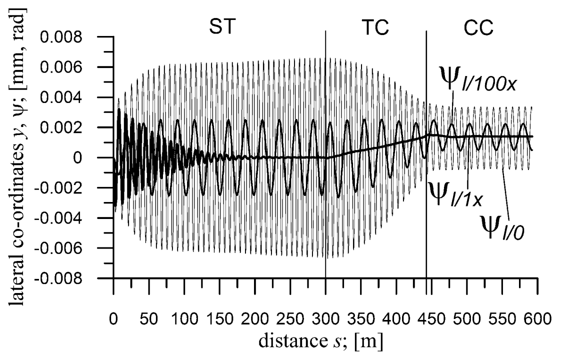

Fig. 9 Selected co-ordinates of of hsfv1 car: R = 600 m, non zero i.c. $y_l(0)$ = 0.0045 m, h = 0,150 m, v = 45.3 m/s, c_{zy} = 56000 N*s/m, **c_{zx}-different**

Figs. 10 and 11 were obtained for an empty freight car of averaged parameters.

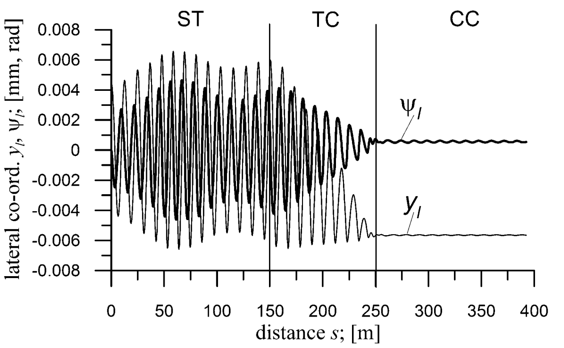

Fig. 10 Selected co-ordinates freight car of average parameters: R = 600 m, non zero i.c. $y_l(0)$ = 0.0045 m, h = 0.150 m, v = 44 m/s, **c_{zy} = 79900 N*s/m (1.7x), c_{zx} = 63000 N*s/m (1.5x),** k_{zy} = 800000 N/m (1.0x), k_{zx} = 800000 N/m (1.0x)

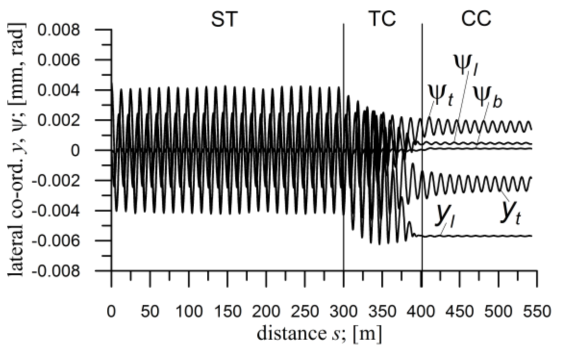

Fig. 11 Selected co-ordinates freight car of average parameters: R = 600 m, non zero i.c. $y_l(0)$ = 0.0045 m, h = 0.150 m, v = 44 m/s, **c_{zy} = 70500 N*s/m (1.5x), c_{zx} = 71400 N*s/m (1.7x),** k_{zy} = 800000 N/m (1.0x), **k_{zx} = 960000 N/m (1.2x)**

Fig. 10 was obtained for lateral damping $c_{zy} = 79900$ N*s/m (1.7x) and longitudinal damping $c_{zx} = 63000$ N*s/m (1.5x). Here, when the damping parameters change the transient phenomena that resemble beat like shape almost always appears. It is very difficult to choose parameters so that this temporary phenomenon can be eliminated. Fig. 11 shows the result for such a selection of parameters where lateral damping $c_{zy} = 70500$ N*s/m (1.5x), longitudinal damping $c_{zx} = 71400$ N*s/m (1.7x), lateral stiffness $k_{zy} = 800000$ N/m (1x) and longitudinal stiffness $k_{zy} = 960000$ N/m (1.2x). Here, a limit cycle was obtained for ST. However, in the CC the vibration of small amplitude for the leading wheelset and the car body was noticed, while the bigger limit cycle amplitude for the trailing wheelset was obtained.

4. Conclusions

The laden freight hsfv1 car seems to be the vehicle of predictable behaviour as compared to the empty car as it is shown in Figs. 2-5. The authors assume that the higher mass of the body than it is for the empty freight car of average parameters results in fewer non-linear phenomena observed. It turned out that the number of different behaviours of the laden vehicles is still noticeable. Some solutions are shown in Figs. 2-9. Fig. 8 shows quite uniform behaviour for different curve radii. However, Fig. 9 shows solutions of various nature for different damping values. Nevertheless, the laden freight car represents quite predictable solutions with less non-linear phenomena than the empty car. The empty car is quite light but of considerable dimensions (especially length), thus it is very sensitive to changes of parameters. It is difficult to find set of parameters for the empty car for which transient phenomena are short. In CC of small radii the amplitude for the empty car is fixed after a longer time. The laden freight hsfv1 car did not exhibit such behaviour.

Acknowledgements

Scientific work performed in the fame of research project no. 2014/15/N/ST8/02668 from funds of National Science Centre, Poland.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Kinematics of the Front Axle of All-Terrain Vehicle

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Abstract

This article describes a geometry suspension of front axle of All-Terrain Vehicle (ATV) with electric drive. A design is focused on the main parts of front axle which are designed with modern trends of ATVs. The geometry is designed by using the programme called Adams. A geometry analysis is created for models of front axle components. The input is a 3D model which is created in a Creo. The aim is evaluated basic angles of the axle's kinematic setting.
KEY WORDS: *All-Terrain Vehicle (ATV), geometry of suspension, front axle, toe-in, camber angel, kingpin angle*

1. Introduction

The development of a new vehicle must include an analysis of the geometry of the axle. For these cases, various commercial software are used. This speeds up the development and protects financial requirements for the prototype. Development of all-terrain vehicles can be divided to two main groups. This is a sports or working version and they are used in a race, farming or forestry.

This article dealt with the suspension geometry of ATV with electric drive. [1] Analysis of an axles is focused on individual angels of their geometry. ATV vehicle will be used in the heavy terrain condition, therefore, the axles must be adapted to it. Adams software was used for a kinematic analysis and results were evaluated. The aim of the suspension geometry analysis was to design a similar setting as for serialized ATV (Fig. 1). For these purposes, it was based on all-terrain vehicle Yamaha Raptor 660 and Kawasaki KFX 450.

The development of this ATV also takes place in the area of vehicle dynamics [2, 3]. There is described how to implement a custom library with blocks for assembling vehicle computational models. It is used to verify the vehicle properties, optimization and depend on the geometry setting in this article.

Fig. 1 Design of ATV vehicle

2. Suspension Geometry Analysis

This axle geometry influences a drive, tire wear, vehicle dynamics, etc. For evaluation of axle geometry, camber angle, kingpin angle, castor angle, kingpin offset and castor trail are used. Combined with the basic assumptions about the design and dynamics of vehicles [4, 5], the analysis and optimization of the kinematics suspension was solved in the Adams software. It is used for various applications as described in [6, 7, 10]. Points of geometry were moved and their

position is described in [1]. The setting values of the main angles geometry were similar to the angles geometry in the manuals for Yamaha Raptor 660 and Kawasaki KFX 450. Single components are joined by suitable bonds. A spherical joint is used for a connection of the arms with frame and arms with hub carrier. Whole frame is fixed to the ground. There is a spring-damper unit between bottom wishbone and frame. A rear axle is connected to spring-damper unit too. There is one spring with a damper. This travels of the spring-damper units were measured on the 3D model for full compress and spread. Zero position is when all-terrain vehicle is loaded only with statistic force.

3. Results of the Geometry

Change of camber angle

The camber angle γ is between centre plane of a wheel and longitudinal plane of a vehicle. It is shown on the transverse plane. The negative camber angle is when top size of wheel is rolled to longitudinal plane of a car. The positive angle is in opposite direction. The camber angle was set for delimiting a gap in the bearing a few years ago. [8] Nowadays bearings have small gap between parts of bearing of personal vehicle. Therefore the camber angle is set smaller and tyres have smaller wear. When change of camber angle is small, high moment doesn't impact the steering pull rod by the influence of gyroscopic moment. Body is rolled by turning and this camber angle is better to be negative. When wheels are stayed in a vertical position on the road, wheels then must transmit maximal lateral forces. This camber angle is changed by the graph in Fig. 2. This graph shows that the ATV is on the statistic state or goes on a small speed on the road, the camber angle is changed with the small differences. When ATV goes or turns on the road with potholes, camber will be higher.

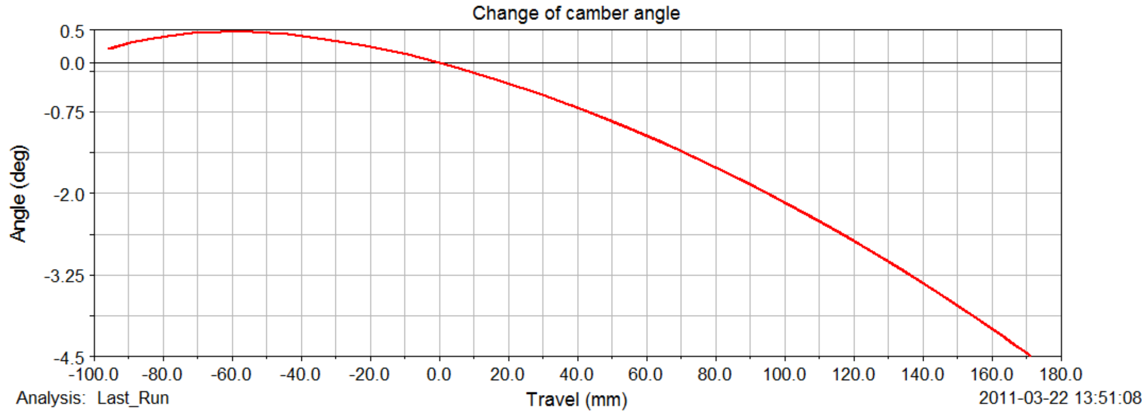

Fig. 2 Change of camber angle

Change of kingpin angle and kingpin offset

Kingpin angle σ is between the axis of steering and the longitudinal plane of vehicle. It is shown on the transverse plane of ATV. This angle is important in terms of returning wheels after turning into a straight line. The axle is raised when cornering due to value of kingpin angle. Therefore a force is created it made reverse torque which returns wheel into a straight line. For this design of ATV, kingpin angle is changed according to the graph in Fig. 3. Its value is inspired by serial ATV and the aim was to reach negative kingpin offset. This kingpin offset is the distance between a point which is created by intersection of steering axis and road and point contact of wheel and road. These points are shown on the transfer plane of ATV. When the intersection of steering axis and road is next to the wheel out, it is negative kingpin offset. This negative kingpin offset is used for stabile influence on the steering [8]. High value of kingpin offset creates higher sensitivity on the steering from longitudinal forces. Therefore kingpin offset is designed negative with a small value. This is shown in Fig. 4. Its value is 0.9 mm.

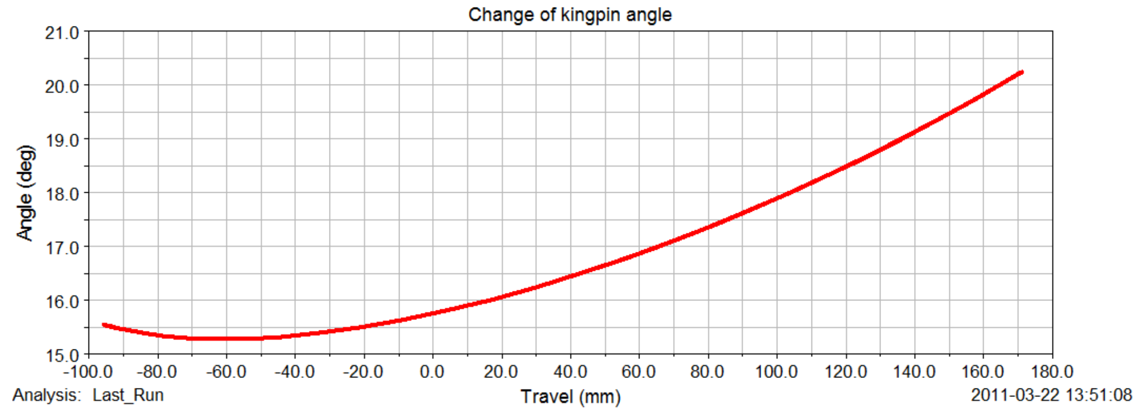

Fig. 3 Change of kingpin angle

Change of caster angle and trail

A caster angle between steering axis and transfer plane of ATV is shown on the longitudinal plane of ATV. This camber angle is positive when top position of steering axis is tilted backwards and negative caster angle is opposite. This camber angle creates a trail which is defined by distance between intersection steering axle with road and point of a tyre touch with road. This is evident on the longitudinal plane. This trail is positive when intersection is in front tyre point touch, and the negative trail is the opposite. During cornering, longitudinal force creates the torque and the wheel is returned to the straight line. The values of caster angle and trail are shown in Fig. 4.

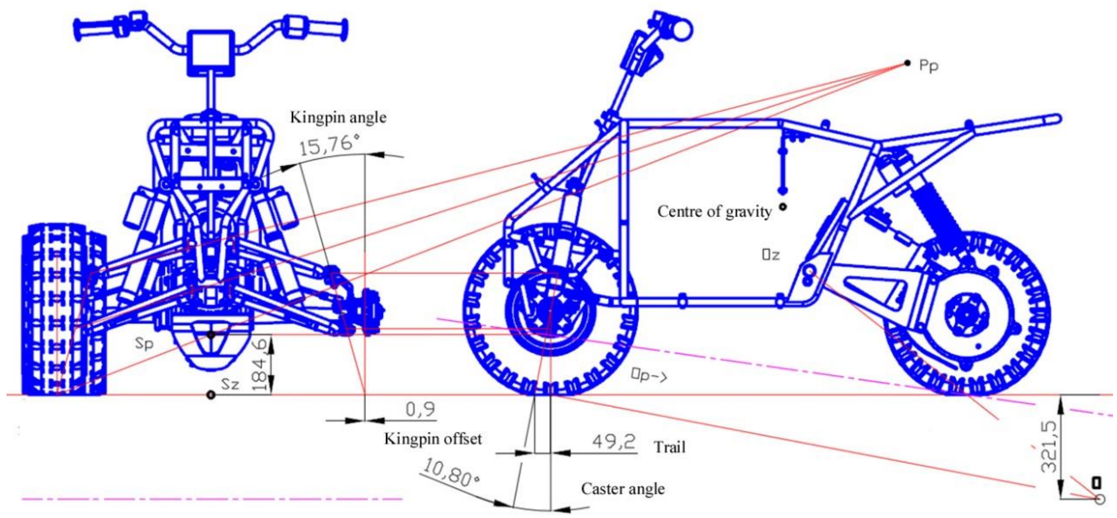

Fig. 4 Angle of geometry of suspension and midpoint roll and pitch of body

Pitch and roll of body

A midpoint of pitch and roll is possible to show graphically. These midpoints can be seen in Fig. 4. When top and bottom wishbones of front axle are elongated, a point of intersection is created. It is instant midpoint of roll *Pp*. This point *Pp* is connected with touch point of front wheel and road. This line intersects with longitudinal plane of ATV and midpoint of roll of the body *Sp* around front axle is created. Instant midpoint of roll rear wheels is at infinity, therefore, midpoint of roll of the body *Sz* is positioned on the road. An instant midpoint pitch of front axle *Op* is at infinity by the influence of parallel wishbones. The instant midpoint pitch of rear axle *Oz* is positioned in the attachment to the rear axle. This midpoint pitch *Oz* and point touch of rear axle between wheels and road are connected. The parallel line segment is made and with wishbones of the front axle. Then the midpoint pitch of the body *O* is created. This point is under the road. It is negative because front part of the frame falls during braking. Therefore the front springs have higher stiffness and fall of frame is not high. The frame is strained by torque in this case and it is influenced by position of midpoint pitch of the body.

Change of tread and wheelbase

Wishbones of front axle are considerably tilted. Therefore a tread is changed by a change of travel. This state causes creation of lateral forces which impact on the wishbones, bearings, pivots and tyre is worn. When we want to design a small difference of tread, the wishbones must be parallel with road plane but it is not positive for driving in terrain. A change of wheelbase influences position of the centre of gravity. It is a problem when a car has a small weight. Then small change of driver’s position influences considerably behaviour of the vehicle. The wheelbase change is shown in Fig. 5.

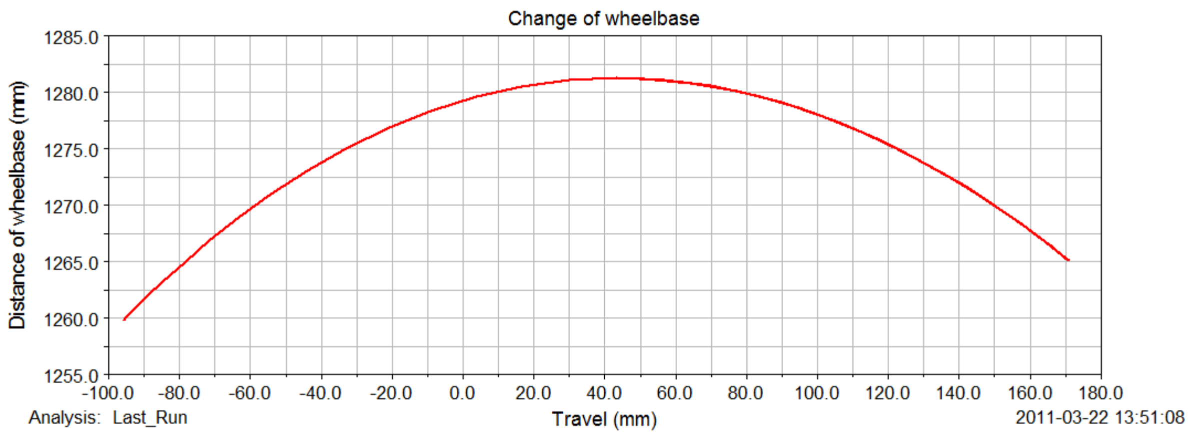

Fig. 5 Change of wheelbase

4. Conclusions

The results of the geometry analysis of designed ATV were evaluated and it was compared with serial ATV. The parameters of serial ATV were taken from their manuals. Kawasaki KFX 450 has a setting: caster angle of 1.8 deg, camber angle of -2 deg, kingpin angle of 14.7 deg and trail of 7.6 mm. Yamaha Raptor 660 has a setting: caster angle of 8 deg, camber angle of -1 deg, kingpin angle of 14.5 deg, trail of 47 mm and kingpin offset of 5 mm. Designed ATV has a setting: caster angle of 10.8 deg, camber angle of 0 deg, kingpin angle of 15.8 deg, trail of 49.2 mm and kingpin offset of 0.9 mm. These results show that the designed ATV has comparable parameters with Yamaha Raptor 660. It was also one of the goals because this ATV is a favourite among manufacturers. Geometry parameters assume that driving qualities could be good. In the next step, it will be necessary to produce a prototype and verify this setting on a real vehicle or to perform a simulation of the computational model for various riding maneuvers. Or consider using the combustion engine and optimizing it as in [9].

Acknowledgement

This work is an output of the internal BUT research project Reg. No. FSI-S-17-4104

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Containers Storage Strategy at the Rail-Road Intermodal Terminal

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Abstract

The article presents the container storage problem in the rail-road intermodal terminal. This issue was considered from the point of view of the distance traveled by transshipment devices and the loading work duration. For the purposes of the research, the processes of a container handling in the rail-road intermodal terminal were presented in detail. A review of the literature in the field of container storage methods and strategies was carried out. A simulation model, which proposed 4 variants of the containers distribution in the storage areas as a function of their distribution on the train in the FlexSim environment was developed.
KEY WORDS: *rail-road terminal, containers storage, simulation modelling*

1. Introduction

Moving the mass of transported cargo from road transport to rail transport is closely related to the dynamic development of containerization observed since the 1980s. This is due to the growing exchange of goods in international trade and the need to look for cheap, fast and reliable forms of transport [10]. Therefore, the possibility of transporting cargo in one loading unit offered by intermodal transport along the entire transport route using any of the transport modes is desired by trade partners [1].

The growing turnover of containers is a challenge for means of transport [20] and container handling points (intermodal terminals).

According to the definition adopted by the European Conference of Ministers of Transport, ECMT), the United Nations Economic Commission for Europe (UNECE) and the Organization for Economic Community and Development (OECD), the terminal is an area for storage of intermodal loading units, which is equipped with transshipment equipment for intermodal loading units handling [5].

Intermodal terminals can be divided into rail-road and marine terminals. In the first case we deal with terminals located on the railway network with access to road infrastructure. In the second case, however, these are terminals located in seaports and are part of the port. Marine intermodal terminals, due to their functions in the intermodal transport, have access to both, rail and road transport infrastructure, and in some cases, inland waterway infrastructure [11]. In addition, such terminals are equipped with own warehouse facilities, which enable the provision of services related to the consolidation of general cargo in containers [8].

Intermodal transshipment terminals play an important role in rail-road transport, performing the following functions [9]:

– transshipment of intermodal loading units in various transition relationships through the terminal. Transshipments depending on the loading units service technology can be carried out both directly and indirectly with operational storage;

– operational and rotational storage of intermodal loading units;

– logistic support of the transport chain (sorting of intermodal loading units, quality control, customs and border clearance);

– providing additional services (current maintenance, repair and cleaning of intermodal loading units).

2. Container Storage in the Rail-Road Terminal

In the rail-road intermodal terminal, after the train arrives, the rail cars with containers are unloaded. The containers are transshipped directly to the road transport vehicles, or in the case of the road vehicles absence, to the storage yard. Thus, either direct or indirect loading operations are performed.

Due to the fact that containers at the storage yard are stacked one on top of the other, it is necessary to plan their arrangement taking into account their gross weight (heavier container should not be stored on a lighter container)

stability (40 'container can not be stacked on two 20 'containers and vice versa), expected date of container's departure (in order to avoid moving containers on the yard trying to get a given container from under another one).

The information of the container storage location in the storage yard is one of the factors determining the speed of processes that are implemented in the intermodal terminal, which indirectly influences the success in the field of customer service. This essentially affects the duration of rail cars loading / unloading operations, which in this case does not depend only on the handling equipment efficiency. At this point, a very important issue is to plan the place of containers storage after unloading process in order to quickly load them at a later date. This issue is further complicated by the containers stacking. The time of loading operations directly affects the time that train stays in the terminal.

The distribution of containers in the rail-road terminal storage yard has not been studied in the literature so far. The interest of scientists in this topic usually focuses on the distribution of containers in the storage yard of a marine intermodal terminal. In this area, many literature have been published. Articles regarding the containers storage can be divided into four categories:

– Individual container distribution.
– Distribution of groups of container.
– Comparisons of container storage strategy.
– Container distribution taking into account other processes in the storage area.

The distribution of individual containers on the storage yard is generally carried out in two stages [6, 15, 3]. First, the container is allocated to the selected storage block and then to the selected location in the given block. This is due to the fact that in marine intermodal terminals the storage yard is divided into blocks. In rail-road terminals, there are blocks, but their division is usually resulting from different types of containers stored in these blocks. In addition, in rail-road terminals, these blocks usually constitute one large block operated by the main transshipment device.

The distribution of container groups on the yard was undertaken in the works [14, 7, 21]. The allocation of container groups to the blocks usually results from the ship berthing place. In [14], the authors minimize the weighted total time of container handling, depending on the unloading times as well as container transport times from the berth to the storage yard. Similarly in [7] authors are using the simulated annealing algorithm to check the possible permutations of the distribution of container groups in the block. A new approach to determining the distribution of container groups is proposed in paper [21]. The authors have developed 4 rules of containers storage in the storage yard assuming that:

– a fixed number of storage places is reserved for each container group;

– the containers storage time is constant. The number of free spaces in the storage yard must correspond to the number of arriving containers;

– empty storage spaces are reserved in proportion to the arrival speed of containers of different groups. Thus, the number of storage places for a given container group is determined by multiplying the average container arrival rate of a given group by a fixed value;

– empty storage spaces are reserved in proportion to the square roots of the number of containers arrived at the respective groups. The number of storage places for a group of containers is determined by multiplying the square root of the average speed of arrival of containers of a given group by a fixed value.

A part of the literature regarding the containers storage is devoted to the comparison of the storage strategies. Essentially, these strategies concern the random containers storage or according to specific categories resulting from technical parameters of containers, dates of their departure from the storage yard or their destination for the transport of selected types of cargo. An example of such a comparison between random strategy and strategy by category using simulation tools is presented in paper [4].

The classification of container storage strategies on the storage yard was made in [17]. These strategies were investigated in papers: [2, 16, 18, 19, 22, 12].

The literature analysis shows that the above mentioned strategies did not consider container storage taking into account their distribution on the train.

3. Problem Description

In this article, the authors consider the problem of the containers distribution in the storage yard. We focus on various strategies for the containers distribution in the storage yard, depending on the arrangement of containers on the train. It was proposed to analyze the distance traveled by the loading device (crane) during the loading operations in the wagon-yard relation depending on whether the containers are placed on the yard relative to their size or container's owner with different container distribution strategies on the rail cars.

The container storage distribution strategies analyzed in this paper are:

– containers distribution in the storage yard by their size;
– containers distribution in the storage yard by their owners (sea or rail carriers).

In addition to the distribution of containers on the storage yard, we also analyzed the distribution of these containers on the train and its impact on the distance traveled by the loading device depending on the strategy. The strategies of containers distribution on a train generally assume:

– random distribution of containers on the train;
– distribution of containers on the train according to their owners (sea or rail carriers).

As a result, in the article we proposed the following variants of the containers distribution on the yard:

1. Distribution by container size. Starting from the head of the train, containers 40 ', 30' and finally 20 'are placed in the yard.

2. Distribution according to container owners and containers size at the same time. Starting from the head of the train, the containers of the owner 1, 2 and 3 are placed. In addition, the containers of individual owners are set in the order 40 ', 30' and 20'.

The above variants of the containers distribution on the yard are schematically shown in Fig. 1. The storage yard in these variants has been divided into areas where the containers are generally stored by their size or by owner and size.

Fig. 1 Containers storage variants (*1) - variant number; 20’ - container size; 1, 2, 3 - container owner number)*

The variants of containers distribution on train are presented as follows:

1. Random containers distribution.

2. Distribution of containers according to their size with random assignment of container owners. From the head of the train containers 40 ', then 30' and finally 20 'are placed on the cars. In addition, distribution of containers of individual owners within containers of a given size is random.

The above variants of containers distribution on the train are shown in Fig. 2. The train was divided into parts in which the containers were distributed randomly, by size or by their owner.

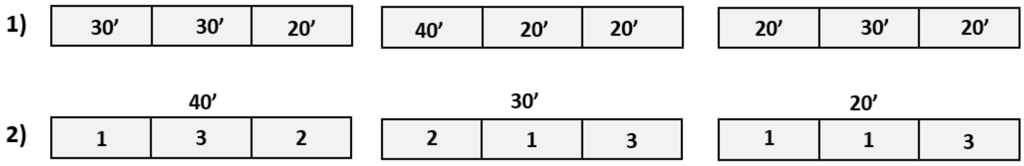

Fig. 2 Variants of containers distribution on train (*1) - variant number; 20’ - container size; 1, 2, 3 - container owner number*)

Considering the problem of the distance covered by the loading device (gantry crane), the above three variants of container distribution on the train were analyzed together with two variants of the containers distribution on the storage yard. As a result, 4 variants were obtained, which were analyzed using a simulation tool. These variants are summarized in the Table 1 below.

Table 1

Variants numbers of containers distribution on the train and on the storage yard

	Variant 1	**Variant 2**	**Variant 3**	**Variant 4**
Number of a variant of containers distribution on train	1	2	1	2
Number of a variant of containers distribution on storage yard	1	1	2	2

For the purposes of the research, a simulation model of containers transshipment process from the train to the storage yard was developed. The model was built in FlexSim environment. It is a software that allows for intuitive mapping and optimization of any transport processes, regardless of their scale. Thanks to the extensive library of 3D objects, it is possible to reproduce the analyzed process (eg the movement of a container through an intermodal terminal). In addition, the ability to visualize the process allows for even more accurate mapping and analysis [13].

To conduct analyzes, the following assumptions were necessary:

– Containers ISO 1A (16 containers), 1B (8 containers) and 1C (24 containers) were the subject of the research.

– Containers belong to 3 different owners.

– The trains consists of 30 rail cars. Every rail car is 19,9 m long and has 3 TEU capacity.

– Containers were stored in one layer in the first row of the storage block.

– The distance between the rail cars and the storage yard was 6 m.

– Konecranes RTG gantry crane was used as a loading device. RTG parameters: lifting/lowering speed – 0,43 m/s; trolley speed – 1,16 m/s; gantry speed – 2.16 m/s.

– Rail cars are unloaded starting from the first car at the head of in the train according to the FIFO strategy.

– Unloading was carried out by a single gantry crane powered by electricity.
– The average time of container capture was 15 s.
– The average time of container release was 25 s.

Schematically, a fragment of the constructed simulation model is shown in Fig. 3.

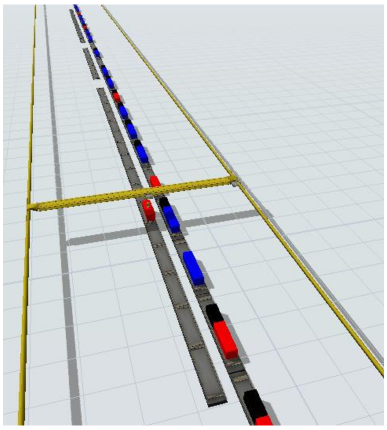

Fig. 3 A piece of the simulation model prepared in the FlexSim tool

4. Results

Due to the random distribution of containers on rail cars in some variants, computational experiments were performed for 100 random samples. The results of the calculations are shown in Fig. 4. The minimum value of the distance covered by the loading device (7513 m) was obtained for variant 2. It results from the fact that in this variant the containers were arranged on the train according to their size and randomly according to their owners. However, on the storage area, containers were arranged according to their size. Thus, the gantry carrying out the transshipment process, put containers on the square parallel to the arrangement of containers on the train.

The remaining variants present results taking into account randomness. The analysis of the results indicates that the variants, where the random distribution of containers on the cars was allowed, differ from each other from the point of view of the distance covered by the loading device (crane). More over crane distances are almost twice longer than in variant 1. The shortest (among variant with randomness) distance was obtained for variant 1, where containers on the storage area were arranged according to their size.

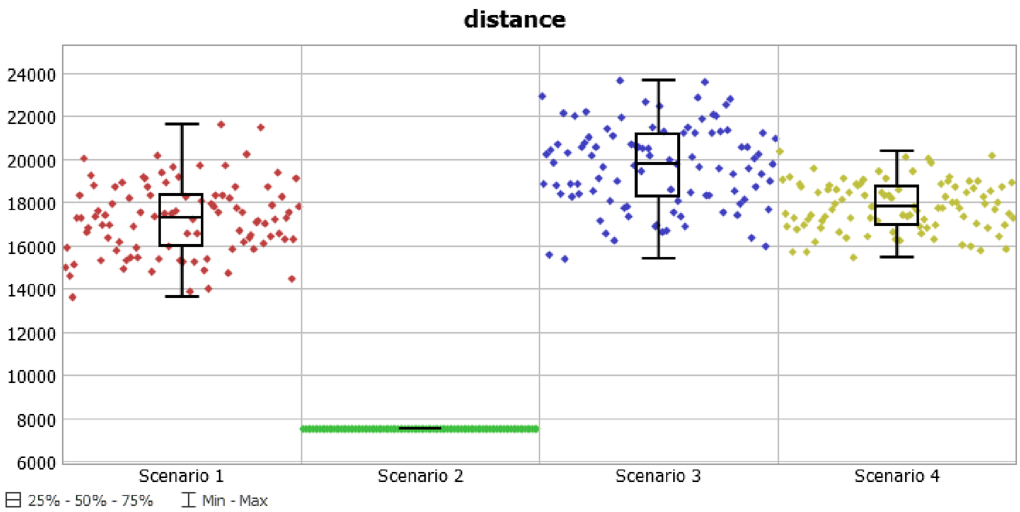

Fig. 4 Experiments results with the use of the FlexSim tool (distances in meters)

5. Summary

The research carried out in the article using a simulation model in the FlexSim environment and their results indicate the need for a structured planning of the distribution of containers on the storage yard and on the train. The values of the distance traveled by the loading device in particular variants differ depending on whether the distribution of containers on the train was planned or not.

The analysis of variants assuming a random arrangement of containers on the train allows to conclude that the distribution of containers in the storage area by their size or by their size and owner allows similar results to be obtained

for the distance traveled by the gantry crane.

The detailed analysis of the results show that the shortest (among variant with randomness) distance was obtained for variant 1, where containers on the storage area were arranged according to their size.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Extreme Weather Impact on Transportation and Energy Infrastructure

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Abstract

In recent years, the climate change and the associated longer and unpredictable occurrence of extreme weather events such as drought, hot waves, fires, heavy rain, floods, storms, hurricanes, landslides, etc. have more and more affected a lot of countries of the world. In recent four decades, the number of natural disasters has risen sharply from about 200 per year to more than 400 per year. Only one out of ten natural disasters is not related to climate. Their devastating impact on the countries and their economy, people and natural environment takes an ever-increasing intensity all over the world [1]. Development of an operational analysis framework minimising the impact of major weather events on the European Union land based infrastructure systems was the main objective of the FP7 project titled "Risk Analysis of Infrastructure Networks in response to extreme weather" (RAIN). The RAIN project was submitted within the call FP7-SEC-2013-1 within the activity "SEC-2013.2.1-2: Impact of extreme weather on critical infrastructure – Capability Project". Duration of the project was from May 2014 to April 2017 and the leader of the project consortium was Prof. Alan O' Connor from Trinity College Dublin. The paper is focused on presenting and disseminating the achieved significant project results amongst the relevant stakeholders and general public. Considered infrastructures are transport, energy and telecommunications. Authors participated as the leaders of the work package 3 Land Transport Vulnerability.
KEY WORDS: *RAIN project, extreme weather, transportation infrastructure, energy infrastructure, risk*

1. Introduction

Natural disasters have been accompanying our planet for ever. In recent four decades, their number has risen sharply from about 200 per year to more than 400 per year. Only one out of ten natural disasters is not related to climate. Their devastating impact on society in term of social, economic and environmental dimension takes an ever-increasing intensity all over the world [1].

According to the Intergovernmental Panel on Climate Change (IPCC), the climate change give rise to three groups of extreme weather events (EWE) [2]:

1. Duration, frequency and intensity of EWE are influenced by climate change (e.g. drought, flood, extreme temperature, storms).
2. Factors of non-climatic character evoke higher exposure to extremes related to climate (e.g. increasing number of people living in towns).
3. New types of EWE (e.g. wildfires in mountains which were wet in former time).

The European Academies Science Advisory Council (EASAC) informs about the growing trend in EWE occurrence that is characteristic especially for storms, floods, heats, droughts and forest fires [3].

These EWE bring adverse effects on day-to-day life of society. They have negative impact on human lives, health and all sectors providing basic and critical economic and social functions of the state such as transport, energy, water and food supply, health services and information and communication technology. Minimizing risks associated with EWE calls for enhancing risk management system together with better awareness of extreme weather impacts and measures applicable for protection of life and property [4].

Scientific and research activity in modelling expected exposes and estimation of vulnerability to natural hazards together with proposals of appropriate prevention, adaptation and mitigation measures have been carried out within the EU research programmes as well as in Slovakia for a long time. The Faculty of Security Engineering of the Žilina University participated also in solution of the FP7 project dealing with impact of extreme weather on critical infrastructure titled Risk Analysis of Infrastructure Networks in response to extreme weather – RAIN (http://rain-project.eu/). This project (solved in years 2014-2017) focused on land based infrastructure (transport, energy and telecommunications) and its outputs contribute to enhancing safety and reliability of above mentioned infrastructures in the case of extreme weather events.

The paper presents the significant scientific project RAIN results achieved by the group of project partners having expertise in climatology, risk and crisis management, transport, energy and telecommunication, statistical methods for quantifying risks and benefits, design, construction, and upgrading of infrastructures, methods and techniques for decision making process and other fields needed to achieve the project results. Authors participated as the members of project team responsible for the work package 3 Land Transport Vulnerability and participated also in solution of other work packages.

2. FP7 Collaborative Project RAIN: Risk Analysis of Infrastructure Networks in Response to Extreme Weather (Grant Agreement No:608166) - Overview

The vision of the RAIN project was to provide a systematic risk management framework that explicitly considers the impacts of extreme weather events on critical infrastructure and develops a series of mitigation tools to enhance the security of the pan-European infrastructure network. The project was focused on critical land transport infrastructure and Energy & Telecommunications infrastructures [5].

The results of the RAIN project were achieved by the project partners' consortium consisting of 15 organizations in eight EU countries (Ireland, Germany, the Netherlands, Spain, Finland, Italy, Belgium and Greece). The list of the partners can be found at http://rain-project.eu/. The project coordinator Prof. Alan O' Connor from Trinity College Dublin (Ireland) successfully managed this demanding work. The RAIN consortium was characterized by multi-disciplinary partners represented by meteorologists (FMI, FU-Berlin), climate researchers (ESSL), economists (TCD), energy specialists (IPTO & AIA), CI owners/operators (DSA), infrastructure risk analysts (TU-Delft &TCD), specialist engineering designers and planners (ROD and GDG), security and strategic response experts (UNIZA, PSJ, HI), social scientists (ISIG) and dissemination experts (YOURIS). The project research activities were organised according to six technicalwork packages (WPs). WP2 focused on hazard identification, WP3 on land transport critical infrastructure and WP4 on energy & telecommunications systems. Developing the risk analysis framework for single and multiple hazards and collateral impacts, quantifying the risks and the benefits of providing resilient critical infrastructure, and developing mitigation strategies were covered in WP5, WP6 and WP7. Management and dissemination activities were realized within WP1 and WP8. Fig.1 indicates the WPs and the interaction and interdependencies between them.

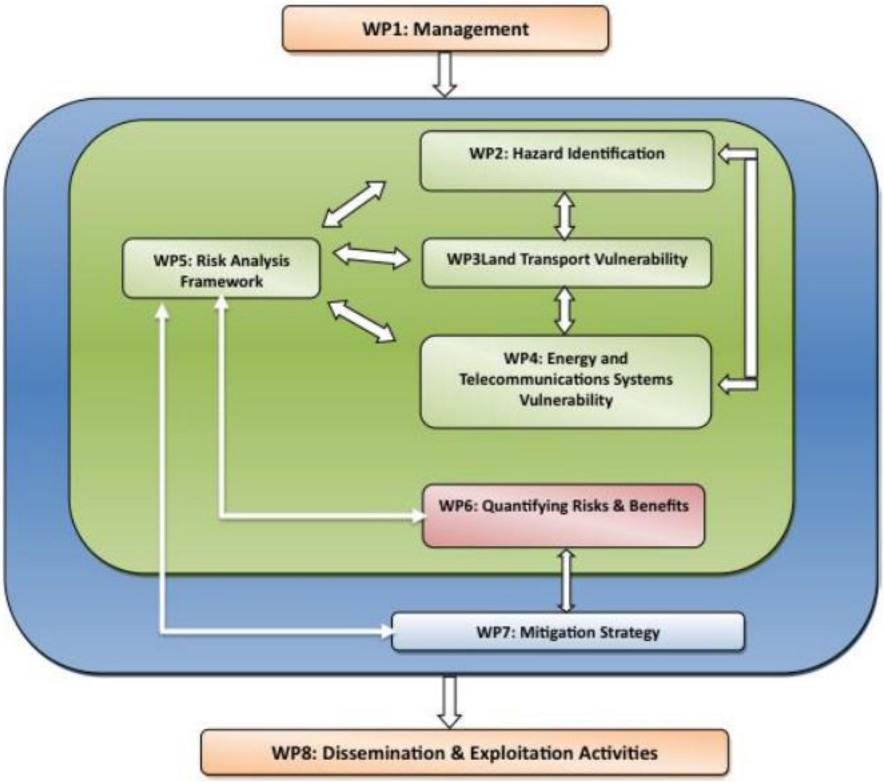

Fig. 1 Work Plan Strategy [5]

3. Scientific Results of the RAIN Project

The principal objective of the RAIN project - Risk Analysis of Infrastructure Networks in response to extreme weather project, www.rain-project.eu, was to develop a systematic risk management framework to minimize the adverse effects of major extreme weather events on land based transportation, energy and telecommunication critical infrastructures in the EU. A holistic risk-based decision making framework was developed to establish the key components of these infrastructure networks and to assess their sensitivity to extreme weather event as well as to facilitate identification of the impact of alternative mitigation measures [5]. The main results of the project have been broken down into the technical work packages and can be briefly characterized as following chapters.

3.1. The Results of the WP2 Hazard Identification

- Selection of past cases of extreme weather events occurred within the last thirty years and having impacts on critical infrastructure throughout Europe. Examples of damages caused by the windstorm "Kyrill" between the 18th and 19th January 2007 are depicted in Fig. 2.

- Interviews with operators or managers of critical infrastructure, including road or railway management, electrical power and telecommunications. The interviews were carried out with the aim to answer the questions related to sectors of CI impacted by extreme weather, ways the impacts take place and preparation for extreme weather.
- Definition and description of these natural hazards: winter weather (e.g. snowfalls, blizzards, snow load, and freezing rain); wildfires; river floods and coastal floods; thunderstorm-related phenomena (e.g. hailstorm, severe wind blasts, tornadoes and lightning); wind storms and heavy precipitation.
- Establishing two thresholds for examined extreme weather events: the 1st threshold means that severity of expected adverse impacts depends on the resilience of the system; the 2nd threshold means that the extreme weather event is so severe that there is probability of such adverse effects that will cause serious destruction of critical infrastructure system [6].
- Review of state-of-the-art early warning systems along with an assessment of the predictive skill of these systems.
- Modelling likelihood of the extreme events occurrence on the present and projections of changes of severe weather probability in the future.

Fig. 2 Damages caused by the windstorm "Kyrill" 18th - 19th January 2007 [7]. An overturned truck in the Harz Mountains, Germany, damaged railways in Sutton Coldfield, Great Britain, toppled power pylon near Magdeburg-Ottersleben, Germany.

3.2. The results of the WP3 Land Transport Vulnerability

- The methodology for identification of critical infrastructure in land transport and a review of its failures as a result of extreme weather events.
- Two case studies describing destruction effects of extreme weather events on critical land transport infrastructure in Slovakia and in Finland.
- The current methods and best practices that relate to the preparedness and response to the serious effects of extreme weather on critical land transport infrastructure and their analysis for specific problems.
- Methodology for measuring societal vulnerability in consequence of failure of critical land transport infrastructure elements (Fig. 3).

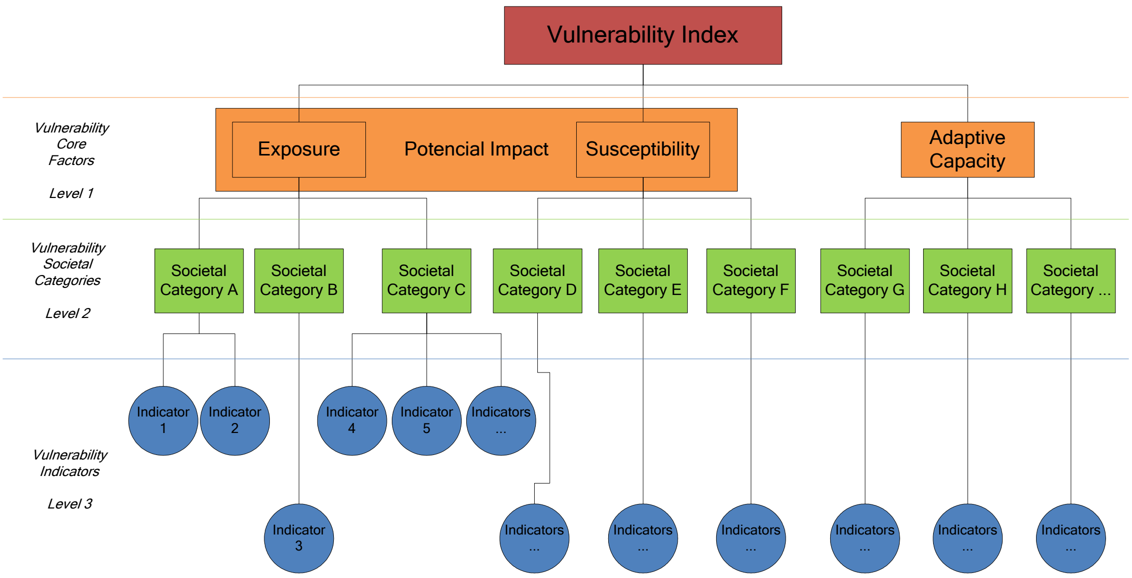

Fig. 3 Multilevel approach to Vulnerability Index calculation [8]

3.3. The results of the WP4 Energy & Telecommunications System Vulnerability

- An overall description of Energy & Telecommunications System.

- Identification of the CI elements and their weather related threats with focus on understanding how the threats affect both the end-user and the operation.
- Interdependencies of the Electrical Power and Telecom Infrastructure with other CI.
- Case studies of past weather-related failures in electricity and telecom networks. (Fig.4).
- Review of the methods and procedures used in electrical power and telecommunication networks to protect critical equipment against damage from extreme weather disasters.
- Social impact of failures in Energy & Telecommunications infrastructures.
- Simulations for estimation of the actual distribution of power flows over the network when some elements fail.

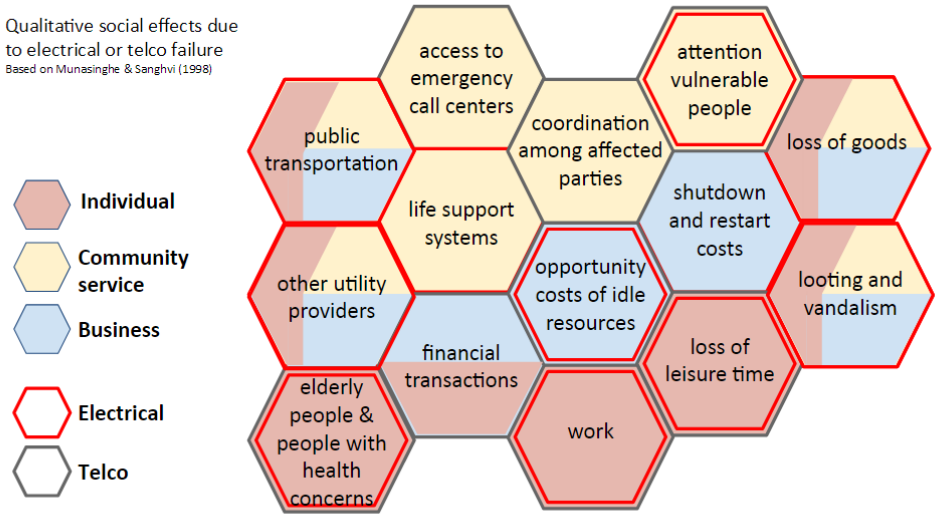

Fig. 4 Affected activities by disruption in the electrical or telecommunications services by type of consumer [9]

3.4. The Results of the WP5 Risk Based Decision Making Framework

- Quantitative risk analysis framework for single and multiple events and for collateral impacts of cascading effects.
- Software tool for the forecasting of the network usage given some geographically distributed consumption and generation profiles for the incident probability forecasting. The source code of this risk assessment web-tool has been released as open source licence. First demonstration videos are already available on web [10].

3.5. The results of the WP6 Quantifying Risks and Benefits

- Advanced risk assessment procedure for quantification of single-mode risks and impacts and multi-mode risks and impacts and report on benefit of critical infrastructure protection.
- Assessment of the impacts of critical infrastructure failures and in the context of two case studies demonstration of the use of the RAIN Risk based Decision Making frame work and calculation of quantifiable benefits of providing resilient infrastructure (Fig. 5).

Fig. 5 Geographical location of Alpine case study area [11]

3.6. The results of the WP7 Mitigation Strategies

- Technical engineering solutions to increase the resilience of infrastructure to the effect of extreme climate events. Fig. 6 presents introduction of geo-cell mattresses on steep engineered slopes to provide added stability and allow the establishment of vegetation.
- Technical Impact Matrices developed as a method for assessing the advantages and disadvantages of various maintenance strategies for reducing the impact of extreme events on infrastructure systems (Fig. 6).
- Pre-standardisation Document & Review of Crisis Coordination and Response Arrangements in the European Union which assesses the latest developments of the EU crisis coordination and decision-making arrangements and gives recommendations on how EU policies and infrastructure protection guidelines could be improved.

- Summary of the effects of climate hazards on European infrastructure and presentation of mitigation procedures, and adaptation and coping with potential impacts to alleviate the impact on citizens.

Fig. 6 Engineered slope and stabilisation of natural slope [12]

4. Conclusions

The main result of the project was focused on providing a systematic risk management framework that thinks carefully devastating impact of extreme weather events on critical infrastructure in sectors transport, energy and telecommunications and contributes to enhancing the security of the pan-European infrastructure network through technical and logistic solutions including novel early warning systems, decision support tools and engineering solutions. The achieved result - risk management framework, allows quantifying the interactions between the examined extreme weather events and land transport, and energy and telecommunication infrastructure systems, assessment of their impact through risk and uncertainty modelling, measuring societal vulnerability and defining the most suitable technical and logistic solutions to minimize the adverse impacts. The RAIN project was dealing with current topic which concern public as well as private organisations that have the obligation to maintain and protect their infrastructures from disruption and destruction. The main RAIN deliverables are free available at http://rain-project.eu/ and can serve for all who are interested in the results e.g. policy makers, local authorities, state and private companies, insurance companies, etc. Innovative ideas and a lot of achieved results of the project were also included into the lectures for our students in modern study programme dealing with ensuring security and protection of critical infrastructure.

Acknowledgments

This paper was supported by project VEGA No. 1/0240/15 “Process model of critical infrastructure safety and protection in the transport sector and the FP7 project No. 608166 “Risk Analysis of Infrastructure Networks in response to extreme weather”.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Using of Green Energy from Sustainable Pavement Plates for Lighting Bikeways

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Abstract

In the frame of current paper authors show the significance of lighting of bike ways. Paper outlines a new approach application of green energy, using innovative technologies. This paper examines investigates how to solve the problem of additional lightening of bikeways, using innovative sustainable pavement plates for green energy production. The aim of this study is to offer innovative solution of sustainable pavement plates enable to produce green energy for additional lightening of the paved bikeways using considerable technologies. This paper sheds new light on the way of application and production of green energy. In this context authors of current research tried to offer innovative solution of sustainable pavement plates enable to produce green energy for lighting bikeways. Authors have performed this research also to initiate debates in scientific world and society about significance of such kind of solutions for sustainable green and clean cities.
KEY WORDS: *green energy, lighting, bikeways, energy conversion, safety, sustainable pavement plates, green transport, bicycle, infrastructure, solar energy.*

1. Introduction

Green energy is commonly discussed and it must become among the most widely used types of energy. This kind of energy widely considered to be the most important source of energy in nearest future, so it is very significant to find new ways and innovative technologies to produce and apply green energy - the energy of our future [4]4. Green energy is increasingly becoming a most discussible kind of energy not only between politics, society and market players, but also in scientific world. It generating considerable interest in terms of unlimited opportunities to research and develop innovative solutions for energy production [3].

The great report about green energy has been done by [5]. In 2015, following the results of the 21st Framework Convention on Climate Change, the Paris Agreement on Climate Change was adopted. It determines that specific measures to reduce climate change should be aimed at decreasing greenhouse gas emissions. Those, the world aspires to clean, green energy, and, consequently, to a better future. In many countries, the development of alternative energy is one of the important components of public policy. For example, as of 2011, more than 50 countries have enacted laws to stimulate electricity generation through green tariffs [6, 7]. It is clear, that green energy solutions become more topical every year. Applications and new ways of usage innovative technologies are also welcome to discuss from different points of view. Not only technologies, but also green way of life become more popular and are welcome across the world.

2. Bicycles – Green and Clean Transport

Bicycles – green and clean transport and its popularity increases from year to year. One of the limitation factors of the fast increasing of the popularity - not enough developed infrastructure.

Bikeway is a path or lane for the use of bicycles. It is significant part of the transport infrastructure in modern world. The trend line of popularization of cycling in the world last decades is huge.

As stated in [1], the Mayor of London set the task of increasing the number of bicycles by 400% in 2026 compared to 2001 levels, and Transport for London (TfL) recognizes that providing a world class infrastructure in London will require a serious study of world practice, to successfully apply the tested methods in the London context and, if necessary, to make innovations.

In «Mayor’s Vision for Cycling» 2013, it described how the development of bicycle transport in London will be transformed. It is emphasized that the infrastructure will contribute to the creation of better, safer, more convenient and efficient facilities for cyclists. Let’s see some quotes from the «Mayor’s Vision for Cycling - 2013»:

“There will be more Dutch-style, fully-segregated lanes and junctions; more mandatory cycle lanes, semi-segregated from general traffic; and a network of direct back-street Quiet ways, with segregation and junction improvements over the hard parts.”

“Where it is not possible to segregate without substantially interfering with buses, we will install semi-segregation: shared bus and bike lanes, better separated from the rest of the traffic with means such as French-style ridges, cats’ eyes, rumble strips or traffic wands in the road.”

Transport for London (TfL) is interested in study of others experience - how others worked to make their cities more attractive for cycling. They believes that study of an international best practice can help make the right choice when deciding on the future development of London's bicycle transport infrastructure. [1].

We have an interesting statistics for European countries and cities. For example, we met high ‘walking’ percentages in South European cities, for instance San Sebastian in Spain: ~3% bicycle against ‘only’ ~34% car, it is significant to say, that public transport plays an important role in San Sebastian ~19%, but mainly walking - a striking 44% of all trips.

Talking about London: ~1% bicycle, ~18% public transport, ~37% walking, and ~44% car.

If cities have high possibilities for walking, cycling and public transports - then often lowest car percentages are found in such kind of cities.

For example, a lot of cities in Switzerland: over 20% walking, over 10% bicycle and approx. 30% public transport – and as a result- a relatively low car use (~ 30% in Zürich, Bern and Basel).

Of course, average bicycle use is lower in most other European countries, but there are some interesting statistical examples could be found:

• In all the Great Britain use of bicycle is average 2% (in London even lower), but there are some interesting cases with higher percent of bicycle use (Oxford and Cambridge ~ 20%, but Hull and York ~11%,). A little bit more extreme differences could be found in Italy and Sweden:

In Italy average bicycle use is ~5%, (Rome shows less than 1%), but extremely different percentages are in cities of Ferrara ~ 30%, Florence - over 20% and Parma - over 15%.

• In Sweden bicycle use ~ 7%, for cities average percentage is ~ 10%. But Malmö and Lund shows 20%. Totally extreme percentage comes from Västerås with only 115,000 inhabitants - it shows an incredible percentage of 33% bicycle.

• Ireland shows 3% - 4%, Dublin 5%.

• Czech Republic, as other Eastern European countries, has a few cities with more or less popular bicycle use - Ceské Budejovice, Olomouc and Ostrava shows between 5% and 10%, but city Prostejov shows approximately ~20%. But if we talk about the entire region - average use is quite low- less than 5%.

• Switzerland shows ~ 11% for bicycle use in average, with some differences in cities: Winterthur ~20%, Basel ~17% and Bern ~15%.

• Austria ~ 9% in average, with Salzburg ~19% and Graz ~14%.

• France has an average ~5%, with Avignon ~10% and Strasbourg ~12%.

This statistics is really interesting - it shows how much bicycle use varies within Europe, by country and in particular by town. It is also possible to mention, that nowhere are the Dutch levels of bicycle use even approached. It is possible also to conclude, that Nordrhein-Westfalen and Denmark are coming closest. It is also significant to remark, that even in non-cycling countries there are some cities with respectable percentage of bicycle use, for instance in Sweden, Czech Republic, Italy and Great Britain. [2].

Bicycles – not only green and clean transport, but also healthy one. In many cities, there are significant problem with bicycles infrastructure. There are not enough paved bikeways, but if bikeways are paved, often lighting is not guaranteed enough for safe rides.

3. Green Energy from Sustainable Pavement Plates for Lighting Bikeways

Sustainable pavement plates, offered in current article, refer to alternative sources of electricity and to bikeway construction. It can be used for prefabricated pavement building and to transform the kinetic energy from the pressure of bikes on the bikeway and solar energy into electrical energy.

Sustainable pavement plates are integrated into a single system and assume autonomous operation of the bikeway irrespective of energy sources (see Fig. 1). This decentralized system is able to fully provide itself with energy, and give surpluses to other consumers [adopted from 3].

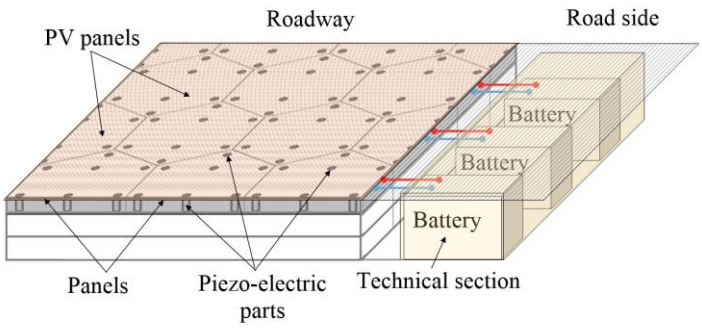

Fig. 1 Sustainable pavement plates [3]

Each panel of the sustainable pavement plates consists of 3 basic components. As it is described in [3], the first is the protective top cover. This element of the panel is made of high-strength transparent plexiglas, on the inside of which there is an electric heating element in the form of heating fibers (analog - car glass heating). At the base of the supports, on which the protective top cover is located, piezoelectric elements (piezo-generators) are installed. They generate electricity when pressed.

The second element of the panel is solar panels (PV panels) with built-in LEDs. In this element, the LEDs and PV panels are located on the entire plane of the panel. The third element of the panel is the base with electronic control boards and a cable channel. To the one accumulator batteries (Battery) from five hundred to a thousand such panels are connected. The battery is located in the technological compartment next to the sustainable pavement plates - on the bikeway side (see Fig. 1).

3.1. The Principle of Operation of the Sustainable Pavement Plates System

During the day, solar energy is converted into electrical energy through PV panels and accumulated in the battery. The energy comes also from piezo-electric parts when bicycles are driving above panels. In the dark, the accumulated energy from the battery is expended on the work of the pavement plates itself and on the LEDs that draw the pavement markings and highlight (if necessary) certain parts of the bikeway. Excess electrical energy is sent to other consumers of electricity (bikeways adjacent to the bikeway, houses, businesses, gas stations, etc.). If necessary, the sustainable pavement plates system is capable of dynamically lighting the road in front of the bicycle. This is determined by the software.

Piezo-electric parts are installed in the top cover supports, generating energy when pressed and signaling that the panel is under load. The value of the signal determines the weight of the load. That is, if necessary, the sustainable pavement plates system can track traffic on a certain bikeway segment, as well as its mass and speed of the object.

The functional of the sustainable pavement plates system is quite extensive and can include (depending on the needs and the corresponding software) the following functions: bikeway illumination both day and night (dynamic LED marking, informing signs, warning signs); heating panels in the cold season (melting snow, ice); drying of the panel due to heating (after rain); alarm system (warning about panel breakage); Determination of the load on the panel (bicycle weight); determining the speed of movement of the bicycle; charging of electric bicycle from PV panels (through special charging stations); generation of electricity; warning of the need to decrease the speed (works with Piezo-electric parts).

Also, here we should mention the analogues of the proposed sustainable pavement plates system. Among them, the SolaRoad bicycle track, consisting of PV panels (see Fig. 2) [9], and the clever road Solar Roadways (see Fig. 3) are the closest in nature and principle of operation [10].

Fig. 2 SolaRoad system [9]

In November 2014, 25 km from Amsterdam (see Fig. 2) TNO built 70 m of the SolaRoad cycle track. It consists of modules measuring 2.5 × 3.5 m. The solar panels themselves are protected by a layer of tempered glass 1 cm thick, which is capable of withstanding the weight of the truck. It was noted that for 6 months of operation this bike path generated 3000 kW·h. This is enough to provide electricity to one average household during the year.

As for the American clever road Solar Roadways (see Fig. 3) [10], in terms of its design features, it resembles the proposed sustainable pavement plates system. Each slab of the Solar Roadways system is rated for a nominal solar panel 230 W with an efficiency of 18.5%. According to calculations and experimental studies by American engineers, for a road length of 1 mile and a width of 12 feet, 15840 panels are needed. Within one year this section of the road will generate 302.506 MW·h. According to data of [10] in the US, one residential utility customer consumes 10,837 kW·h. That is to say, the 1 mile road Solar Roadways can provide approximately 30 private households with electricity for one year.

The above data show that in roads of this type there is a great potential and in the near future they can become an alternative source of electric energy.

But the considered roads have significant disadvantages, which are as follows:

- SolaRoad system - these are ordinary PV panels, which are protected by high-strength glass. This system is only able to generate electricity and does not have other functions;

• Solar Roadways system - designed for roads; each panel includes a lithium-ion battery; does not include piezoelectric elements (piezo-generators); cannot detect the weight of the vehicle, its direction and speed of movement; LEDs are designed only for the designation of road markings and warning labels.

a b c

Fig. 3 Solar Roadways system [10]: a - Artist's conception of an Solar Roadways panel; b - Actual Solar Roadways prototypes; c - upper layer of panel designed from high-strength glass.

Unlike analogues, the proposed sustainable pavement plates system is able not only to draw the necessary road markings and generate electricity, but also to illuminate the bike path in the dark. In more detail all the functional of sustainable pavement plates is described in the publications [3, 8].

Based on the presented calculations and experimental data of analogs, it is proposed to carry out calculations for the sustainable pavement plates. These panels will be integrated into a single system that forms a bicycle path.

3.2. Assessment of the Sustainable Pavement Plates System Electricity Generation

Filling one panel of the sustainable pavement plates PV panel is 75%. To generate 1 kW · h of energy at 100% coverage by the solar panel, it is necessary to 6.6 m^2 of sustainable pavement plates. Then 75% of the filling of the panel corresponds to the area:

$$6.6 \cdot 25/100 = 1.65 \text{ m}^2. \tag{1}$$

Therefore, 1 kW · h of electrical energy can be generated by a bikeway section with an area of:

$$6.6 + 1.65 = 8.25 \text{ m}^2. \tag{2}$$

Accordingly, to generate 100 kW · h of electricity, 825 m^2 of sustainable pavement plates is needed. The radius R of the hexagonal sustainable pavement plates is 0.46 m, and then its area is determined by:

$$S = \frac{3\sqrt{3} \cdot R^2}{2} = \frac{3\sqrt{3} \cdot 0.46^2}{2} = 0.55 \text{ m}^2. \tag{3}$$

To generate 100 kWh of electrical energy from (3), let`s determine the number of sustainable pavement plates:

$$825/0.55 = 1500 . \tag{4}$$

The width of bilateral bicycle paths in European countries is 3 - 4 m. Therefore, we will carry out calculations for these boundary values. For greater clarity and convenience, both in the analysis of the results obtained and in comparing them, we will recalculate the generated energy of the sustainable pavement plates for the length of the 1-mile bicycle path.

Let`s define the length of the section of the chosen bikeway with sustainable pavement plates (width – 3 m and 4 m), which is able to generate 100 kW · h of electrical energy:

$$825/3 = 275 \text{ m}; \tag{5}$$

$$825/4 = 206.25 \text{ m}. \tag{6}$$

This means that a section of the bikeway of (3 × 275) m is capable of generating 100 kW of electricity in one hour of its operation. And the bikeway of (4 × 206.25) m is capable of generating 100 kW of electricity in one hour of its operation.

Similar to calculations and experimental studies for the Solar Roadways panel [10], we calculate the actual (taking into account the specific location of the panel) generated electricity. That is to say, let us calculate the angle of

incidence of the sun's rays ~ 72°. This corresponds to the northern latitude of 48.19°. In fact, this northern latitude is the geographical center of Europe. Experimental data show that if the panel is in a horizontal plane, then its efficiency is 69% [10].

Then, taking into account the real conditions, we will determine the amount of generated electricity in the selected sections of the bicycle paths.

The section of the bicycle path of (3 × 275) m will generate 69 kW · h., as well as a section of (4 × 206.25) m and a length of 206.25 m.

Next, we will recalculate the generated electricity for a 1 mile bicycle path:

- 3 m wide:

$$69 \cdot 1609/275 = 403.7 \text{ kW} \cdot \text{h}; \tag{7}$$

- 4 m wide:

$$69 \cdot 1609/206.25 = 538.3 \text{ kW} \cdot \text{h}. \tag{8}$$

Let`s calculate the necessary number of plates, for a bicycle path 1 mile long:

- 3 m wide:

$$1500 \cdot 403.7/69 = 8776\,; \tag{9}$$

- 4 m wide:

$$1500 \cdot 538.3/69 = 11702\,. \tag{10}$$

One sustainable pavement plate includes 150 LED RGB, which consume 9.6 W · h of electricity. This will allow us to evaluate the work of sustainable pavement plates in conditions of maximum power consumption and draw conclusions about its capabilities. Each sustainable pavement plate has also a heating element of 25 W. Accordingly, in the winter months, a section of the bikeway, generating 69 kW of electricity, will consume in one hour of work in the dark, less amount of energy, then produce.

So, for own needs in the winter season, one sustainable pavement plate will spend 34.6 W · h. Then one section of the 1 mile long and 3m wide bicycle path, consisting of 8776 sustainable pavement plates, will consume:

$$34.6 \cdot 8776 = 303.65 \text{ kW} \cdot \text{h}. \tag{11}$$

In turn, one section of the 1 mile long and 4m wide bicycle path, consisting of 11705 sustainable pavement plates, will consume:

$$34.6 \cdot 11702 = 404.89 \text{ kW} \cdot \text{h}. \tag{12}$$

The above calculations show that for their own needs in the winter, the bicycle path will consume ~ 75% of the generated electricity. It should be noted that the power of the generated electricity from piezo-electric parts was not taken into account here. In the case of piezo-electric parts, the traffic intensity directly determines the amount of electricity that is capable of generating sustainable pavement plates. In view of such uncertain circumstances and assumptions, it is suggested not to consider the amount of generated electricity from piezo-electric parts. These elements are used as sensors, the indications of which can determine the weight of the bicycle, the direction and speed of its movement. And the generated energy from the piezo-electric parts will be directed to the operation of the electronic circuit boards of the panel.

The calculations carried out are indicative and show possible potential for sustainable pavement plates for bikeways. So, for example, the results of the calculations allow estimating the amount of generated electricity by any arbitrary segment of the bikeway.

4. The Significant Role of Energy Consumption Minimization and Efficient Lighting

The artificial lighting is one of major electrical energy consumers, which shares about fifth part of the global electricity market. At the regular rise of electricity price, the total cost of consumed energy by any electrical appliance during its lifetime is getting more noticeable in contrast to initial expenditures. From this perspective, the efficiency of whole street lighting infrastructure should be optimized from the point of view of energy consumption minimization. [11].

As the research results from [12] that saving 1 kWh of electrical energy, potentially could save the equivalent of 2 kWh of fossil fuel. It relates with the total system efficiency of energy delivery to end-user from mining site, which

includes energy loses at middle stages, like use of energy during mining fossil fuels, energy conversion and transmission (mechanical and electrical) losses, as well as end-device efficiency. Consequently, locally generated energy (especially from renewable energy sources) is much preferable, because it excludes the major of mentioned losses. For this reason, enhancement of street lighting infrastructure is an important task, leading to minimization of global energy demand and reduction of municipal expenditures on illumination of public places and streets [11].

As it was described at [13], the main problem related with all „free" energy sources is its unpredictability and inconstancy that requires using of some energy storage elements providing constant output voltage. It is clear, that the design of power supply unit should meet the following claims: efficient harvesting; efficient conversion; minimized leakage currents in standby mode or in off state. In this case, solar energy harvesting system is proposed as the most suitable solution and autonomous data logger design describes several steps of system development. Specific ICs are used to implement an uninterruptable power supply which uses also Li-ion battery. Several features of program code design which uses microcontroller's internal peripheral modules and significantly affecting energy consumption are described.

5. Conclusions

The green way of life gains its popularity across the world. Green and clean technologies, as well green and clean transport will be used wider. Bicycle is clean transport, which become more popular each year, but need better infrastructure development at every city. Sustainable pavement plates - is green way - how to produce energy for lighting bikeways, making it safer. Green and clean energy must become among the most widely used types of energy.

The evaluation of the possible work of the sustainable pavement plates in real operating conditions was carried out. The results of the assessment show that for own needs in the winter time the bicycle path will spend ~ 75% of the generated electricity. Thus, one section of 1 mile long (3 m wide), bilateral bicycle track, can generate about 403.7 kW · h of electricity. At the same time, up to 303.65 kW · h will be used for own needs. So, it is possible to assume, that roads of this type has a great potential and in the near future they can become an alternative source of electric energy.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Design of Reaction Time Measuring Device

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Abstract

At present, the concept of reaction time measurement is used as one of the methods of psychological testing. Its usage spectrum, however, covers rehabilitation medicine, neurosciences and similar. Available systems used to measure reaction time deal with complex reaction time, i.e. the time between generating the stimuli and respective reaction via effector. Typical limitation is the design of these devices, which usually fits specific application, but it is not reusable for other applications. The goal of this paper is to introduce concept of device measuring reaction time of both upper and lower limbs, to visual or acoustic stimuli. Design of the device allows for application independence, i.e. it is reusable for wide range of different applications. This independence is supported by open software platform, including base set of testing tasks. In case of measurement of upper limb reaction time, the device allows measurement of individual components of the reaction time, opening new capabilities for deeper understanding of human sensory systems with respect to the speed of reaction to external stimuli.

KEY WORDS: *device, measurement, myopotentials, reaction time*

1. Introduction

Recording of reaction time is one of important methods of cognitive and experimental psychology. Reaction time evaluation found use in many applications, where except for experimental science and medicine, it is also used as an indicator during selection of candidates for pilots, drivers, security staff etc. [1].

From the perspective of reaction time measurement, the so-called complex (overall) reaction time RT_T, is obtained, which is calculated as the sum of perception time t_P and muscle response time t_M. Decision time t_D is then covered in the total reaction time. If the used device can record time t_D independently, the overall reaction time can be expressed as:

$$RT_T = t_P + t_D + t_M. \tag{1}$$

The most frequently used RT_T and associated tasks are the so-called Simple Response Time (SRT) task and Choice Response Time (CRT) task. SRT measurement is based on tasks where reaction time to single stimuli is monitored. In case of visual or acoustic stimuli, the subject react to only this one stimuli. By contrast, CRT measurement is based on the principle of multiple stimuli, where each requires exactly one reaction. From this follows that SRT and CRT are different, where reaction to simple stimuli is by nature faster as in case of CRT [2]. Nevertheless, both the times are used to describe cognitive capabilities of individuals or monitored group, whether together or separately, depending on specific scientific question.

In case of measurement of these times by single device, it is possible to directly compare the times within one or multiple studies. However, in most cases it is not possible to perform exact inter-study comparison with respect to the variability of measured values, caused by usage of various measurement concepts, non-uniform tasks, different hardware solutions and others.

In general, available devices utilize principle of reaction time measurement to specified stimuli. With respect to this, these devices are oriented to specific domain and it is not possible to use them for measurement to other, more complex or specific tasks [3]. Reaction time evaluation is based on device hardware components, i.e. dependent on fabrication of the very device. Most devices and measurement concepts are, consequently, able to measure only overall reaction time. Similarly, these devices and measurement principles (mostly software solutions) are measuring RT_T with considerable variability. This is because mostly the $\mathrm{RT_T}$ components are not recorded but only $\mathrm{RT_T}$ as a whole. The most significant variability can be introduced by t_M, which depends for example on reference position of limb as the effector. In fact, there are numerous devices based on pushing buttons but the limb reference position is not considered thus the distance from target sensor may change, eventually changing the time of motor reaction, e.g. [5, 6]. This way, it is also not possible to detect other $\mathrm{RT_T}$ components. The situation is similar with respect to other SW-based concepts [4], which use for example monitoring of response to visual stimuli by mouse, where the actual cursor position may, again, introduce measurement error.

Among the studies it is then often difficult to distinguish which type of reaction time is measured and what are

its components. At present, there are devices eliminating the above mentioned limitations to significant extent, but these are mostly costly and allow measurement based on available task set.

To precisely measure reaction time, this paper introduces a concept of device capable to measure individual components of complex reaction time, serving primarily for performance and psychological testing of subjects, but suitable for wide range of applications.

2. Materials and Methods

Based on the defined limitations, base concept of device for measuring reaction time was proposed. The device was proposed to measure user's reaction to external optoacoustic stimuli, i.e. to determine time needed to evaluate stimuli with engagement of specific motor units to perform required movement. The proposed concept can, unlike typical reaction time measurement devices, deduce change in the decision making process, introduction new variable into the measurement process. This property is ensured by continuous monitoring of limb position during the measurement. Apart from measuring reaction time or change in decision making, the device was also proposed to indirectly measure efferent pathway.

A. Design Solution

Device design considers user's ergonomic requirements, simulating control elements of a means of transport. The device consists of two main parts. To measure reaction time of upper limb to optic and acoustic stimuli, USB Button box with sliding touch plates is used (Fig. 1), measurement of feedback from lower limb to optic stimuli are recorded by pedals (Fig. 2).

Fig. 1 Device visualization as USB box decomposition with sliding touch plates. *1* - touch plates; *2* - numeric keyboard; *3* - electromyographic measurement unit; *4* - frame; *5* - cover; *6* - buttons; *7* - control unit; *8* - button cover; *9* - connection element; *10* - micro switches; *11* - LED strips.

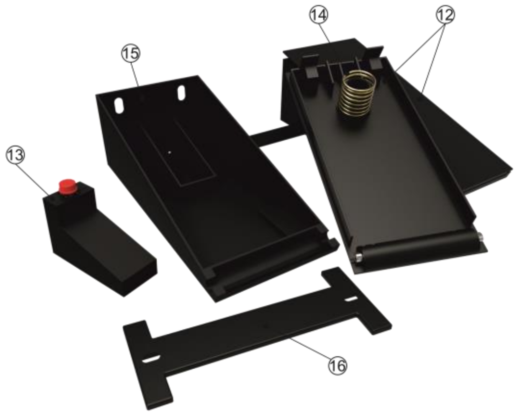

Fig. 2 Pedals decomposition. *12* - pedals; *13* - sliding block; *14* - pushing spring; *15* - device cover; *16* - connecting slat.

The main construction elements of the box are device body and sliding part, containing two touch plates *1*, numeric keyboard *2* and electromyographic measurement unit *3*. Device body consists of frame *4*, transparent upper case *5*, three illuminated buttons *6* and electronic control unit *7* (Fig. 1).

Each button consists of dome-shaped transparent cover *8* and connection element *9* with one RGB diode located in its center. The purpose of the element is mechanical connection of button cover with four micro switches *10* build into the device frame (Fig. 1). The reason for suing such excessive amount of micro switches is to increase overall button resistance force from 2.5 to 10 N and to prevent no switching in cases where the acting force on the button is not orthogonal to the button surface. The micro switches are connected in parallel. There are two advantages of this connection. The first is increase in device reliability, i.e. if any of the switches stops working, its measurement function is replaced by the next switch in the connection. The second indisputable advantage is improvement in the measurement device quality. It is enough to gently push the button to switch and the control unit evaluates that as logical one, i.e. response to external stimuli.

The device frame includes, apart from three sets of micro switches, also the same amount of 12V LED RGB strip sets *11* (Fig. 1), buzzer and command and control unit Arduino Mega. LED strips are to allow optically independent three color fields located on the upper transparent cover with high diffraction property. The division of the cover into color fields as well as individual illumination of the buttons enables testing of subjects independently from external source of optical stimuli. Because the USB port of control unit does not support higher input power needed for LED strips, it was necessary to use 12V direct current transformer as additional energy source. The connection between the

source, control unit and LED strip was realized by N-Mosfet. The protection of control unit was proposed by 5V optocouplers for cases of N-Mosfet failure. If the control unit needs to light the LED strip, it sends 5V signal from digital output to optocoupler, where the optic element excites light ray to photosensitive component, opening the input for signal into Mosfet and, secondarily, opening 12V source for LED strips. This way, penetration in the other way from 12V source to control unit is avoided.

Touch plates are, similar to buttons, attached to sliding part of the device via set of four micro switches located at the edges of respective plate. Due to ergonomic reasons, the front edge of a plate has rounded design. The plates are made from transparent material, also illuminated by set of RGB LED strips. The task of the plates is to determine position of upper limb before sending visual stimuli, to which the reaction time is measured. Plates' illumination informs the subject whether the measurement device recognizes limb position in default phase before the next measurement. Between the touch plates there is numerical keyboard and two electromyographic measurement units build into the main cover.

The device to measure reaction time of lower limb contains two pedals, each for one limb. The pedals *12* (Fig. 2) in neutral position are 20° to horizontal line. The construction of the pedals accounts for different limb weight of various measured subjects. The element to set resistance force against the weight of lower limb in neutral position is the sliding block *13* (Fig. 2).

To increase the resistance, the block slides by pushing matrix, reducing the length of pushing spring *14* attached to pedal body, increasing the resistance of the device. In opposite case, by releasing the pushing matrix, the block slides into its previous position by the pressure of the spring relying on the pedal body. The pedal will never exceed maximum allowed angle due to securing geometry of the body – the device cover *15*. In the sliding block, there is micro switch build in to record change in pedal angle within the range of 2.5°. To protect the sensors, there are stop geometries created between the frame and pedal. The connection between left and right pedal into single peace is assured by connecting slats *16*.

B. Software and experimental task setup

Microprocessor and graphical user interface (GUI) comprise the device software part, both programmed in C\#. Microprocessor uses program, which captures individual hardware components, defines their logic and the very measurement of reaction time. The program waits for delivery of an input from GUI. The GUI and microprocessor communicate via serial communication channel implemented by the means of USB 3.0.

Because the microcontroller Arduino Mega used in the presented system has no integrated real time clock, it was necessary to set it up. The necessity of this step stems from the fact, that in case of accurate reaction time measurement it is important to consider hardware processing time of system requests, data transfer speed and similar. Time synchronization (i.e. time setup on the microprocessor) was implemented so that immediately after connection of the device to PC and opening of serial USB port, system time is sent through communication interface to microprocessor to eliminate transfer delay.

It is possible to exemplify the principle of reaction time measurement with this device on software, which generates five color patterns in five areas of a monitor. Exactly one pattern produces the necessity of motor reaction with exactly one upper or lower limb.

After the check of correct placement of upper limbs on reference areas, a task is generated which, at the same time, marks start of measurement (S, start), where the reference time is set to 0 ms (see Fig. 3). In case of visual tasks, time t_P is eliminated, as the subject perceives the tasks immediately after its generation. Between the start of measurement and upper limb reaction (HW, hand response), time t_D is measured. The interval between raising the hand from reference area and pushing the button (PB, push button) is marked as t_M. This time depends, besides other things, on the arm trajectory. Variability related to adjusting the limb was eliminated by monitoring reference position of the hand. After pushing the button, the hand returns, i.e. adjusts back to reference area (HP, hand positioning). After the detection of correct hand position, new task is generate within the interval of 2 – 5 seconds. Start of new task in random time was used to minimize learning process that could occur if there was fixed time interval between HP – S phases. User defined number of process repetitions takes place between test start (B, beginning) and its end (E, end).

In case of lower limb reaction measurement, both limbs are placed on the pedals. After task generation, where response of lower limb is expected, the goal is to press respective pedal. In this case, complex reaction time is measured, i.e. time from task generation until motor reaction by effector.

The above-described concept and task type was used for experimental verification of device functionality and identification of its limitations. The described software solution is not limiting and new task types can be included as per the purpose of the measurement.

3. Device Functionality Verification

Device functionality verification was performed on series of experimental measurements, from which follow the next findings.

From EMG signal on Fig. 3 it is apparent, that muscle activity is provable before releasing the hand from reference plate. From this point of view, description of activity between muscle activation and plate release is difficult. If the subject is determined about task solution, this time interval should be in narrow range of values and its size would reflect only physical condition of measured subject. However, it is possible that, at some times, muscles are activated

even though the subject hesitates about task solution and his or her hand stays on reference surface for longer time, or the limb is not raised (see Fig. 4). Based on EMG signal, therefore, it is not possible to decide about the boundary between t_D and t_M. Considering that, raising the hand from reference surface is monitored. From this point until pushing the button, time t_M is measured. The measured EMG signal can then serve the post-hoc analysis to deepen the understanding of reaction time.

In case of lower limbs, with respect to the absence of reference areas, it is not possible to decide on the boundary between t_D and t_M. For this purpose, EMG signal record of both lower limbs is used, which allows the determination of approximate boundary between individual times.

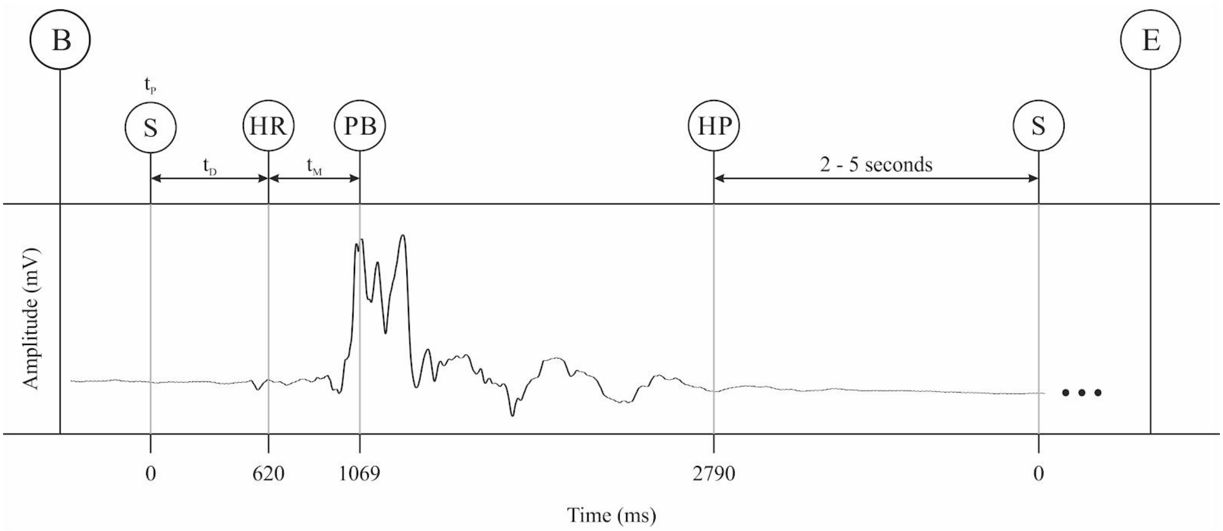

Fig. 3 Example of performed measurement with EMG signal demonstration and description of individual task phases from the perspective of upper limb measurement of reaction time. Phases B and E mark the beginning and end of measurement, phase S marks start of the task, phase HR shows hand reaction, phase PB marks pushing the button, phase HP shows hand return into initial position, i.e. adjusting the hand into reference position.

Considering the above mentioned limitation, the boundary is only approximate but it allows indicative insight into the issue of decision making – reaction in case of lower limb.

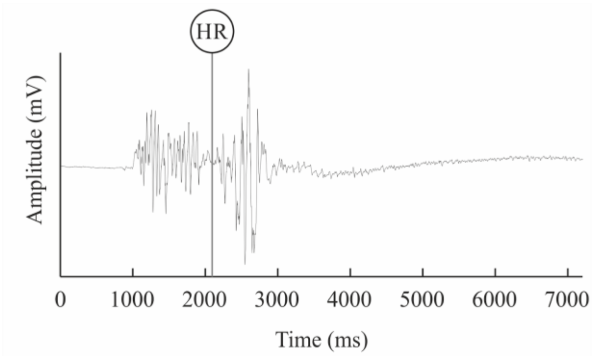

Fig. 4 Example of muscle activity measurement by the means of EMG record. During muscle activation, reaction of upper limb is marked (HR), i.e. the time when the subject raised his or her hand from the plate

4. Conclusions

The system for reaction time measurement is, according to the presented technical solution, able to detect motoric activity of upper and lower limb in response to visual or acoustic stimuli. The system is intended for measurement of complex reaction times during performance of psychological testing of subjects.

The research oriented to measure reaction time, i.e. the study of human reaction speed, is applied especially in the domain of transport (both ground and air) with the goal to reduce transport accident rate. In the aviation, in particular with respect to the character of the industry staff, there are high requirements placed on the personnel [6]. The demanding character requires new tools and procedures, which could assure selection of suitable candidates, capable of adequate reactions to emerging situation whilst carrying out their daily tasks. The proposed concept of device, which allows exploration of human sensory system via reaction to external stimuli, can serve these transport applications, but due to the combination of both upper and lower limb monitoring and the open software platform, the device is no limited to any particular application. The device is suitable for other medical applications requiring accurate measurement of reaction time, such as in neurology or rehabilitation.

Acknowledgement

This work was supported by CTU in Prague research program no. SGS17/150/OHK2/2T/16 „Evaluation of psychophysiological state of pilots based on physiological parameters“.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Small Engines Spark Ignited (SI) for Non-Road Mobile Machinery- Review

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Abstract

Non-road mobile machinery driven by small spark ignited (SI) engines are one of anthropogenic sources of air pollution [18]. In combustion engines the highest influence on the generated emission of harmful exhaust fumes the kind of fuel used, construction and the way ignition-injection system is controlled as well as the system of exhaust emission converters. The article presents the review of small engines for non-road mobile machinery prepared in January 2017. It shows constructions, the authors got familiar with, available on the market worldwide. It includes 900 models of engines of almost 60 producers. The review took into consideration kind of power supply including alternative fuels in reference to directive 2014/94/UE [9], and kind of fuel supply system. It was indicated that 2% of all the offered engines are adapted to be powered by alternative fuels. Taking into consideration engines only with spark ignition, the alternative fuels may be used to power 7% of SI engines available on the market. Additionally, authors pointed out to innovative solutions for SI engines among which are engines equipped with injections systems and they stand for 11% of available constructions [27]. The prepared overview may help to choose a drive unit or determine the direction of development of these drives.
KEY WORDS: *small engines SI, non-road mobile machinery, engines review, engines supplied with alternative fuels*

1. Introduction

The exceeded limits of air pollution all over the world lead to an increased search of methods of their reduction [26]. One of the major sources of pollution are combustion engines. In the applications where engines account for the biggest group (vehicles) long-term actions are undertaken in order to limit their influence on the environment [1, 2, 4, 10, 11, 13-15, 21, 26, 38, 39]. These actions are carried out in many directions, and the basics one are: strict law regulations concerning the homologation of these devices and investments in activities that lead to technological development of their constructions. A group of drives for small engines for non-road mobile machinery also underlies the detailed homologation regulation that are constantly updated [3, 5-8, 16, 22, 26, 38, 39]. However, when comparing the regulations concerning vehicles with the ones for non-road mobile machinery, it is visible that non-road mobile machinery has much more liberal regulations, even after novelizations planned for the year 2019 [22, 26]. In order to determine the influence of regulation on the construction of engines, the review of engines was prepared. The review takes into account kinds of fuel supply systems and kinds of fuels. Both the kind of fuel [20, 24] as the way injection occurs influences the quality of generated exhaust fumes [25]. Technologically advanced drive units allow to design innovative machines [23, 29] and ways of steering [28] allowing to limit to power-consuming of production processes.

2. The Overview of Constructions

The drives for non-road mobile machines can be characterized by varied construction due to the kind of burnt fuel and kind of fuel supply system. The constructions of small engines for non-road mobile machinery authors got familiar with are presented in Table 1, also including the names of producers and drive units offered in sale in 2017.

Table 1

The drives for non-road mobile machines

No	Producer of the engine	Number of offered models	Number of models supplied with fuel (carbourator systems / ignitron systems)	Number of CI engine models	Number of models powered by alternative fuels
1	Kohler Engines [56]	108	89 (60/29)	7	12
2	Briggs & Stratton [34]	71	71 (66/5)	–	–
3	Loncin [63]	67	63 (63/-)	4	–
4	Pezal [73]	64	39 (39/-)	25	–
5	HuaSheng [50]	34	30 (30/-)	4	–

No	Producer of the engine	Number of offered models	Number of models supplied with fuel (carbourator systems / ignitron systems)	Number of CI engine models	Number of models powered by alternative fuels
6	Taizhou Nimbus Machinery Co., Ltd. [70]	34	29 (29/-)	5	–
7	Lutian Machinery Co. Ltd. [65]	32	12 (12/-)	9	2
8	Honda [48]	30	30 (28/2)	–	–
9	Kawasaki [54]	30	30 (15/5)	–	–
10	Kipor [55]	30	19 (19/-)	11	–
11	Zhejiang Wenxin Mechanical & Electrical Co., Ltd. [87]	29	25 (25/-)	4	–
12	Greenmall Power Equipment Co., LTD. (Mitsubishi) [68]	22	22 (22/-)	–	–
13	LCT Liquid Combustion Tehnology [59]	21	21 (21/-)	–	–
14	Jiangsu Excalibur Power Machinery CO. Ltd (SinoQuip I Excalibur) [77]	20	7 (7/-)	11	2
15	Lifan [60]	20	20 (20/-)	–	–
16	Zhejiang Changyang Machinery & Electrics Co., Ltd. [35]	18	13 (13/-)	5	–
17	Hatz Diesel [46]	18	–	18	–
18	Taizhou Genour Power Machinery Co., Ltd. (ZHEN HAO, ZH) [93]	18	14 (14/-)	4	–
19	Yancheng Jiangyang Foreign Trade Engine Co., Ltd. (JYDE, JIANG YANG) [53]	17	7 (7/-)	10	–
20	Subaru Robin Industrial Power Products [79]	15	14 (13/1)	–	1
21	Ningbo Spark Motors Ltd. (Forcemar, SPARK) [41]	14	7 (7/-)	7	–
22	Holida [47]	14	14 (14/-)	–	–
23	Fusinda Power Technology Co., Ltd. [43]	13	13 (13/-)	–	–
24	Taizhou Zetong Machinery Co., Limited (ZTON, Cosmec) [95]	13	13 (13/-)	–	–
25	Taizhou Anpasi Cleaning Machinery Co., Ltd. (EPSILON) [40]	13	8 (8/-)	5	–
26	Taizhou Longfa Machinery Co., Ltd, (Anditiger Engine, ANDITIGER, ANDI, Amoda ,ELEFUJI, ELEMAX, ASTRA KOREA) [64]	12	12 (12/-)	–	–
27	Chongqing Jiuxin Machinery Co., Ltd. (CQJIUXIN) [37]	12	9 (9/-)	3	–
28	Launtop [58]	11	4 (4/-)	7	–
29	Taizhou Wedo Import and Export Co., Ltd. (WEDO) [86]	11	6 (6/-)	5	–
30	Shenguang Universal Machinery Co, Ltd. [75]	11	8 (8/-)	3	–
31	Yamaha [90]	10	10 (7/3)	–	–
32	Taizhou Haohui Mechanical and Electrical Co., Ltd [45]	10	5 (5/-)	5	–
33	Taizhou Newland Machinery Co., Ltd. (Newland, Ewand, ODM, OEM) [69]	10	5 (5/-)	5	–
34	Zhejiang Wanhao Machine Science and Technology Co. Ltd. (WAHOO) [85]	10	7 (7/-)	3	–
35	Taizhou XingGang Mechanical and Elestrical Co., Ltd. (SUNNYSTORM) [80]	10	7 (7/-)	3	–
36	Zhejiang Penwang Machinery Co., Ltd [72]	8	8 (8/-)	–	–
37	Taizhou Belten Mechanical & Electrical Manufacture Co., Ltd. [32]	8	8 (8/-)	–	–
38	Mohard Import and Export Co., Ltd. (Robin) [74]	8	8 (8/-)	–	–
39	Yanmar [91]	7		7	–
40	Taizhou Aodisen Machinery Co. Ltd. (Aodisen) [30]	7	7 (7/-)	–	–
41	Zhejiang Anqidi Power Machinery Co., Ltd. (AQD, ANQIDI) [31]	7	7 (7/-)	–	–
42	Ningbo Howseen Imp.& Exp. Co., Limited [49]	7	7 (7/-)	–	–
43	Taizhou Decapower Import & Export Co., Ltd. [81]	7	7 (7/-)	–	–
44	Taizhou Menghua Machinery Co. Ltd. [67]	6	6 (6/-)	–	–
45	Taizhou Wokun Machinery Co., Ltd. [88]	5	5 (5/-)	–	–
46	Yongkang Zuofu Industry & Trade Co., Ltd. (PENGTIAN) [71]	5	5 (5/-)	–	–
47	Taizhou Xuanyi Machinery Co., Ltd. [89]	4	4 (4/-)	–	–
48	Huahe Heavy Industries Co., Ltd. [51]	4	4 (4/-)	–	–
49	Lion (China) Engin CO., LTD [61]	3	-	3	–
50	Kubota [57]	3	3(-/-)	3	–
51	Taizhou Huali Mechanical Co., Ltd. [52]	2	2 (2/-)	–	–
52	China Artex Group Co., Ltd (C.A.G.) [36]	2	1 (1/-)	1	–
53	Chongqin FOWEI Technology Co., Ltd. [42]	2	2 (2/-)	–	–
54	Taizhou Dongwa Machinery & Electronic Factory [82]	1	1 (1/-)	–	–
55	Taizhou Bobang Machinery Technology Co., Ltd. [33]	1	1 (1/-)	–	–

No	Producer of the engine	Number of offered models	Number of models supplied with fuel (carbourator systems / ignitron systems)	Number of CI engine models	Number of models powered by alternative fuels
56	Shindaiwa [76]	1	1 (1/-)	–	–
57	Stihl [78]	1	1 (1/-)	–	–
58	Makita [66]	1	1 (1/-)	–	–

3. Innovative Constructions

The biggest group of small engines comprises spark ignition engines. Such engines with innovative constructions are presented in Table 2, underlining those units which are supplied with fuel, have ignitron systems and engines powered by alternative fuels.

Table 2

Engine models with fuel injection system or alternative source of power supply

No	Engine producer	Engine models with fuel injection system or alternative source of power supply
1	Kohler Engines [56]	**Engines powered with fuel:** Command PRO EFI ECV880, Confidant EFI EZT725, Command PRO EFI ECV980, Command PRO EFI ECV730, Command PRO EFI Flex Fuel FCV749, Confidant EFI ETZ750, Command PRO EFI ECH740, Command PRO EFI Flex Fuel FCV740, Command PRO EFI ECH940, Command PRO EFI ECV870, Command PRO EFI ECH650, Command PRO EFI ECH440, Command PRO EFI ECV650, Command PRO EFI ECH980, Confidant EFI EZT740, Command PRO EFI ECV630, Command PRO EFI ECV749, 7500 Series EFI EKT750, 7500 Series EFI EKT740, Command PRO EFI Flex Fuel FCH749, Command PRO EFI ECV940, Command PRO EFI ECV860, Command PRO EFI ECH630, Command PRO EFI ECV850, Confidant EFI EZT715, Command PRO EFI ECH730, Command PRO EFI ECH440LE, Command PRO EFI ECH749, Command PRO EFI ECV740; **Engines powered with alternative fuels:** Command PRO CH270TF, Command PRO CH395TF, Command PRO CH440TF, Command PRO CH740NG, Command PRO CH730LP, Command PRO EFI Propane PCV680, Command PRO CH740LP, Command PRO EFI Propane PCH680, Command PRO EFI Propane PCV740, Command PRO EFI Propane PCH740, Command PRO EFI Propane PCV850, Command PRO EFI Propane PCV860;
2	Briggs & Stratton [34]	**Engines powered with fuel:** Vanguard 33.0 Gross HP EFI, Vanguard 37.0 Gross HP EFI, Vanguard 35.0 Gross HP EFI, Vanguard 28.0 Gross HP 810cc EFI, Vanguard 26.0 Gross HP 810cc EFI;
3	Lutian Machinery Co. Ltd. [65]	**Engines powered with alternative fuels:** LT-188F-LPG, LT-168F-LPG;
4	Honda [48]	**Engines powered with fuel:** iGX 340, iGX 380;
5	Kawasaki [54]	**Engines powered with fuel:** FD851D-DFI, FD791D-DFI, FS730-EFI, FX730V-EFI, FX850V-EFI;
6	Jiangsu Excalibur Power Machinery CO. Ltd (SinoQuip i Excalibur) [77]	**Engines powered with alternative fuels:** S20K Kerosene Series, S20G LPG Series;
7	Subaru Robin Industrial Power Products [79]	**Engines powered with fuel:** EH 72FI; **Engines powered with alternative fuels:** EH 72 LP/NG;
8	Yamaha [90]	**Engines powered with fuel:** MW825V-EFI, MX800V-EFI, MX775-EFI;
9	Taizhou Haohui Mechanical and Electrical Co., Ltd [45]	**Engines powered with alternative fuels:** Robin EY20A, Robin EY20C, Robin EY20D, Robin EY20E, Robin EY20K

4. The Analysis of Results

In January 2017 the author prepared a review of available driver for non-road mobile machinery (Table 1). On the basis of these data it is possible to point the most frequently applied sources of power supply of these engines. Among 900 models (offered by almost 60 producers) 78% are engines powered by fuel, 20% diesel engines and 2% engines powered by alternative fuels (Fig. 1). Alternative fuels are: LPG, CNG and purified parrafine. Part of the analyzed engines are two– or three– fueled engines with the possibility to be supplied with fuel: E85, E95 or E98. Models of engines that run on conventional fuels make up for 93% of the total number of engines and only 7% can be supplied with alternative fuels (Fig. 2). The review also lists the alternative sources of power supplying of these engines (Fig. 3), with the most popular LPG (65%). Engines powered with fuel as the most numerous ones underlie additional

analysis in terms of the kinds of applied fuel supply systems (Fig. 4). Engines with carburetors make up 89% of this group, however the possibilities of introducing there more innovative systems are limited. That is why the engines with injection systems (Table 2). were given an additional analysis. They were characterized and compared with modern systems used in vehicles and also the possibility of using them in innovative supply systems was assessed in this article [27].

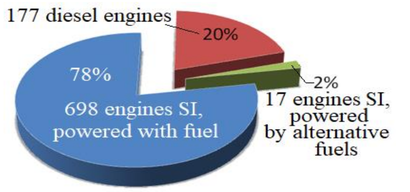

Fig. 1 Division of models of engines depending on the source of power supply [%]

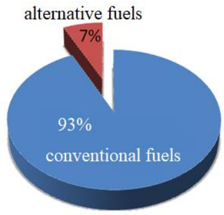

Fig. 2 Division of models of engines depending on the source of power supply (alternative fuels according to directive 2014/94/UE) [%]

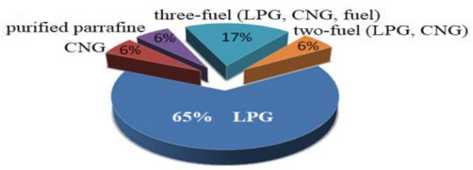

Fig. 3 Division of models of engines depending on the kind of alternative fuels [%]

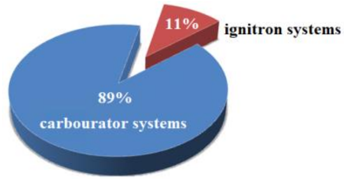

Fig. 4 Division of models of engines depending on the fuel supply system [%]

5. Summary

On the basis of detailed analysis of sources of power supply, it can be stated that the fuel supply systems are the most popular. Additionally, it was proved that 11% of offered models are equipped with electronic fuel supply system. The assumption was proven that liberal homologation regulations concerning this group of engines are connected with low technological advancement. The drives for non-road mobile machines used for the modernization of construction allowing to created innovative steering systems should be characterized by the following features: low emission of harmful exhaust gases, low fuel consumption and the possibility of controlling the drive electronically. It was also observed that there is a development tendency in this group of engines, which allows the possibility of using alternative fuels. Also the statement introduced by Krakowski in 2017 was confirmed about the tendency of introducing in industry new technologies connected with unconventional fuels [17]. The tendency of the development of contemporary mobile machinery is the use of drives of low energy consumption and low emission of harmful exhaust fumes.

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Proceedings of 21st International Scientific Conference. Transport Means 2018.

Analysis of Operation Wear of Brake Fluid Used in a Volvo Car

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Abstract

To enable the quality and productivity of transport processes, it is becoming increasingly important to ensure the use of safe and reliable means of transport. The automobile's circuit brake system relies on the incompressibility of brake fluid based on glycol when transmitting power. Fluid operating above its boiling point contains gas which is highly compressible. This paper presents the results of the wet boiling point temperature assessment of the DOT 4 Plus brake fluid used in Volvo cars. By investigation the brake fluid of 48 cars during service inspection, we found that boiling point was within the interval 222–238° C, with a 95% probability i.e. higher than the manufacturer specified wet boiling point of 180° C. Using infrared spectrometry it was verified that the brake fluid is highly hygroscopic.
KEY WORDS: *brake fluid, boiling point, reliability, operation wear, fluids ageing, water content*

1. Introduction

The most used system for control of brake systems of cars and light commercial vehicles is the automobile dual circuit brake system. In this system, the brake fluid (BF) transfers force through pressure. This basic braking system is often equipped with additional electronic components such as Anti-lock Brake System (ABS), Anti-Slip Regulation (ASR), Electronic Data Systems (EDS), Electronic Stability Programme (ESP) etc. [1, 2].

The basic requirements for brake fluid are following: (1) to transfer the pressure acting on the main brake cylinder through the brake pedal to the brake cylinders of the vehicle's wheels; (2) lubricate and seal the entire hydraulic system; (3) protect from corrosion; (4) cool of parts with high temperature etc.

For the brake fluids production must meet industry standards. Automotive sectors across the world use several different standards. The most well-known is the US Standard FMVSS CFR 571.116, which uses the DOT (Department of Transportation) or SAE J 1703f specification, the ISO 4925 is used in Europe [3].

For the purpose of efficient transfer of force from a brake pedal to the brake pads the brake fluid must be incompressible, i.e. no free space between the molecules. The external force is thus transferred directly to the compression of chemical bonds. For this reason, the boiling point temperature must be sufficiently high; the temperature increases due to strong or repeated braking.

Because oil damages rubber seals and hose of a braking system, the brake fluids are not produced from crude oil usually. Nowadays overwhelming majority produced brake fluids are on based hygroscopic polyglycol ethers/borate esters [4, 5] (DOT 3, DOT 4, DOT 5.1). However, mineral oil-based fluids (Citroën liquide hydraulique minéral LHM) and a silicone oil (DOT 5) are also produced. The glycol, glycol ether borate esters based brake fluids represent more than 95% of the world market, while the silicone-based brake fluids represent less than 5% of the global market [4]. From the operational and safety point of view, the most important physicochemical parameters of the glycol brake fluid are viscosity [6], boiling point and pH [4]. The term for boiling point designation is the equilibrium reflux point (ERPB). An important indicator of the quality of the new brake fluid is a dry boiling point which represents the boiling point of brake fluid to the weight percent water content max. 0.2%. This value guaranteed by the brake fluid manufacturer. Wet boiling point (ERBP wet) brake fluid corresponding to a weight percentage of water content of about 3.5%. If brake fluid achieved the value of wet boiling point, must be carried out exchange of brake fluid. In operational is air humidity absorbed into brake fluid mainly through cap brake fluid reservoir [7]. The higher water content in the brake fluid gradually deteriorates the function of the braking system until it fails. Also, decreasing lubricate ability of brake fluid and cause corrosion metal parts [8, 9].

Nowadays physical (Equilibrium Reflux Boiling Point), electrical (specific conductivity, permittivity) or optical (refractometry, spectrometry) methods are used to estimate the boiling point of brake fluid. Physical method to determine ERPB is standardized and measures boiling point of brake fluid directly under controlled conditions. The method cannot be used in daily practical work due to difficulty and need a large amount of samples. This amount can be the total volume of brake fluid reservoir. Furthermore, the heated sample cannot be further to use because of chemical reactions which were done at high temperatures during the analysis. Electrical and optical methods are non-destructive methods that indicate boiling point indirectly. They use the dependence between the brake fluid water content and its other properties (electrical conductivity, permittivity, refractive index, and light absorption). Barabas et al. [10] compared conduction and

capacity methods to estimate boiling point of brake fluids on based glycol. They ascertained that capacity method ensures more accurate results because conduction method is strongly affected by water conductivity. Mogami [11] described the new method for measure boiling point of the small amount of brake fluid using thermocouple; the accuracy of the method was ± 3°C.

The paper presents the results from long-term testing operational wear of brake fluid used in Volvo cars. During the technical inspection of cars were determined water content in brake fluid by the Alba Diagnostics set. The results were statistically evaluated. In the experiment, the FTIR spectrometry method was used to control the absorption of air humidity by the brake fluid over time.

2. Materials and Methods

For 48 passenger cars (different types) of the renowned Swedish Volvo factory were evaluated the current DOT 4 Plus boiling point during the regular service inspections. The physico-chemical parameters of the brake fluid have been identified from safety data sheet and are shown in Table 1. The table shows that the boiling point of the brake fluid should not be lower than 180°C. It is corresponds to the wet boiling point for this type of brake fluid, ie the boiling point of the brake fluid that absorbed 3.5% of the water.

Table 1

The physico-chemical parameters of the brake fluid

type of brake fluid	DOT 4 Plus
color	light yellow
dry boiling point	280°C
wet boiling point	180°C
mass density at 15°C	1070 $kg.m^{-3}$
viscosity at -40°C	1500 $mm^2.s^{-1}$

The boiling point was evaluated by Alba diagnostics. It is a high quality and accurate measuring instrument used to determine the boiling point of liquids based on glycol. The instrument allows measuring in a vehicle's expansion vessel or test cup that is part of the meter's accessories. Fig. 1 shows the realized measurement. For the analysis was taken approximately 20 cm^3 of the brake fluid sample into the test cup. The Alba diagnostics has been connected to an external power supply.

Fig. 1 Measure the boiling point of the brake fluid with the Alba diagnostics

The experimentally determined data were statistically processed in Statistica. Descriptive statistics were expressed. The hypotheses were tested by Student's t-test. It is a test of the mean value of one selection of one homogeneous group. The tested one-sample t-test statistics have the form (1):

$$t = \frac{\overline{x} - \mu_0}{s}\sqrt{n}\ , \tag{1}$$

where t - one-sample t-test statistics; $\overline{x}$ - arithmetic mean; μ_0 - expected value; s - standard deviation; n - number of measurements.

Test statistics were consequently compared with the critical limits. The critical region has the form $K = \{|t| > t_{\alpha\ (n\text{-}1)}\}$. If the inequality was valid for the examined data then we rejected the zero hypothesis otherwise we do

not reject it.

The ability of the brake fluid to absorb air humidity over time was assessed by the infrared spectrometry (IR spectrometry) method. The measurement was performed by FTIR-ATR (Fourier transfer infrared technic-Attenuated total reflection) technique at half-hour intervals by scanning the infrared spectra of the new DOT 4 Plus brake fluid deposited on the ZnSe crystal.

3. Results and Discussion

Verification operation wear of brake fluids expressed as a wet boiling point were evaluated at 48 samples of brake fluids taken from different types of Volvo cars. Cars were subjected to regular service checks according to the manufacturer prescribed after a certain number of kilometers or after a period of one year. Table 2 shows the results of the testing wet boiling point from different car types of company Volvo.

Table 2

Values from the measurement of boiling point

Type of vehicle	wet boiling point [°C]	Type of vehicle	wet boiling point [°C]
S40	255	V70	252
V70	228	V70	259
V50	194	V70	248
XC90	202	S60	188
XC70	246	XC90	245
S80	226	XC90	226
XC90	202	XC90	236
V70	220	C30	252
S80	250	S80	275
V70	248	XC90	248
S60	214	S60	202
XC90	148	XC70	172
XC60	248	XC90	222
S60	180	XC90	248
XC90	259	S40	180
S80	248	XC70	252
XC90	192	S40	271
V70	226	V50	244
XC70	240	S80	220
XC70	248	V70	208
XC90	263	XC90	230
XC90	246	XC90	214
XC60	252	S40	252
S80	238	S80	234

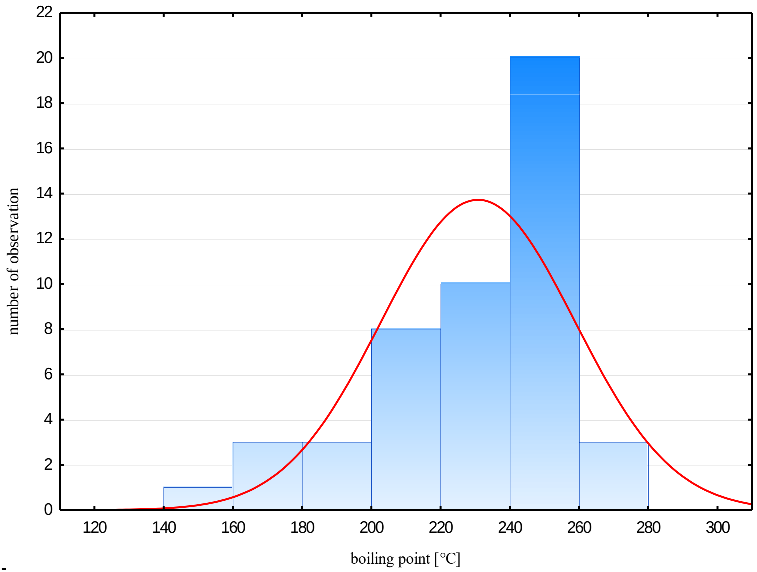


Fig. 2 Shapiro-Wilk Test of normality

The Volvo manufacturer recommends replacing the brake fluid every second year from the date of operational. Brake fluid (DOT 4 Plus) was used in the monitored cars. The boiling point (see Table 1) should not fall below 180°C,

which is the wet boiling point of the brake fluid intended by the manufacturer. Based on the above, the following hypotheses were expressed and tested:

H0: The boiling point of the brake fluid reaches value of 180°C after two years of operation.

H1: The boiling point of the brake fluid is after two years of operation > 180°C

The use of statistical tests is conditional on the type of distribution. The normality of the data was verified by Shapiro-Wilk's (S-W) test [12], see Fig. 2. Shapiro-Wilk's test was S-W = 0.9229 at the significance level $p = 0.0038$. Fig. 2 shows that the measured values slightly deviate from the assumption of data normal distribution. When testing a larger data set ($n \geq 30$) due to the validity of the central limit clause, the failure to fulfill the assumption is not a problem. Given that in the present case the data set tested was $n = 48$, a one-sample Student t-test was selected for testing the hypothesis.

Descriptive statistics are shown in Table 3 from the surveyed group of the 48 samples brake fluid taken from Volvo cars.

Table 3

Descriptive statistics for the boiling point of 48 samples brake fluids

variable	$\bar{x}$	median	minimum	maximum	s	variation coefficient
	230°C	238°C	148°C	275°C	28°C	12°C

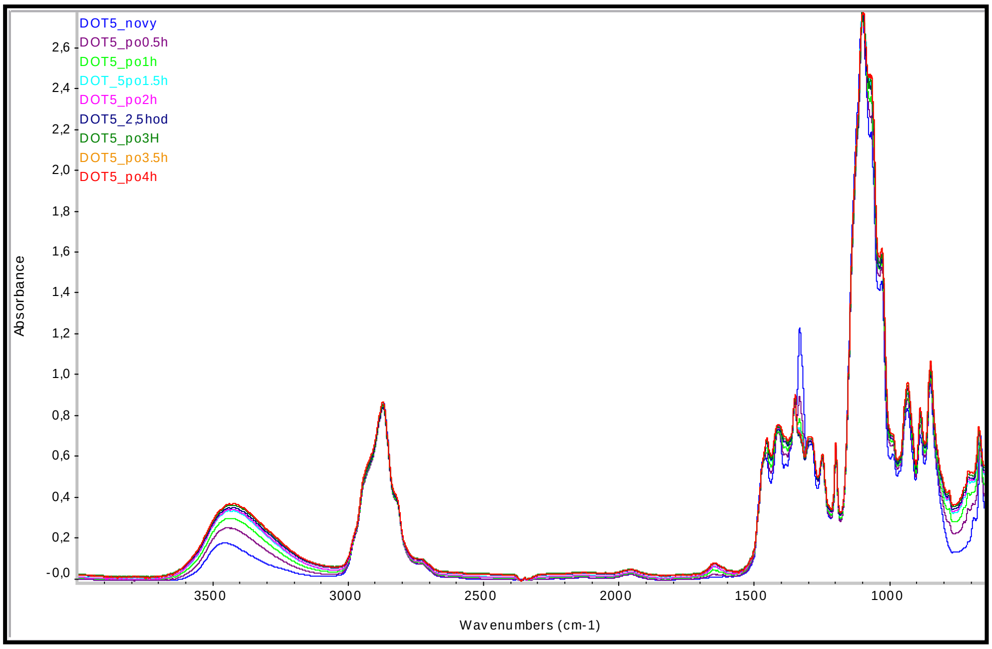
The one-sample statistical t-test was tested at a significance level of $\alpha = 0.05$. The results of these statistics are shown in Table 4.

Table 4

Results of t-test

variable	confidence interval -95%	confidence interval +95%	reference value	t	degrees of freedom	p
	222°C	238°C	180°C	12,4718	47	0,0000

Table 4 shows the value of the statistics t- and p-test for the statistical significance of the hypotheses tested. the p-value is less than the chosen 5% level of significance of the test, ie the zero hypothesis is rejected at a significance level of 0.05. With a 95% probability, the actual boiling point will be between 222-238°C. It is clear that the Brake fluid (DOT 4 Plus) to comply with the requirement of the Volvo car manufacturer after two years. The boiling point is higher than the indicated boiling point (180°C) by the brake fluid manufacturer. Lee in the study [13] states that increasing vehicle speeds or kilometers have a significant effect on the water content in brake fluids. Caban et al. in their study [5] have reached a conclusion that in the case of low-kilometers vehicles without excessive load is the possibility of prolonging the brake fluid exchange interval.



Legend: the new brake fluid spectrum; BF spectrum after 0.5 hod; BF spectrum after 1 hod; BF spectrum after 1.5 hod; BF spectrum after 2 hod; BF spectrum after 2.5 hod; BF spectrum after 3 hod; BF spectrum after 3.5 hod; BF spectrum after 4 hod

Fig. 3 IR spectra of the new brake fluid during the half-hour periods

Inasmuch as the brake fluid boiling point is dependent on the amount of absorbed air humidity, therefore, the IR spectrum of the new DOT 4 Plus brake fluid was measured immediately after it was opened. The brake fluid was then left on the measuring crystal, and the infrared spectra were gradually scanned at half-hourly intervals within four hours (see Fig. 3). The primary water absorption area is located in the wavelength region 3050–3650 cm^{-1}, the secondary absorbent area corresponding to –OH bonds is in the range about 1600–1700 cm^{-1}.

Fig. 3 shows that after opening a new brake fluid package is humidity from the air absorbed immediately. The most striking increase water content in brake fluid is within two hours after opening the original brake fluid package.

4. Conclusions

Monitoring selected parameters of brake fluid and replacement at the proper time not only ensures proper function of the braking system but also contributes to the removal of brake system failure and thus increases the safety of road traffic. Based on the tests of the boiling point of the brake fluid DOT 4 Plus that used in Volvo cars was found that recommended two years exchange interval is set properly. By infrared spectrometry was verified that the brake fluid is highly hygroscopic after the opening of the original packaging. Garages technician staff should take extra care to ensure immediately closed bottle with the brake fluid after when the new brake fluid added to the car.

Acknowledgments

The research was supported by the project SGS 2018-023. The authors are thankful to University of Pardubice.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Simulation Methods Used for Planetary Gearbox Analysis

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Abstract

Planetary gearbox is a mechanism that has found wide application in a design of the both wheeled and tracked military vehicles transmission systems. A large scale of kinematic and dynamic effects appears in different designs of these mechanisms. These effects can seriously affect the dynamic and tractive effort characteristics of the vehicle and consequently can affect the applicability of the certain planetary gearbox in the vehicle powertrain. Therefore, the determination or the computation of these effects and parameters values of each design at each mode is a necessity. Currently three main wide-spread computing approaches are used. Due to longer computing time and simplifications of the analytical approach and higher costs of practical gearboxes testing, different simulation tools are nowadays used more and more. Despite some cons like its simplifications, it is very effective and economically advantageous to prove applicability of certain gearbox design in vehicle powertrain by using simulation tools before practical test execution. One of the simulation tools which can be used for this purpose is the Simscape Driveline module of the Matlab software.
KEY WORDS: *mobile equipment, planetary gearbox, transmission system, simulation, simscape driveline*

1. Introduction

Despite the fact that understanding of the analytical approach is essential for correct gearbox analysis and consequently for suitable gearbox design, using of the simulations seems to be more effective. In general, there are several benefits that make software simulations very effective tool for gearbox analysis:

1. Low cost;
2. Calculation time – lower due to computers improving;
3. Cover multiple parameters by one calculation;
4. Possibility of parameters values monitoring at each mode by simple model editing;
5. Simple change of input parameters;
6. Simple change of model components parameters.

On the other hand, in the simulation process, there are various simplifications which make the simulation results less accurate and less reliable. Therefore, it is necessary to verify these results either by practical test execution or/and by analytical calculation. Since the manufacturing of the transmission mechanisms is expensive, in order to reduce the costs of the gearbox designing it is beneficial and effective to verify the simulation results by analytical calculation. If the results were verified and the values of output parameters are identical (eventually with an insignificant deviation), we can assume that the simulation model is correct. This model can be then used for other gearbox modes as well [1].

Simscape driveline

Matlab software is designed for iterative analysis and design processes with a programming language that expresses matrix and array mathematics directly. Simscape driveline is a tool of Matlab software used especially for modeling and simulating translational and rotational mechanical systems.

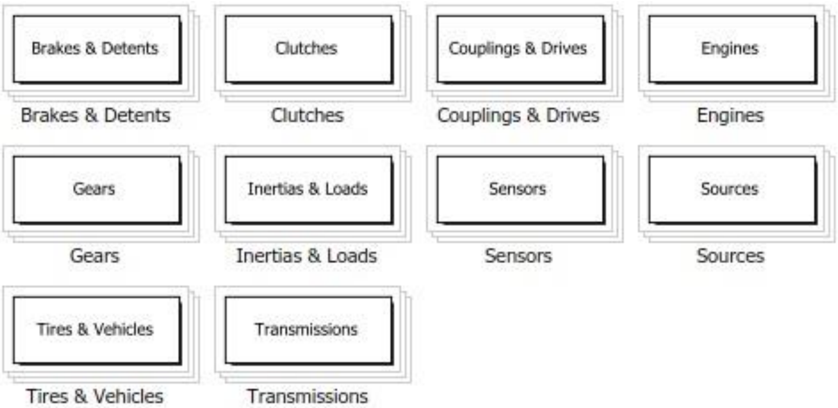

Fig. 1 Simscape driveline libraries

Its most significant advantage is its components library. This library includes basic models of drivetrain components (Fig. 1). Therefore, there is no need to design these components, but just to determine their parameters and links between them to create a model. Driveline modeling employs a physical network approach, where Simscape blocks correspond to physical components, such as engines, gears, brakes, clutches, tires, pistons and so on. The lines that connect these components represent the physical connections that transmit power. The resulting models let us describe the physical structure of a system, rather than the underlying mathematics [1].

2. Gearbox Modeling

This paper deals with verifying Simscape driveline software models as tools of modeling and designing gearboxes. For this reason, the model of the particular planetary gearbox was created using the Simscape driveline software. The analytic calculation of the output parameters was carried out as well. The aim of this paper is to compare these values with the values of result parameters of the Simscape driveline model simulation.

2.1. Planetary Gearbox RECO 606

Planetary gearbox RECO 606 (Fig. 2) was chosen to verify applicability of the Simscape driveline software as a tool of designing gearboxes. This gearbox with gear change carried out without discontinuance of torque transfer is a part of different vehicles drivetrains (Aligator 4x4, Fennek 4x4, OMC Taipan 4x4, etc.). It has three degrees of freedom and provide six forward gears and one reverse gear. Torque converter with lock-up clutch and retarder are placed between engine and gearbox. RECO 606 is composed of four planetary gear trains (PGT) 1., 2., 3. and 4., three multiple disk brakes B1, B2 and B3 and two multiple plate clutches S1 and S2. Gearbox uses 7 (6+R) of 10 theoretically possible gears [2-4].

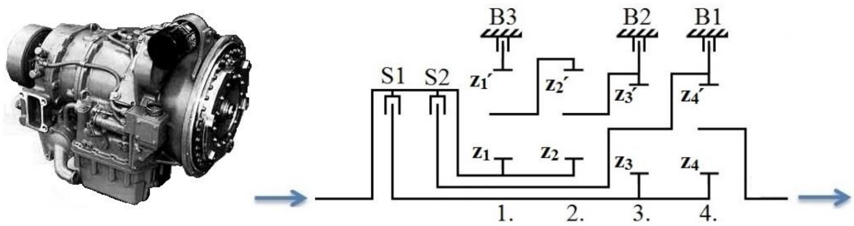

Fig. 2 Planetary gearbox RECO 6O6 [3]

2.2. Model of the Planetary Gearbox RECO 606

To verify applicability of the Simscape driveline as a tool of the gearboxes designing was chosen the systematical approach – from the simplified models (Fig. 4) to the more complex models and simulations (Fig. 3) [1].

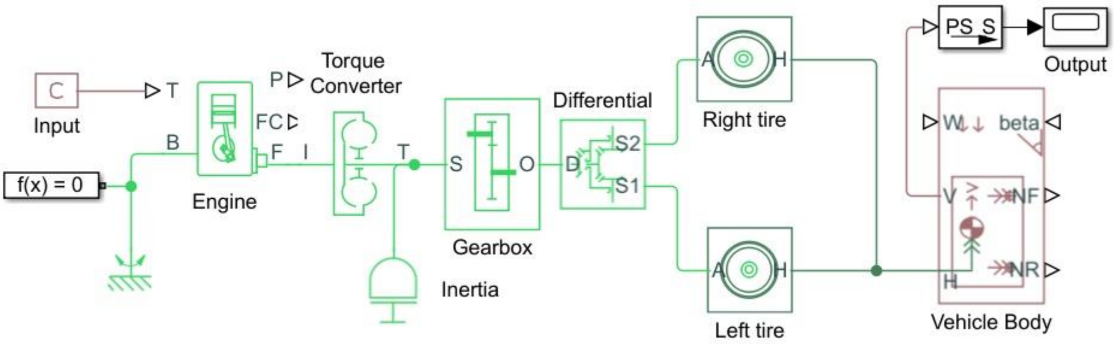

Fig. 3 Example of the basic complex drivetrain model

In complex models we can measure a number of parameters, which are on the other hand influenced by many components and not just by the gearbox. Therefore, some of the drivetrain components were not involved in the gearbox model and so we could focus on the gearbox modeling. This way we excluded possible mistakes and errors which could occur for example in an engine block, torque converter block, differentials blocks, tires blocks etc [1].

Consequently, in this particular model (Fig. 4) the input of the basic gearbox model is an ideal angular velocity source block or an ideal torque source. The input constant block represents the value of the torque or the revolutions flowing from the engine through the torque converter to the gearbox at the certain tim. [1].

In case of simplified model, we can measure the revolutions of the output shaft of the gearbox with ideal rotational motion sensor. In previous models (Figs. 3 and 4), the gearbox component is simple gearbox with two shafts which provides only one gear ratio. Nevertheless, in case of planetary gearbox, we need to measure the revolutions and of each main component of each PGT. Therefore we replaced simple gearbox block with RECO 606 planetary gearbox subsystem (Fig. 5) composed of four PGTs, two multiple plate clutches (S1, S2) and three multiple disk brakes (B1, B2, B3) [1, 5].

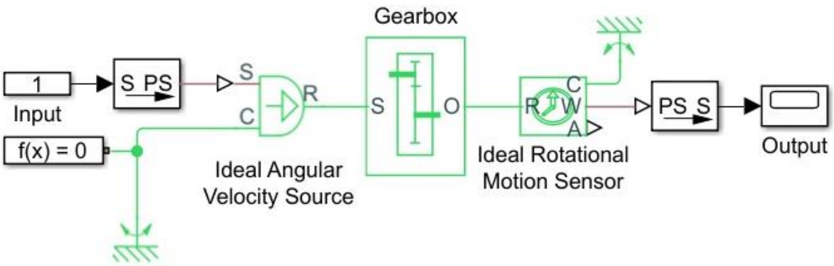

Fig. 4 Example of the simplified drivetrain model

Fig. 5 Simplified RECO 606 gearbox model

We also added the ideal rotational motion sensor to each main component. This way we were able to compute the revolutions of each main component relatively to the input revolutions

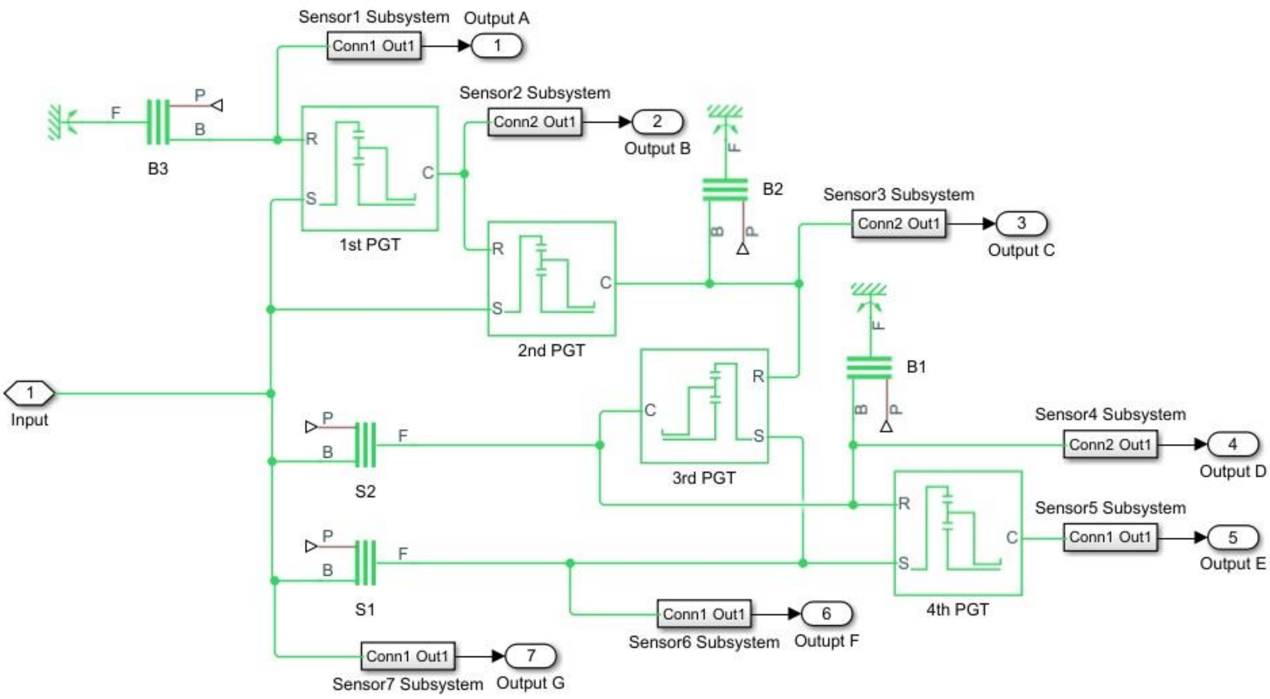

Fig. 6 Gearbox RECO 606 Subsystem

3. Results

For verifying the usability of the Simscape driveline software as a tool of modeling and designing of the transmission mechanisms was chosen the basic output parameter of the planetary gearbox analysis – revolutions of the each main gearbox component on the each gear.

Revolutions of the gearbox main components

Using simplified RECO 606 gearbox model (Figs. 5 and 6) we were able to compute the revolutions of each main component of the planetary gearbox. In case of analytical approach, the simple gearbox analysis on each gear using basic PGT kinematic equation has been conducted (1).

***Basic PGT kinematic equation* [3, 5]:** $$n + n'\alpha - n_0(1+\alpha) = 0, \tag{1}$$

where n - sun gear revolutions; n' - ring gear revolutions; n_0 - planetary carrier revolutions; α - PGT parameter and is:

$$\alpha = \frac{z_1'}{z_1}. \tag{2}$$

In the revolutions comparison table (Table 1) the symbols from the Simscape driveline model are used: n_s - sun gear revolutions; n_R - ring gear revolutions; n_c - planetary carrier revolutions.

Table 1 represents values of revolutions of each component of the planetary gearbox RECO 606 relative to the input shaft revolutions. Each triple of columns represents three main components of all four PGTs (1.-4.) – (Sun gear, Ring gear and Carrier). There are the values of the main components revolutions calculated both analytically and by simulation. Finally, there is a deviation of these two values at each gear for all gearbox main components. As we can see, the values of the deviation are zero or insignificant. Furthermore, these small deviations may have occurred during rounding of the values.

Table 1

Revolutions of the main components relative to the input revolutions

Gear	Calculation	Revolutions of the main Component											
		nS1	nR1	nC1	nS2	nR2	nC2	nS3	nR3	nC3	nS4	nR4	nC4
1st	Analytically	1,0000	-1,6981	-0,9381	1,0000	-0,9381	-0,3922	1,0000	-0,3922	0,0000	1,0000	0,0000	0,2646
	Simulation	1,0000	-1,6980	-0,9381	1,0000	-0,9381	-0,3922	1,0000	-0,3922	0,0000	1,0000	0,0000	0,2646
	Deviation	**0,0000**	**-0,0001**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**
2nd	Analytically	1,0000	-0,9381	-0,3922	1,0000	-0,3922	0,0000	1,0000	0,0000	0,2817	1,0000	0,2817	0,4717
	Simulation	1,0000	-0,9381	-0,3922	1,0000	-0,3922	0,0000	1,0000	0,0000	0,2817	1,0000	0,2817	0,4717
	Deviation	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**
3rd	Analytically	1,0000	0,0000	0,2817	1,0000	0,2817	0,4840	1,0000	0,4840	0,6294	1,0000	0,6294	0,7274
	Simulation	1,0000	0,0000	0,2817	1,0000	0,2817	0,4840	1,0000	0,4840	0,6294	1,0000	0,6294	0,7274
	Deviation	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**
4th	Analytically	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
	Simulation	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
	Deviation	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**
5th	Analytically	1,0000	0,0000	0,2817	1,0000	0,2817	0,4840	2,3157	0,4840	1,0000	2,3157	1,0000	1,3481
	Simulation	1,0000	0,0000	0,2817	1,0000	0,2817	0,4840	2,3160	0,4840	1,0000	2,3160	1,0000	1,3480
	Deviation	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**-0,0003**	**0,0000**	**0,0000**	**-0,0003**	**0,0000**	**0,0001**
6th	Analytically	1,0000	-0,9381	-0,3922	1,0000	-0,3922	0,0000	3,5500	0,0000	1,0000	3,5500	1,0000	1,6746
	Simulation	1,0000	-0,9381	-0,3922	1,0000	-0,3922	0,0000	3,5500	0,0000	1,0000	3,5500	1,0000	1,6750
	Deviation	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**-0,0004**
7th	Analytically	1,0000	0,0000	0,2817	1,0000	0,2817	0,4840	-1,2343	0,4840	0,0000	-1,2343	0,0000	-0,3265
	Simulation	1,0000	0,0000	0,2817	1,0000	0,2817	0,4840	-1,2340	0,4840	0,0000	-1,2340	0,0000	-0,3265
	Deviation	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**-0,0003**	**0,0000**	**0,0000**	**-0,0003**	**0,0000**	**0,0000**

4. Conclusion

This paper deals with the verifying of the usability and applicability of the Simscape driveline software as a tool of the modeling and designing of the transmission mechanisms. To verify applicability of the software as a tool of the gearboxes designing was chosen the systematical approach – from the simplified models to the more complex models and simulations. For this purpose, were compared the results of both analytical calculation and software simulation of the planetary gearbox RECO 606. We created the simplified model of the gearbox and conducted a simulation. We also made an analytical calculation. The revolutions of each main component of the gearbox relative to the input revolutions were the parameters chosen for comparison. These parameters were calculated by both methods, the results were compared and we analyzed the deviation between analytical and simulation results. As mentioned, the values of the deviation were zero or insignificant. Therefore, we can claim that the Simscape driveline software is applicable and usable tool of the transmission systems simple designing process. This paper also indicates the possible path of further effort – to verify the software under different conditions, e.g. torques calculation or efficiencies calculation. This effort should also lead to more complex models using real input, output and control elements.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

The Simulation of Hospital Supply in case of Emergency Deliveries

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Abstract

Many threats threaten today's world. We can include cyber-attacks, terrorism, but also natural threats. These threats can cause a power outage. Besides, they may cause food and water supplies to be interrupted. Hospitals cannot afford these outages. Therefore, emergency supplies for hospitals are provided. Each hospital solves this supply individually. The aim of this article is to present a simulation of the logistics process from the point of supply to the hospital. The hospital and distribution warehouse of a selected company in the city Uherské Hradiště (Czech Republic) was selected for this simulation. The PTV Vissim software will be used for this simulation.
KEY WORDS: *hospital supply, emergency delivers, logistics process, PTV Vissim, simulation, Czech Republic*

1. Introduction

Disaster constitutes sudden shocks to both environmental and socioeconomic systems, entailing loss of life and property [1]. The following definition of the United Nations International Strategy for Disaster Reduction is one of the most common: A disaster is a severe disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its resources [2]. For a disaster to be entered into the database of the UNISDR, at least one of the following criteria must be met:

- A report of 10 or more people killed;
- A report of 100 people affected;
- A declaration of a state of emergency by the relevant government; and/or
- A request by the national government for international assistance.

The Czech Republic belongs to the group of the European Union member states and defines disaster in the Act

No. 586/1992 Coll. This act defines a natural disaster as an event “not caused by fire and explosion, lightning, storms with wind speeds above 75 km/h (kilometers per hour), floods, flooding, hail, slumping soils, landslides and rock collapse, if they occurred in the context of industrial or construction traffic, sliding or collapse avalanches and earthquakes reaching at least the fourth international scale indicating the degree of macroseismic effects of earthquakes [3].

Many of the mentioned situations threated the Czech Republic each year. There are many threats to the flood, storms and these situations influence the health, life, and property of the inhabitants. These situations can be caused by other emergencies. There we can take power outage, food outage, water outage and others. The Czech Republic is one of the few member states of the European Union that has identified European CIs on its territory. Subsequently, the Czech Republic has focused its attention on the Safety/Security and Risk Management areas, with relation to practical approaches to critical infrastructure protection development [4]. The primary interest of the state is ensuring the essential services provided to its inhabitants and to other persons who are currently in its territory [5].

The Fire Rescue Service of the Czech Republic defines the emergency survival of the population. Fig. 1 shows the types of emergency survival of the population in the Czech Republic. One of them is emergency food supplies. These supplies are essential in times of crisis. Emergency food supplies are essential for the affected population and the elements of the key infrastructure. One of them can be hospitals and others healthcare facilities. The aim of the Czech Republic in the following years will define the key infrastructure elements and give him the priority of the delivery in times of crisis. For this article, we choose the hospital in Zlín region, Czech Republic.

For these emergency food supplies is an essential logistic process. This process involves involving a whole team of people to cope with the crisis. In some situations, it is also necessary to involve a multicultural team. Krenar and Taraba analyze the multicultural team that shows that motivation, communication, and teamwork are necessary when working in such a team [6]. Some of the hospitals in the Czech Republic have contractual deliver in times of crisis. For the selected hospital we choose distribution warehouse. This warehouse is only a few kilometers from the hospital and has food supplies. In times of a crisis, it is essential to provide emergency supplies quickly and efficiently. As mentioned above, a frequent crisis is a flood in the Czech Republic. In this situation, it may happen that the driveway to

the hospitals will be flooded. In these cases, new ways of delivering emergency food supplies need to be found. This thesis will found a new way of solving these situations. There will be used software PTV Vissim to simulate it. The aim of this paper will analyze of the crisis preparedness of the hospital and propose the read as a new way how to deliver the hospital in times of crisis.

Fig. 1 Emergency survival of the population

2. Methodology

Five methods of scientific work were used in this article. The method of analysis is used due to the fact that it uses the principles of logic to achieve the set goal and provide the framework to explore the principles of crisis preparedness of the hospital and the emergency deliveries. The induction method was used, where this method serves to examine the fact of creating a hypothesis from the points obtained. Comparison method allows to evaluate and analyze processes and approaches in the emergency supplies.

Heuristic analysis of preparedness was used for the selected hospital. This method is based on a quantitative assessment of the crisis preparedness of the hospital. In the context of this assessment, we will get an actual idea of the weaknesses and strengths of the assessed hospital. This analysis is divided into five parts. For these paper, we choose only emergency food supplies. This category assesses whether a kitchen is built in the hospital. In the event of a food supply outage, it is assessed whether the hospital has a supply of food. It is also assessed whether hospitals are contractually supplied with hot food suppliers, food supplies or finished meals and others. It is only short analysis, but we take information about the tested hospital.

Finally, the simulation was used by the software PTV Vissim. PTV Vissim software has been used to simulate transport services in the state of crisis. It is the software that solves microscopic simulations of individual and public mass transport. This program can affect both urban traffic, including cyclists, and motorway sections, including significant, cross-country intersections. The extensive analytical tools gathered in Vissim make it a tool for traffic planning and optimization of transport and transport systems, as well as some interfaces for different traffic management systems.

Vissim simulates some familiar but also unique geometric and operating conditions that occur in the transport network. The Vissim can define an unlimited number of vehicle types allows the user full range of multimodal operations. Types of vehicles include passenger cars, trucks, buses, cyclists, wheelchairs, pedestrians, airplanes,

Vissim offers the unique ability to allocate vehicles to the network using one or a combination of three methods. The primary method assumes that traffic is stochastically distributed on fixed routes from a user-defined starting point to a destination point. The definition of junction maneuvers allows traffic to be distributed at a junction or several junctions. Dynamic routes provide dynamic allocation of traffic to user-specified routes.

The Dynamic Load Method allows Vissim to assign traffic to the source/target matrix network (depending on vehicle time and category) and stochastic (load and load) loading techniques.

3. Results

For this paper was choose the hospital and the emergency food supply. In case of crisis, it could be the situation, which the hospital has not food for the clients. In these case, the hospital has or have not contractors. For the selected

hospital we choose the food warehouse, where they have much durable food and durably finished meals. This warehouse is located few kilometers from the hospital; however, he is in the zone of the flood.

The results are divided into two parts. Firstly, we will evaluate crisis preparedness of the selected hospital. Secondly, we will propose the new way for the emergency food supply.

Firstly, there was used the heuristic analysis of preparedness.

Table 1

Heuristic analysis of preparedness

Points	Questions	Results
1	Does the hospital own kitchen?	1
1	Does the hospital warehouse with food?	1
1	Are these food available for 1 day?	0
2	Are these food available for 2 days?	0
3	Are these food available for 3 days?	3
1	Does the hospital contract the supply of raw materials to the kitchen?	1
1	Does the hospital contract the supply food to the kitchen?	1
1	Is the hospital contracted to provide hot food (in the event of a faulty kitchen)?	-1
1	Does the hospital contractually provide other food for clients (breakfast/dinner)?	-1
1	Does the hospital have a supply of meals for the patients (without their kitchen)?	0
1	Is the hospital contractually provided with ready meals (intended for heating)?	-1
Total	=(results + number of heuristic)/(2 x number of heuristic)	72.22%

Table 1 shows the results of the evaluation of crisis preparedness of the hospital to the food supply. As can be seen in the table, the total crisis preparedness is 72.22% of the selected hospital. The advantages of this hospital are that they have own kitchen and the warehouse with the food. The food, which is situated in the warehouse are available for the three days of cooking for the hospital. During the next advantages belongs that the hospital has contracted the supply food to the kitchen. On the other hand, there are disadvantages. Belong the main disadvantages belongs that the hospital has not contractually offered hot food in the event of a faulty kitchen. Next, the hospital has no contractually offered other food for clients – breakfast, dinner. And the final disadvantage is, that the hospital has not contractually provided with ready meals, which is intended for heating. The recommendation in this paper could solve this situation.

Secondly, there is the recommendation about the selecting the appropriate supply path. The current way is flooded in times of crisis. However, there are the situations, when the road to the hospital could be flooded out of the times in the crisis. The driveway to the hospital includes subway (as can be seen in Fig. 2).

Fig. 2 Subway to the hospital

The Fig. 2 shows the subway to the hospital, which is flooded in times of crisis – flood. The river Morava flooded this subway during the flood in 1997. The hospital has not the main driveway to the hospital. The constriction of the new driveway could solve the solution to this situation to the hospital. This driveway is out of the flooded area and is connectable from the main road. The following figures show the current state of the situation and the possible solution design.

Fig. 3 shows the current state of the driveway to the hospital. As can be seen in Fig. 3, the road runs through the city. There is enormous flow in the times when the inhabitants go to the works and schools and back. The following Fig. 4 shows the main junction, which leads to the hospital.

Fig. 3 Current state of the driveway to the hospital

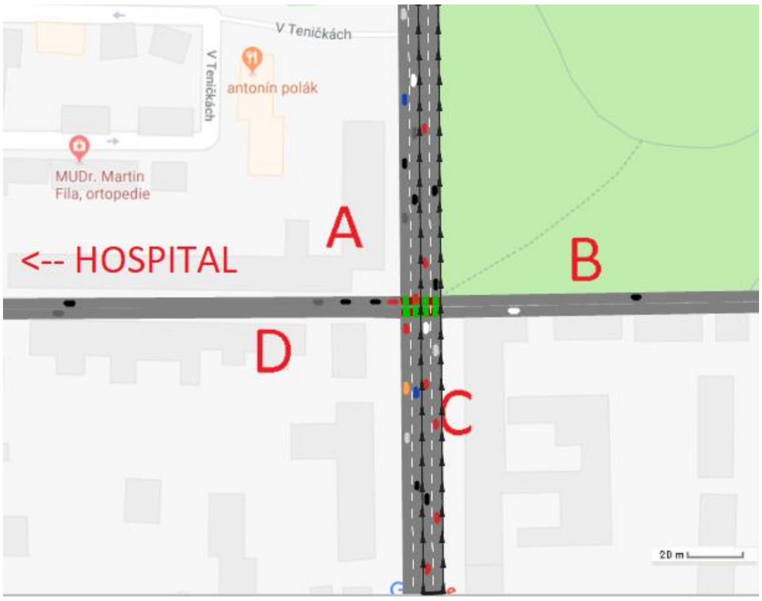

Fig. 4 Junction to the hospital

Table 2

Capacity of the junction

Entrance	**from A**	**from C**	**from D**		
Exit	**to D**	**to D**	**to A**	**to B**	**to C**
8:00 – 8:30 a. m.	48	118	64	7	40
8:30 – 9:00 a. m.	94	167	111	13	76
9:00 – 9:30 a. m.	101	166	89	9	67
9:30 – 10:00 a. m.	80	154	79	4	96
10:00 – 10:30 a. m.	71	148	75	5	92
10:30 – 11:00 a. m.	83	149	95	2	116
1:00 – 1:30 p. m.	60	107	81	7	109
1:30 – 2:00 p. m.	67	124	114	8	96
2:00 – 2:30 p. m.	80	130	120	8	93
2:30 – 3:00 p. m.	84	164	93	10	104
3:00 – 3:30 p. m.	99	134	125	13	102
3:30 – 4:00 p. m.	79	152	128	8	92
4:00 – 4:30 p. m.	68	127	123	9	97
4:30 – 5:00 p. m.	66	112	90	10	91
Total	**1080**	**1952**	**1387**	**113**	**1271**

Fig. 4 shows the main junction, which leads to the hospital. There is often traffic jam. The following table shows the capacity of the selected junction.

Table 2 shows the results of the capacity of the new junction, which is critical for the hospital. As can be seen in the table, the highest intensity of the way is in the time interval from 10:30 a.m. to 11:00 a.m. The second highest intensity of the road is in the time interval from 1:00 p.m. to 1:30 p. m.

The following Fig. 5 shows the proposal of the new road to the hospital.

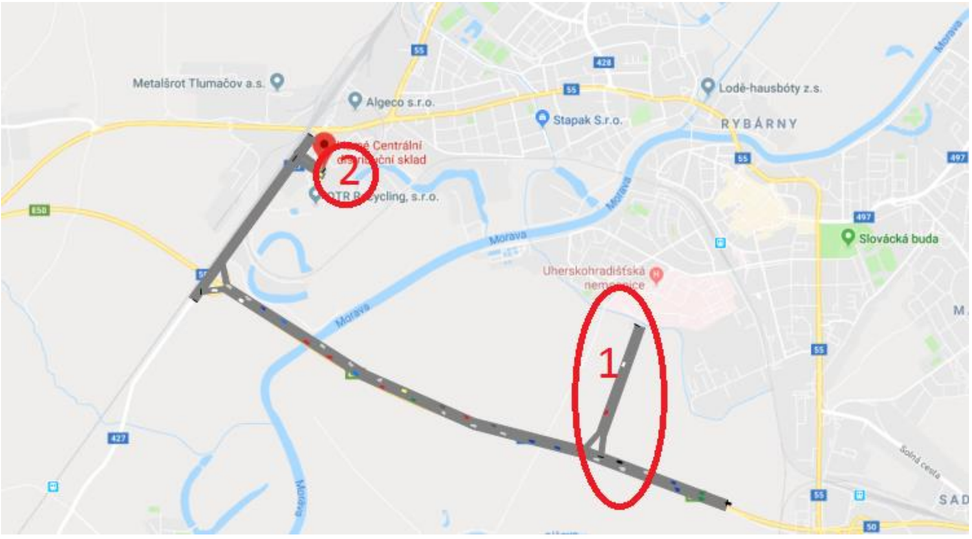

Fig. 5 Simulation the new road to the hospital

Fig. 5 shows the simulation of the new road to the hospital. Number 1 indicates the new route to the hospital. Number 2 shows warehouse. This way will be quicker and efficient for the delivery food in times of crisis.

4. Conclusion

The aim of this paper was the analysis of the crisis preparedness of the hospital and propose the read as a new way how to deliver the hospital in times of crisis. Firstly, there was used the heuristic analysis of preparedness for the selected hospital. This analysis was focused on emergency food supply. Total crisis preparedness for the emergency food supply is 72.22 percent. During the main advantages belongs own kitchen, food in ware for three days and contracted the supply food to the kitchen. On the other, there are some disadvantages. Hospital has not contractually offer hot food in the event of a faulty kitchen, no contractually offer other food for clients (breakfast and dinner) and no contractually provide with ready meals, which is intended for heating.

Secondly, there was analyzed the current way to form the selected warehouse to the hospital. There was found, that in the way is one underpass, which could be flooded in times of flood and flood from the summer storm and torrential storm. For these case, we propose new road for delivering the hospital in times of crisis. This road was analyzed by the software PTV Vissim and was found that this way is quicker and efficient.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Controlling Efficiency of Engine's Adjustment Parameters in Relation to Ecological Criteria

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Abstract

In the study is presented proposal of a method how to assess controlling results of adjustment parameters of a self-ignition combustion engine in relation to ecological criteria. As a partial criteria to the assessment were taken changes in emission of individual harmful compounds of exhaust gases after usage of new adjustment parameters. Process of the assessment required also definition of significance levels of the individual partial criteria, and required usage of the Promethee method of multi-criterion analysis. Proposed method of the assessment was used in relation to results obtained for minimization task of nitrogen oxides emission in conditions of partial engine loads.
KEY WORDS: *compression ignition engine, control of exhaust emissions, numerical model*

1. Introduction

Selection of the adjustment parameters' values in a self-ignition engine, aimed at restriction of emission of harmful components of exhaust gases, is possible in area of partial engine loads with simultaneously maintained not exceeded and acceptable mechanical and thermal loads of engine components. Numerical analysis connected with search after optimal set of the adjustment parameters, for a preset criterion, can be used to solve the task defined in such a way. Assessment of efficiency of performed selection of the adjustment parameters for individual points of engine operation can be accomplished in relation to many criteria, which can be grouped within two basic cumulated categories: i.e. ecological and operational ones. In the presented study, issue of assessment of the adjustment efficiency in relation to ecological criteria was taken to minimization of nitrogen oxides emission.

2. Task of Minimization of Nitrogen Oxides Emission

Assessment of selection's effectiveness of engine adjustment parameters will be used to the results obtained from performed task of minimization of nitrogen oxides emission, analyzed in previous studies of the authors, in the [4] among others. It means that the adjustment parameters were obtained in course of numerical simulation, after taking objective function in form of:

$$\bar{\Omega}_{NO_x}\left(\boldsymbol{X}\right)=C^F_{NO_x}F_{NO_x}\ , \tag{1}$$

here $\mathbf{X}$ - vector of the adjustment parameters, $C^F_{NO_x}$ - coefficient defined as converse of nitrogen oxides emission for the factory settings, F_{NO_x} - nitrogen oxides emission in the exhaust gases.

Simultaneously, criteria for additional limitations were taken into considerations, in relation to not-exceeded allowable emission levels of other compounds of exhaust gases:

$$F_i \le \delta_i\, F_{i,0}\ \text{ for }\ i\in\left\{CO,HC,D\right\}, \tag{2}$$

here δ_i - coefficients defined for a given compound, $F_{i,0}$ - emission or smokiness of the *i*-th compound for the factory settings, and not exceeding allowable changes in characteristic parameters of the working cycle:

$$l_i = l_{i,0}\ \text{ for }\ i\in\left\{p_i\right\}; \tag{3}$$

$$\gamma\, l_{i,0} \le l_i\ \text{ for }\ i\in\left\{\eta_c\right\}; \tag{4}$$

$$l_i \le \zeta_i\, l_{i,0}\ \text{ for }\ i\in\left\{p_{\max},T_{\max}\right\}, \tag{5}$$

here $p_i, p_{\max}$ - indicated pressure and maximal pressure in the cycle, respectively, $\eta_c, T_{\max}$ - thermal efficiency and

maximal temperature in the cycle, γ, ζ_i - coefficients defined for a given operational point, $l_{i,0}$ - value of the *i-th* parameter of characteristic working cycle for the factory settings.

Values of individual coefficients are put together in the Table 1.

Table 1

Values of the $\delta_i, \gamma, \zeta_i$ coefficients taken to definition of limitations in the selection task of the adjustment parameters

Coefficient	δ_{CO}	δ_{HC}	δ_D	γ	$\zeta_{p_{\max}}$	$\zeta_{T_{\max}}$
Value	1.3	1.2	1.5	0.95	1.1	1.1

Assessment of the controlling efficiency due to ecological criteria will be used for results obtained from accomplished task in form of (1), for eight selected points of engine operation, from area of partial engine loads, as in the Table 2.

Table 2

Points of engine operation, for which assessment of the controlling efficiency is analyzed (M_{max} denotes maximal engine torque at a given rotational speed)

	P1	P2	P3	P4	P5	P6	P7	P8
Rotational speed [rpm]	2500				3500			
Engine load	0.25 M_{max}	0.50 M_{max}	0.75 M_{max}	0.90 M_{max}	0.25 M_{max}	0.50 M_{max}	0.75 M_{max}	0.90 M_{max}

Main parameters of the engine, for which calculations of the working cycle were performed with use of the numerical model defined in the study [3], are presented in the Table 3.

Table 3

Main technical data of the engine

Engine	Self-ignited, turbocharged, Common Rail fuel supply system
Swept capacity	1.3 dm^3
Max power	55.2 kW / 4000 rpm
Max torque	200 Nm / 1500 rpm

New vectors of the adjustment parameters have been obtained in result of solved selection task of adjusting parameters with respect to minimization of nitrogen oxides emission. List of obtained levels of the emission for the factory settings and after implemented changes in the settings has been presented in the Tables 4 and 5 respectively.

Table 4

Emission of harmful compounds in the analyzed points of engine operation for the factory settings

	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8
F_{CO} [%]	0.068	0.017	0.007	0.007	0.049	0.015	0.010	0.011
F_{HC} [ppm]	265	80	50	44	162	89	61	50
F_{NO_x} [ppm]	97	253	769	898	343	554	887	962
F_D [FSN]	0.3	0.8	0.2	0.2	0.2	0.2	0.2	0.3

Table 5

Emission of harmful compounds in the analyzed points of engine operation after implemented changes in the settings

	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8
$F_{CO}^{(*)}$ [%]	0.089	0.021	0.009	0.008	0.064	0.018	0.010	0.011
$F_{HC}^{(*)}$ [ppm]	303	74	48	43	147	84	60	48
$F_{NO_x}^{(*)}$ [ppm]	70	175	697	812	300	439	769	812
$F_D^{(*)}$ [FSN]	0.36	1.21	0.24	0.28	0.3	0.37	0.27	0.52

Subject-matter of the analysis performed within framework of presented study is multi-criteria assessment of obtained results, enabling comparison of efficiency of selection of the adjustment parameters for analyzed points of engine operation due to ecological criteria.

3. Assessment of the Effectiveness in Respect of Ecological Criteria

In the presented study it has been undertaken task of cumulated assessment of controlling efficiency due to ecological criteria. It means that in process of the assessment are simultaneously analyzed partial criteria in form of differences in emission of individual harmful compounds in exhaust gases for the factory settings, and after application of the settings evaluated in result of solved selection task of the adjustment parameters. The analysis was carried out with regard to emission of carbon oxide (CO), hydrocarbons (HC), nitrogen oxide (NOx) and smoke in exhaust gases (D). Significance level of the individual partial criteria has been evaluated on the base of the following presumptions:

1. in relation to the objective function applied in the selection task of the adjustment parameters, emission of nitrogen oxides was assumed as the dominant criterion;
2. smoke of exhaust gases was considered as more significant factor than emissions of hydrocarbons and carbon oxide;
3. emission of hydrocarbons and emission of carbon oxide, in case of the analyzed engine type, is the issue having similar significance with a weak indication on preference in area of limitation of hydrocarbons emission.

Taking into account the above mentioned presumptions, to obtain weight vector representing significance of a given partial criterion, it has been applied proceeding based on comparison in pairs with use of classic Saaty scale, leading to definition of the evaluation matrix [5]. The evaluation matrix of the partial criteria significance obtained in result of applied method of comparison in pairs is characterized by the consistency ratio of $C.R. = 0{,}091$, and has form of:

$$\mathbf{M} = \begin{bmatrix} 1 & r_{CO\leftrightarrow HC} & r_{CO\leftrightarrow NOx} & r_{CO\leftrightarrow D} \\ r_{HC\leftrightarrow CO} & 1 & r_{HC\leftrightarrow NOx} & r_{HC\leftrightarrow D} \\ r_{NOx\leftrightarrow CO} & r_{NOx\leftrightarrow HC} & 1 & r_{NOx\leftrightarrow D} \\ r_{D\leftrightarrow CO} & r_{D\leftrightarrow HC} & r_{D\leftrightarrow NOx} & 1 \end{bmatrix} = \begin{bmatrix} 1 & 1/2 & 1/9 & 1/7 \\ 2 & 1 & 1/7 & 1/5 \\ 9 & 7 & 1 & 5 \\ 7 & 5 & 1/5 & 1 \end{bmatrix}. \tag{6}$$

Vector representing significance of the partial criteria was evaluated from the equation:

$$\mathbf{MW} = \lambda \mathbf{W}, \tag{7}$$

here λ - eigenvalue of the evaluation matrix, obtaining:

$$\boldsymbol{W} = \left[0.043; \quad 0.070; \quad 0.645; \quad 0.242\right]^T \quad \text{for} \quad w_1 = CO; \quad w_2 = HC; \quad w_3 = NO_x; \quad w_4 = D. \tag{8}$$

To calculate cumulated assessment of the controlling efficiency for the analyzed points of engine operation, and as consequence, to point at arrangement of obtained solutions, it has been used the Promethee II method [1]. In the first step of the proceeding the decision matrix has been created, in which, based on the tables 4 and 5, were collated values of relative change in emission of a given compound $f_k(P_i)$ after usage of new settings of the adjustment parameters for each from operational points of the engine $P_i, i = 1..n$, i.e.:

$$f_k(P_i) = {F_k(P_i)} \big/ {F_k^{(*)}(P_i)}, \tag{9}$$

here $F_k(P_i)$, $F_k^{(*)}(P_i)$ - emission of *k-th* component of exhaust gases for the operational point P_i suitably as in the Tables 4 and 5. In the next step it have been evaluated matrixes of preference for each partial criterion with elements having form:

$$MP(k)_{i,j} = \begin{cases} 1 & \text{for} \quad f_k(P_i) - f_k(P_j) > 0.1 \\ 0 & \text{otherwise} \end{cases}. \tag{10}$$

Assumed threshold value of 0.1 to evaluation of the preference has resulted from approved „a priori” uncertainty level for approximation of the emissions during creation of model [2].

In the next step it has been determined matrix of aggregated indices of the preferences with elements having form of:

$$MIP_{i,j} = \sum_{k=1}^{4} w_k \, MP(k)_{i,j}, \tag{11}$$

here w_k is the weight of significance of *k*-th criterion according to (8).

Finally, flows of the preferences have been determined for each from analyzed operational points of the engine:

$$\varphi^{+}(P_i)=\frac{1}{n-1}\sum_{x=1}^{n}MIP_{i,x}\ ; \tag{12}$$

$$\varphi^{-}(P_i)=\frac{1}{n-1}\sum_{x=1}^{n}MIP_{x,i}\ . \tag{13}$$

Value $\varphi^{+}(P_i)$ denotes cumulated assessment, to what extent the solution for P_i is better than others, while $\varphi^{-}(P_i)$ to what extent is worse than others. Finally, values of the net flow are evaluated on the basis of obtained values of the flows of preference, i.e.:

$$\varphi(P_i)=\varphi^{+}(P_i)-\varphi^{-}(P_i). \tag{14}$$

The final ranking is determined by decreasing ordering of the variants due to calculated value of the net flow. Results of the calculations are summarized in the Table 6, together with demonstrated change of position in the ranking resulted from implemented multicriteria assessment, in comparison to results of the ranking based on dominant criterion in terms of reduction of NO_x emission level.

Table 6

Calculated values of the net flow and summary of the final results

	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8
$\varphi(P_i)$	0.637	0.516	-0.106	-0.266	-0.319	-0.025	-0.16	-0.276
Ranking accor-ding to the domi-nant criterion (NO_x)	2	1	8	7	6	3	5	4
Ranking for the multicriteria assessment	1	2	4	6	7	3	5	8
Change of position	+1	-1	-4	-1	+1	0	0	+4

4. Conclusions

From the viewpoint of limitation of emissions of all harmful components of exhaust gases, analysis of the obtained results shows that obtained controlling effectiveness of the adjustment parameters is diverse. In majority of the cases the multi criteria assessment doesn't match with the assessment performed solely on the basis of the dominant criterion, i.e. effectiveness of reduction of the NO_x emission. Coherence of the assessments exists only in case of the operating points corresponding to engine operating points P_6 and P_7, and hence the operating points corresponding to engine speed of 3500 rpm and engine load 0,25 and 0,5 M_{max} respectively. In two other cases represented by the points P_3 and P_8, result of implemented multicriteria assessment differs significantly from result of the assessment performed solely on the basis of the dominant criterion. For half of the analyzed cases, use of the multicriteria assessment can be interpreted as some kind of correction of the assessment performed on the base of effectiveness of reduction of the NO_x emission. To the set of such solutions belong, e.g. results obtained for the operating points P_1 and P_2.

Presented in this paper assessment of selection results of the adjustment parameters for individual points of engine operation may be complemented and accomplished also in relation to other criteria, such as indicating pressure and temperature of the cycle. These criteria belong to the second cumulated category, which can be described as the operational category.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Selected Problems of Vehicle Microclimate Modeling

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Abstract

The optimum humidity and temperature conditions must be maintained for the comfort of the operator and the crew within the vehicle. In the article, a mathematical model is designed to assess the impact of the temperature in the vehicle cabin and the effect of the variables in relation to the occupants of the vehicle.
KEY WORDS: *microclimate of vehicles, mathematical model, variables, modelling*

1. Introduction

In order to improve the quality of the microclimate in the vehicle, there is a good sound, thermal insulation. These improvement, however, lead to the need for high-quality air extraction and fresh air supply, allowing the crew to survive longer in the vehicle cabin without any negative effects on the fatigue of the driver or the crew of the vehicle. The author has already dealt with negative influence about of the CO_2 concentration of the driver in the vehicle. [6, 7] This article builds on the analysis of the negative effects of the vehicle cabin on the driver.

2. Legislation

Problematics of temperature at the workplace and its permissible values are set out in the ISO guidelines, methodologies and standards listed below:

- Decree of Ministry of Health of the Czech Republic No. 343/2009 Coll., On hygiene requirements for premises and operation of facilities and facilities for education and education of children and adolescents.
- Decree of the Ministry of Health of the Czech Republic No. 6/2003 Coll., Which sets hygienic limits of chemical, physical and biological parameters for indoor environment of living rooms of some buildings.
- Decree of the Ministry of Health of the Czech Republic No. 137/2004 Coll., On hygienic requirements for catering services and on the principles of personal and operational hygiene in epidemiologically relevant activities, as amended by Ministry of Health Decree No. 602/2006 Coll.
- Methodological manual of HH CR No. 12 - Measurement of microclimatic parameters of working environment and indoor environment of buildings, Bulletin of Ministry of Health of the Czech Republic 2009,amount 2.
- ČSN EN ISO 7726 Ergonomics of the thermal environment - Instruments for measuring physical quantities.
- EN ISO 7730 Ergonomics of Thermal Environment - Analytical determination and interpretation of thermal comfort by calculation of PMV and PPD and local thermal comfort criteria. In order to ensure the thermal comfort of the driver and crew, efficient ventilation of the vehicle and good bodily thermoregulation are required.

3. Thermal Balance Model

If we take the interior of the vehicle as a closed space Fig. 1 where only the operation of a ventilation fan that supplies fresh air at a certain temperature as input.

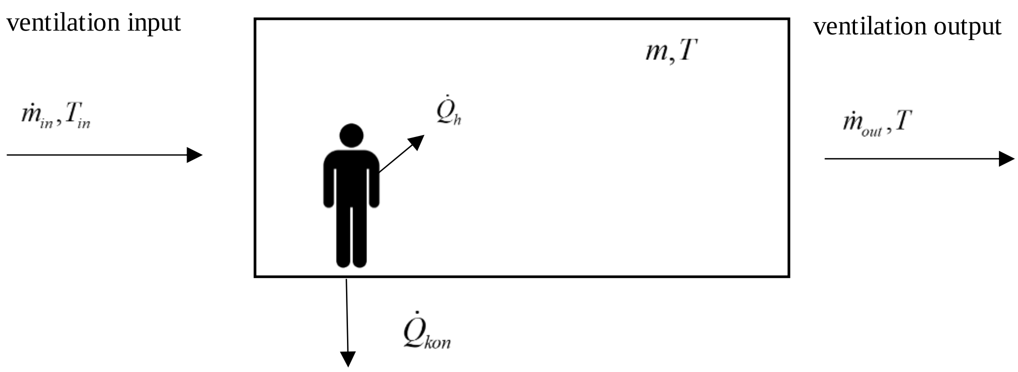

Fig. 1 Schematic of a vehicle cabin thermodynamic system

Where m is the air mass in the vehicle; T is the air temperature in the vehicle; T_{in} is the air temperature at the input; $\dot{m}_{in} = \dot{m}_{out}$ is the mass flow rate through the ventilation; $T = T_{out}$ is the air temperature at the output; $\dot{Q}_h$ is the amount of heat shared by human; $\dot{Q}_{kon}$ is the amount of heat shared by the convection with the interior of the vehicle.

In the case where the pressure in the vehicle cab is constant, it can be assumed that fresh air at a certain temperature in the vehicle's cabin is subsequently influenced by the crew who, over time, releases some heat into the surroundings. The crew affects the temperature inside the vehicle by breathing and body surface. Subsequently, when changing the air in the vehicle cabin, part of the air from the vehicle cab is taken out of the vehicle cabin.

The air quality change in the interior of the car is most affected by the air supplied by the fan. By breathing, the person does not only increase the concentration of CO_2, but heats the ambient air with exhalation, thanks to the exhalation also increases the air humidity in the vehicle.

The thermal balance of a simple thermodynamic system of a vehicle (Fig. 1) can be expressed by the application of the first law of thermodynamics for the open system [1] the general expression is given by the equation:

$$\sum \frac{dH_i}{d\tau} + \sum \dot{Q}_i = \frac{dU}{d\tau} d\tau \,, \tag{1}$$

where H_i is the incoming and outgoing air enthalpy; $\dot{Q}_i$ is the incoming and outgoing heat flows; U is the internal energy of the air in the system; τ is time.

The general Eq. (1) we can rewrite to the form suitable for the given thermodynamic system (Fig. 1) as:

$$\frac{dH_{in}}{d\tau} - \frac{dH_{out}}{d\tau} + \dot{Q}_h + \dot{Q}_{kon} = \frac{d\left(mu\right)}{d\tau} \,. \tag{2}$$

By introducing the enthalpy and the internal energy by using their specific quantities and assuming the constant mass of the air in the vehicle, we obtain:

$$\dot{m}_{in} h_{in} - \dot{m}_{out} h_{out} + \dot{Q}_h + \dot{Q}_{kon} = m \frac{du}{d\tau} \,, \tag{3}$$

where h_{in}, h_{out} - specific enthalpies; u - the specific internal energy.

Assuming the ait as the ideal gas, we can express specific enthalpy and specific internal energy by:

$$h = c_p T \,; \quad u = c_v T \,. \tag{4}$$

Then, by introducing to the Eq. (3) we obtain the final form of the equation of the first law of thermodynamics as:

$$\dot{m}_{in} c_p T_{in} - \dot{m}_{out} c_p T + \dot{Q}_H + \dot{Q}_{kon} = m c_v \frac{dT}{d\tau} \,, \tag{5}$$

where c_v - the specific thermal capacity at constant volume; c_p - the specific thermal capacity at constant pressure.

By adjusting the equation of the first law of thermodynamics (5), we obtain a time course of air temperature in the vehicle cabin:

$$\frac{dT}{d\tau} = \frac{\dot{m}_{in} c_p \left(T_{in} - T\right) + \dot{Q}_h + \dot{Q}_{kon}}{m c_v} \,. \tag{6}$$

Human is classified into warm-blooded (homothermic) animals, so his body temperature is constant. The body temperature of the human being is in itself 37°C, which is the temperature inside the body itself. The limbs and the skin have a lower temperature, which mainly depends on the ambient temperature and body thermoregulatory processes. The individual temperatures are shown in Fig. 2.

The vehicle crew bodies produce the most important part of the incoming heat. The amount of heat that one human body radiates at rest is 100 W, at medium load of 400 W and in extreme exertion at professional athletes up to 2000 W [5]. The second source of the incoming heat is breathing. Therefore, the overall heat flow rate released by human is given by:

$$\dot{Q}_h = i_p 100 + i_p \dot{m}_b c_p \left(T_0 - T\right) , \tag{7}$$

where $\dot{m}_b$ - the mass flow of breathing; i_p - a number of persons in the vehicle; T_0 - the exhaled air temperature.

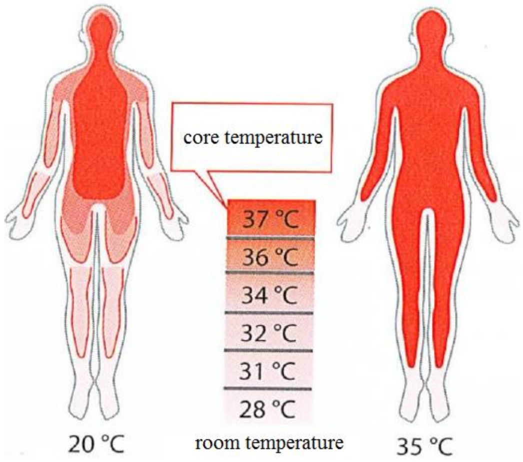

Fig. 2 Evolution of heat loss of heat in a human without clothing [3]

Depending on the psychological and physical state of a person, the frequency of breathing changes. The number of exhales affect the change in air temperature and humidity. There are determined three basic groups of breathing [6]:

- eupnoe - rest breathing - 15-20 min^{-1};
- tachypnoe - fast breathing - above 25 min^{-1};
- bradypnoe – slow breathing – under 12 min^{-1}.

The mass flow rate of a person-exhaled air is:

$$\dot{m}_b = \rho i V_l, \tag{8}$$

where ρ - the air density; i - the number of exhales per second; V_l - the lung volume.

The convective heat transfer between the air within the vehicle cabin and the its inner surface is given by the Newton´s law of cooling [1] in form:

$$Q_{kon} = \alpha A(T_s - T), \tag{9}$$

where A- the heat transfer area of the vehicle inner surface; α - the convective heat transfer coefficient; T_s - the average vehicle interior temperature, which we consider to be constant in relation to the ratio of the air mass and the weight of the vehicle interior material.

The average value of the convective heat transfer coefficient was chosen α = 5 W / m^{2}K.

4. Model for Moisture Balance

When arranging the moisture balance model, it is necessary to consider all factors influencing the humidity increase in the vehicle interior. The most important producer of humidity is human. The individual factors are shown in Fig. 3. The optimum humidity of the environment for humans is 55 to 60% [5].

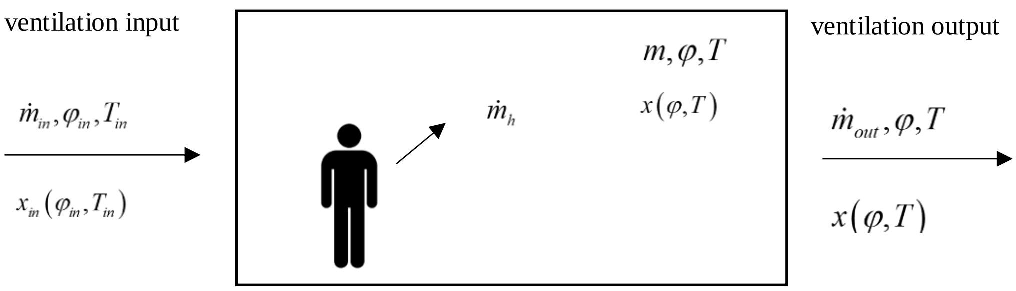

Fig. 3 Schematic of the moisture balance in a vehicle cabin system

Where m - the mass of the air in the vehicle; φ - the relative humidity in the vehicle; T - the temperature in the vehicle; φ_{in} - the relative humidity of the inlet; $\dot{m}_{in} = \dot{m}_{out}$ is the mass flow rate by the ventilation; $\dot{m}_h$ is the mass flow rate of water produced by the human body; T_{in} is the inlet air temperature; $T_{out} = T$ is the air temperature at the outlet.

Due to the mass balance of the water, it is necessary to express the specific humidity x as a mass of moisture per 1 kg of dry air.

When fresh air from the environment is brought into the vehicle cabin with a certain humidity and temperature, the interior of the vehicle is primarily influenced by the crew that has an influence on the humidity inside the vehicle.

Table 1

Water balance in the human body [4]

	Water gain [l/day].		Water loos [l/day].	
Totals	Food and drink	2,2	Skin	0,9
			Lungs	
	Metabolism	0,3	Urine	1,5
			Feces	0,1
		2,5		**2,5**

System of insensitive loss of water from the body. If we consider these losses, it is a daily loss of 900 ml of exhaled air, 300 ml of which diffuses daily with epithelial cells, and 300 ml of water per day is excreted through the lungs. Individual water leaks are shown in Table 1. 300 ml of water is released daily from the skin surface [2].

The increase in moist air humidity in the vehicle cab is through the surface of the human skin and the exhalation of persons in the interior of the vehicle. At the exit, the air from the vehicle cab is drained off the cabin and then replaced with fresh air again. The moisture balance in the interior of the vehicle cabin (Fig. 3) is expressed by means of specific humidities as:

$$\dot{m}_{in}\left(x_{in}-x\right)+\dot{m}_h i_p=\frac{dx}{d\tau}m\,, \tag{10}$$

where x_{in} - the specific humidity of incoming air; x - the specific humidity inside the vehicle.

The specific humidity is given by the recalculation from the relative humidity [1] by:

$$x=0.622\frac{\varphi p_p''}{p-\varphi p_p''}\,, \tag{11}$$

where p_p'' is the pressure of water saturation at temperature T; p - the barometric pressure; φ - the relative humidity of moist air.

The pressure of saturated water vapor is a function of temperature. This dependence is expressed in the following general approximation, which will need to be expressed using steam tables.

$$p_p''=f\left(T\right). \tag{12}$$

Air humidity in the vehicle cabin increases with the surface of the human skin and number of exhaled persons in the vehicle interior. The air from the vehicle cab is drained off the cabin and then replaced with fresh air by ventilation. By rearranging the Eq. (10), we can obtain the time course of the specific humidity in the vehicle:

$$\frac{dx}{d\tau}=\frac{\left(x_{in}-x\right)\dot{m}_{in}+m_h i_p}{m}\,. \tag{13}$$

Since the measuring instruments measure the relative humidity, it is necessary to determine the relative humidity of the air in accordance with the experiment from the calculated specific humidity values:

$$\varphi=\frac{x}{x+0.622}\frac{p}{p_p''}\,. \tag{14}$$

From the above, a mathematical model for relative humidity in the vehicle cabin can be determined.

5. Verification by Using Measuring Devices

A TESTO 435 heat and humidity measuring device was used to verify the MATLAB mathematical model. TESTO 410-2 air flow rate sensing equipment was used to determine the input flow mass flow of the ventilator. The measurement was carried out in a passenger vehicle, when four persons were driven into the outgoing vehicle, is with optimal values, the vehicle was in motion for 10 minutes. TESTO 435 and TESTO 410-2 were used during the journey.

The development of the values can be seen in Fig. 4.

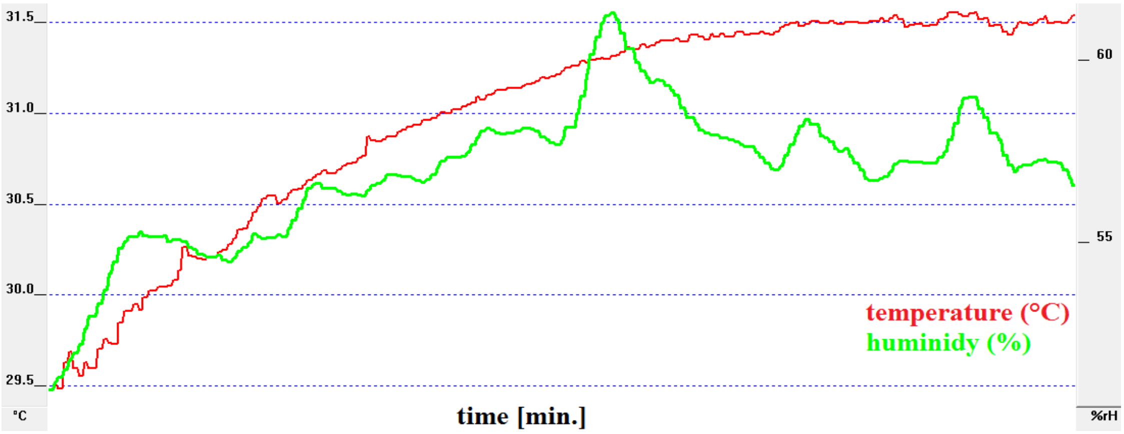

Fig. 4 Evolution of temperature and humidity in the vehicle cabin

The result of the measurement is the resulting graph, which records the increase in values in the vehicle cabin. These are 4 people sitting in the vehicle cabin without a fan running. During the measurement, the lowest humidity value in the vehicle cabin (purple curve) was 50.954% and the highest value during the measurement was 61.287%.

When monitoring humidity, the temperature development (blue curve) in the vehicle cab was monitored, with the lowest measured value being 29.5°C and the highest measured value being 31.5°C.

6. Discussion and Conclusion

The proposed calculation will then be solved by modelling the amount of humidity and the temperature level in the vehicle cab simulates the different types of occupancy of vehicles in different situations. Thanks to this model, it is possible to observe the possible development of temperature and humidity in the vehicle cabin, which can be verified by real measurements in normal operation. Modulation allows you to edit all selected values.

From this modelling, it is possible to monitor the situation where the limits of permitted values in the vehicle could be exceeded. Using this model, it is possible to design sufficient fan power to develop the vehicle or provide other room ventilation options. High temperatures and humidity affect the driver's fatigue, and the driver's safety breaks can be properly planned thanks to the proposed model.

The research follows the monitoring of the concentration of CO_2 in the interior of the vehicle, when the complex modelling will monitor the dependence between CO_2 concentration, temperature and humidity in the vehicle cabin. This development will then evaluate to what extent it negatively affects the crew.

Acknowledgement

The presented paper has been prepared with the support of the Ministry of Defence of the Czech Republic, Partial Project for Institutional Development, K-202, Department of Combat and Special Vehicles, University of Defence, Brno.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Study of Railway Transport Using Correlation and Regression Analysis

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Abstract

The determination of railway capacity is an important condition for the realization of rail transport. The aim of this study is to determine the relationship between railway capacity and factors related to transportation. Certain factors are determined for the research of the capacity, as: length between stations, travel time on passenger trains, ratio between numbers of passenger and freight trains, ratio between time travels of passenger and freight trains, coefficient of non-identity between the stations. In this research is examined the case study of the capacity of railway lines within the railway network of the Republic of Macedonia. Correlation and regression analysis is applied in order to examine linear and nonlinear, single and multi-factor dependencies. As a result is obtained regression dependencies that could be used for preliminary assessment and forecasting of the capacity for rehabilitation of the railway, the introduction of new types of rolling stock, and in the design of new railway lines during repair and restoration work on railroads.
KEY WORDS: *railway transport, train, correlation, regression analysis*

1. Introduction

The development of rail transport services depends on the state of the railway infrastructure and the rolling stock, which influences of the transport capacity. The goal of capacity analysis is to determine the maximum number of trains that would be able to operate on a given railway infrastructure during a specific time interval, and the operational conditions. The capacity of a given operational element of the railway infrastructure is determined by the period of movement of one, pair or group of trains in a restricted section. Capacity is defined as: maximum (theoretical capacity) - one that can be realized with certain technical equipment, organization of movement and technology; necessary - one that must be realized to implement predictive traffic volumes, and available - one that is implemented in the existing transport technology. The maximum capacity per day is a major factor in planning, operations and management decision processes. It is therefore a necessary instrument by which can be quickly and accurately analyzed depending on the operating restricted conditions.

Some of the fundamental factors affecting capacity are infrastructure, traffic, and operating factors. The infrastructure parameters are: block and signaling system, single/double tracks, definition of lines, routes, network effects, track structure and speed limits, as well as the length of the sections. The traffic parameters are: train category, timetables, peak period, and priority. The operating parameters are: track interruptions, train stop time, time travel, speed difference between train services, time windows, market demand and quality of service, reliability, and reliability and delay acceptance of railway customers.

Numerous approaches and tools have been developed to solve the problem of determining railway capacity. The most relevant methods can be classified in three levels: analytical methods, optimization methods, and simulation methods. Examples of analytical methods have been presented in several studies [1-3]. One of the most recent references regarding railway capacity involves approach [4] which have been developed to calculate theoretical capacity ("absolute capacity") for railway lines and networks. In [5] the main factors that influence railway capacity for Spanish railway infrastructures have been studied. The optimization methods for evaluating railway capacity are based on obtaining optimal timetables. The International Union of Railways (UIC) proposes a new method [6-8], which is included in the framework of the optimization methods (UIC, 2004, [8]), and is also based on a timetable filling method. By modifying the base timetable, existing train paths are scheduled as close as possible to each other. Modifying the travel times, the overtaking, the crossings, and the commercial stops is prohibited during the process of filling. In [9-13] the relatively new UIC 406 method for calculating capacity consumption on railway lines is described. This method is applied for railway network in Denmark. A simulation method is the imitation of an operation of a real-world process or system over time. The simulations methods was elaborated in [14, 15]. A model called Strategic Capacity Analysis for Network (SCAN) was developed in [15], which defined factors at different levels of detail that together determined the capacity of a network.

The most scientific studies do not investigated regression dependencies to determine the capacity of the rail tracks. In [16] regression models are composed to determine the capacity of one-way and two-way rail tracks depending on restricted section and the average speed of a freight train. In [17], a research has been conducted through the enforcement of regression and correlation analysis of the railway network of Bulgaria by considering various operational factors.

The aim of this study is to investigate the relationship between maximum capacity and factors relevant to transportation. The case study is for the rail network in the Republic of Macedonia.

2. Methodological Approach

The maximum capacity of a railway section or line is determined by the number of trains per hour that can be operated on a railway line. The maximum capacity shall be determined for the restricted section, i.e. what has the greatest period of the schedule adopted by the default timetable of passing trains.

In homogeneous timetable, the maximum train capacity is determined by the formula, [16]:

$$N_{max}^{ho} = \frac{\left(1440 - T_T\right)}{T_P}.k \text{ , number of trains (pair of trains)/day,} \quad (1)$$

here k - is the number of trains in the timetable period T_P, when k = 2 the maximum capacity is determined in train/day, when k = 1 is determined by pair of trains/day; T_P - is the timetable period. This period is determined for the main categories of trains that run in the restricted section ensuring safety of the movement. It depends on the time travel of trains from the main category, station intervals, accelerations and train stops at the stations; T_T - is the time that is not related to train movements and it is used for the repair or other activities that are not related to the movement of trains.

In the heterogeneous timetable, the maximum train capacity can be determined by the formula:

$$N_{max}^{he} = \frac{\left(1440 - T_T\right)}{T_P}.k.\eta \text{ , number of trains (pair of trains)/day,} \quad (2)$$

here η is the maximum utilization coefficient of the restricted section, depending on the factors of the movement, speed of trains, number of trains in different categories and other factors. It could be assumed that η = 0,95.

In this research have been studied the relationship between capacity and factors affecting the transport resistance.

The transport resistance is formed as a set of parameters that limit the capacity of the railway infrastructure, such as:

- Restricted interstation. This is section between two stations of the observed rail line, which has a maximum period of the timetable. The restricted interstation is presented by its length - L, km;
- Period of the timetable in the restricted interstation – T_P, min;
- Travel time of the main category of trains in railway line - T, min. The main category of trains is that for which there are the most trains.
- Ratio of non-identity between stations:

$$J_i = \frac{L_{Pi}}{\sum_{i=1}^{n} L_{Pi} \Big/ n} \quad (3)$$

here, $i=1,\ldots,n$ is the number of the rail sections, in this case are 14; L_{Pi} is the length of restricted interstation for the i-th section.

- Ratio of travel time of passenger trains to travel time of freight trains at the restricted interstation - $T^{PT}\big/T^{FT}$;
- Ratio of the number of passenger trains to the number of freight trains at the restricted interstation - $N^{PT}\big/N^{FT}$.

To solve the studied problem, we are using the methods of mathematical statistics - correlation and regression analysis. The development of a statistical model is related with the determination of the relationship between capacity and a group of factors. The approximation is done by linear and non-linear functions, using single-factor, two-factor and multi-factor dependences, [18].

3. Case Study for Macedonia's Railway Network

The railway infrastructure in the Republic of Macedonia is composed of 1435 km (standard European size), tracks with a total length of 925 km, of which 315 km are electrified. Fig. 1 shows a scheme of the railway network.

The railway network of the Republic of Macedonia consists of the following railroads, Fig. 1:

- Serbian Border - Tabanovce - Kumanovo - Skopje - Veles - Gradsko - Gevgelija – Greece border. This railway line is part of the European railway corridor X and is the only electrified railway in the Republic of Macedonia.
- Kumanovo - Beljakovce. Is envisaged construction of the railway lines to the Kriva Palanka and the border with Bulgaria and is part of the European Rail Corridor VIII.
- Urban - Shivets.
- Kosovo border - Volkovo – Skopje.
- Skopje - Tetovo - Gostivar - Zayas - Kitchevo. Along this line provides complete to Ohrid, Struga and the border with Albania and it is a part of the European rail corridor VIII.
- Zayas - Taimiste.
- Veles - Prilep – Bakrno Gumno - Bitola - Kremenica - border with Greece. This railway line is part of the European rail corridor X.

- Bakrno Gumno - Sopotnista.
- Veles – Ovce Pole - Stip - Kocani.

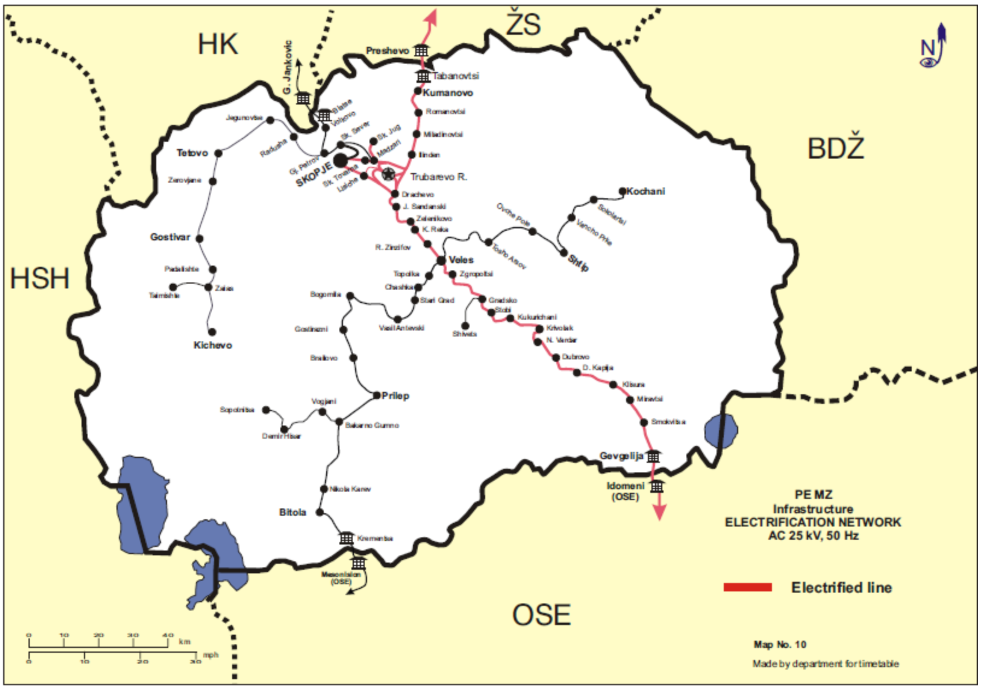

Fig. 1 Scheme of the railway network of the Republic of Macedonia, according to [19]

The railway network runs the following trains:

- International. These are trains that serve two or more railway countries. The composition of the train has sleeping cars.
- Inter City. These are international trains connecting major European centers and have fewer stops than the international trains.
- Inter-regional expression. They are trains for domestic traffic (domestic traffic) with compulsory reservation, stopping at major cities.
- Inter-regional. These are fast trains to domestic traffic serving several regions. They have a large number of stops in comparison to the inter-regional express trains.
- Regional. These trains operate in one region of the country and are served on electromotor or diesel engine power trains.
- Quick. These trains are for internal communication and connect the main cities.
- Passenger.
- Local passenger trains.

The main sections by which range the different categories of passenger trains are: Tabanovci - Skopje, Skopje - Veles, Veles - Gevgelia, Veles - Kocani, Veles - Bitola. Fig. 2 shows the percentage distribution of passenger trains per sections of the railway network of the Republic of Macedonia.

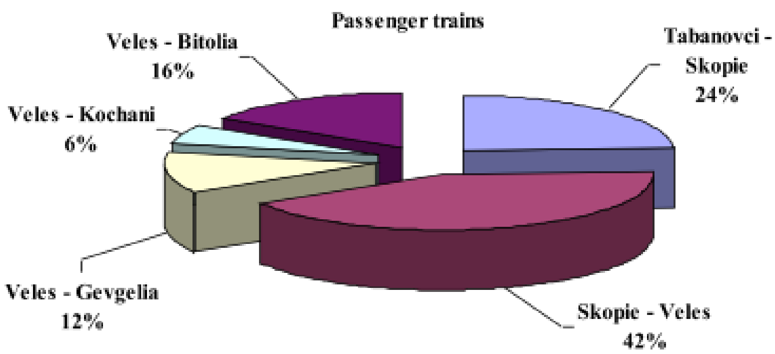

Fig. 2 Percentage distribution of passenger trains per sections

The freight trains are moving after prior consultation with shippers. The main directions in which freight trains run are: Tabanovci - Trubarevo, Trubarevo - Veles, Veles - Gevgelia. In sections Veles-Kochani and Veles-Bitolia, the number of freight trains is very small during the year and they run on an occasional basis. Fig. 3 shows the percentage distribution of freight trains within the main sections of the railway network of the Republic of Macedonia.

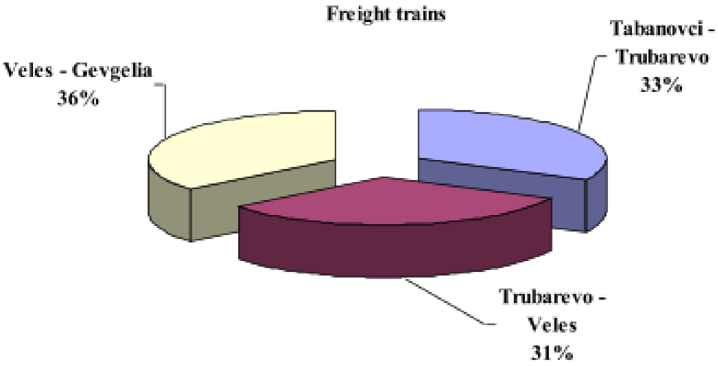

Fig. 3 Distribution of freight trains per sections

Fig. 4 shows the distribution of passenger and freight trains within the main sections of the railway network of the Republic of Macedonia. Section Veles - Gevgelija is characterized by intensive freight traffic, while the remaining sections are characterized by passenger trains primarily.

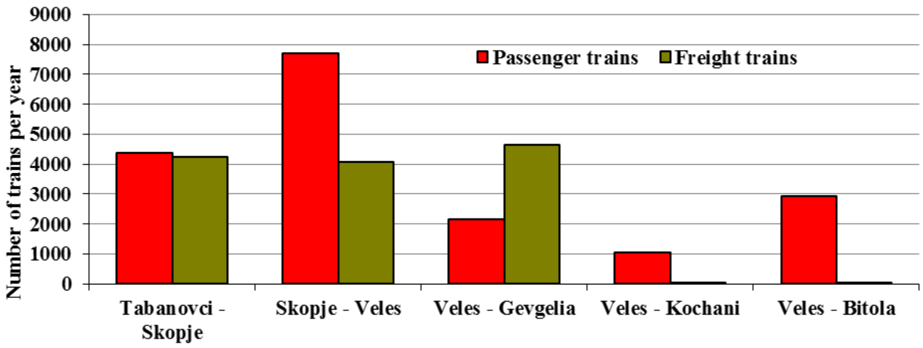

Fig. 4 Ratio of passenger and freight trains on the main sections of the railway network of Macedonia

4. Results and Discussion

The research to establish the analytical relationship between maximum capacity and the factors examined was conducted by rail sections.

For the purposes of the study, the network of the Republic of Macedonia is divided into 14 sections. These are: Skopje – Volkovo; Skopje - Tetovo ; Tetovo - Gostivar ; Gostivar – Kitchevo; Skopje – Kumanovo; Skopje – Veles; Veles – Stip; Stip – Kocani; Veles - Bogomila ; Bogomila – Prilep; Prilep – Bitola; Veles – Negotino; Negotino - D.Kapija ; D.Kapija – Gevgelija. The sections are formed between stations that meet at least one of the following conditions: main railway stations with significant passenger and freight stream; junctions formed by the intersection of railways; terminal of the railway transport.

The main railway junctions are Skopje and Veles. Main stations with significant passenger and/or freight stream are Tetovo, Gostivar, Stip, Prilep, Bogomila, Negotino, D.Kapiya. Terminuses are Kicevo, Kumanovo, Gergely, Bitola, Kocani. Figs. 5 and 6 shows the parameters of passenger and freight transport in major railway stations in the Republic of Macedonia.

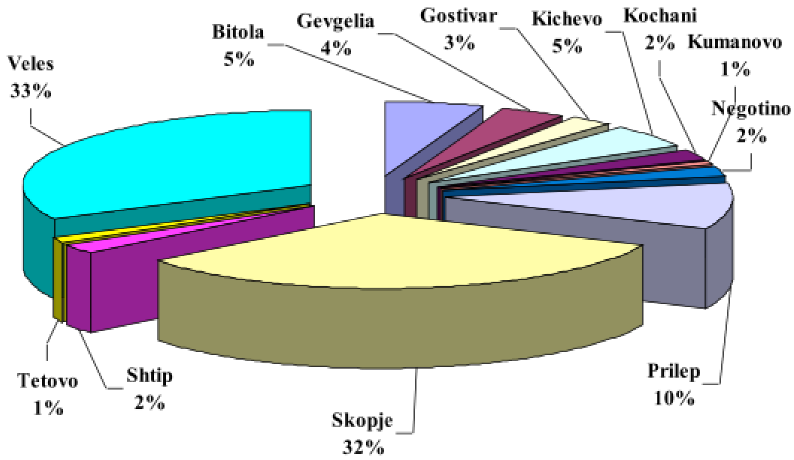

Fig. 5 Percent distribution of departed passengers from the main stations

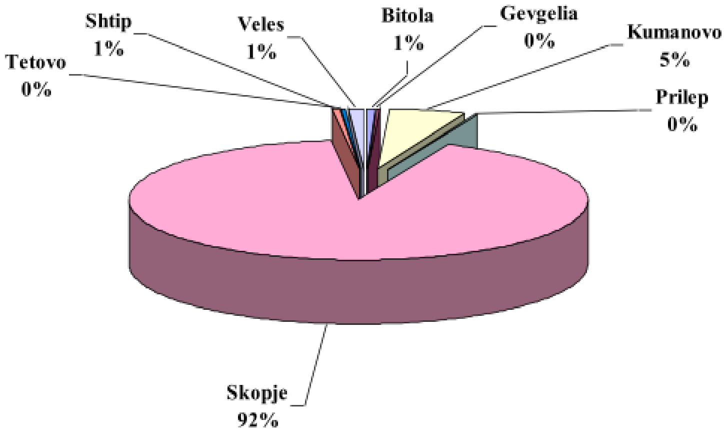

Fig. 6 Percent distribution of loaded tones from main stations

Table 1 presents the values of parameters for investigated sections. The main category of trains for Macedonia's railway network is the passenger trains. Therefore the period of timetable is determined for the passenger trains. In this research when defining the maximum train capacity by formulas (2) and (3), for the time that is not related to train movements is accepted that $T_T = 0$.

Table 1

Parameters of sections

Section	L, km	N^{PT}, train/day	N^{FT}, train/day	T^{PT}, min	T^{FT}, min	N^{he}_{max}, train/day	T^{PT}/T^{FT}	N^{PT}/N^{FT}	J_i	T_P, min
Skopje - Volkovo	11,5	2	1	8	10	58	0,800	2,00	1,110	25
Skopje - Tetovo	9,8	4	1	9	11	53	0,818	4,00	0,946	27
Tetovo-Gostivar	10,8	4	1	7	9	63	0,778	4,00	1,042	23
Gostivar-Kichevo	8,4	4	1	11	13	46	0,846	4,00	0,810	31
Skopje-Kumanovo	7,3	8	2	8	9	58	0,889	4,00	0,704	25
Skopje-Veles	10	18	12	9	10	53	0,900	1,50	0,965	27
Veles-Stip	11,5	2	1	14	15	39	0,933	2,00	1,110	37
Stip-Kochani	8	2	1	15	16	37	0,938	2,00	0,772	39
Veles-Bogomila	7,2	8	1	10	12	50	0,833	8,00	0,695	29
Bogomila-Prilep	10,2	8	1	11	13	46	0,846	8,00	0,984	31
Prilep-Bitola	9,6	8	1	7	9	63	0,778	8,00	0,926	23
Veles-Negotino	14,7	4	10	15	17	37	0,882	0,40	1,418	39
Negotino-D.Kapia	11,4	4	10	10	12	50	0,833	0,40	1,100	29
D.Kapia-Givgelija	14,7	4	10	12	14	44	0,857	0,40	1,418	33

Tables 2-4 show the results of regression models that have been investigated: single-factor, two-factor and multi-factor linear regression models. The comparisons are made according the coefficient of determination. The results show that for single-linear models the most important factor is the travel time of the passenger trains at the restricted interstation; the regression has a high coefficient of determination (over 0.9), Table 2. The factor period of restricted interstation T_P has coefficient of determination from 0,69 to 0,71, indicating a strong relationship with the train capacity. The factor ratio of travel time of passenger trains and travel time of freight trains in restricted interstation shows average connection with the train capacity. The coefficients of determination are in the range 0,55-0,6. The factors like length of restricted interstation, coefficient of non-identity of restricted interstation and the ratio of the number of passenger to freight trains have not a connection with the train capacity.

Table 3 shows investigated linear regression between two factors. The results presents that the main factors that determine the capacity are time travel of passenger trains in restricted interstation, the period of the timetable, the ratio of travel times of the passenger trains and freight trains in restricted interstation. Between traveling times of passenger trains T_{PT} in restricted interstation and the period Tp is linear dependence with a coefficient of linear correlation of 0.76. Due to the presence of multicollinearity between the two factors in the study of regression, dependencies with two or more factors will not take into account the factor period of restricted section Tp.

Table 4 shows the results of multi-factor linear regression correlation. Most variants show functional relationship between the factors and train capacity, with a correlation coefficient of 0,96.

Due to the high value of the coefficient of determination, nonlinear models have not been studied. The SPSS software (Statistical Package for Social Science) is used to make research. The highest coefficient of determination (0,99) is at a polynomial model with the factor of time travel of passenger trains in the restricted interstation. A comparable model, featuring a simplified form of the equation, is the linear model with the similar coefficient of determination (0.96). In Table 5 is presented the regression equation.

Table 2

Single-linear regression

№	Type of function		Factors Coefficient of determination R^2					
	y is the dependent variable; x is the factor		L	J	T_{PT}	N^{PT}/N^{FT}	T^{PT}/T^{FT}	T_P
1	Linear	$y = a + bx$	0,09	0,08	0,96	0,17	0,55	0,69
2	Exponential	$y = \exp(a + bx)$	0,11	0,09	0,97	0,18	0,56	0,70
3	Reciprocal regarding to y	$y = \frac{1}{a + bx}$	0,11	0,09	0,97	0,18	0,56	0,73
4	Reciprocal regarding to x	$y = a + \frac{b}{x}$	0,06	0,09	0,95	0,19	0,57	0,76
5	Logarithmic	$y = a + \ln x$	0,02	0,06	0,93	0,23	0,56	0,70
6	Grading	$y = ax^b$	0,04	0,07	0,92	0,21	0,56	0,70
7	Square root by x	$y = a + b\sqrt{x}$	0,11	0,08	0,93	0,17	0,57	0,74
9	Square root by y	$y = b\sqrt{x}$	0,11	0,08	0,92	0,17	0,57	0,71
9	Polynomial of second degree	$y = a + bx + cx^2$	0,30	0,21	0,99	0,30	0,60	0,71

Table 3

Linear regression between two factors

	T_{PT}, N^{PT}/N^{FT}	T_{PT}, T^{PT}/T^{FT}	J, T^{PT}/T^{FT}	J, N^{PT}/N^{FT}	T_{PT}, J	T^{PT}/T^{FT}, N^{PT}/N^{FT}
Coefficient of determination R^2	0,96	0,96	0,65	0,17	0,96	0,57
Standard error	1,69	1,70	5,6	8,69	1,96	6,25

Table 4

Multi-factor linear regression

Factors	T_{PT}, T^{PT}/T^{FT}, N^{PT}/N^{FT}	T_{PT}, J, T^{PT}/T^{FT}	J, T^{PT}/T^{FT}, N^{PT}/N^{FT}	T_{PT}, J, N^{PT}/N^{FT}	J, T_{PT}, N^{PT}/N^{FT}, T^{PT}/T^{FT}
Coefficient of determination R^2	0,96	0,96	0,67	0,96	0,96
Standard error	1,76	1,77	5,76	1,77	1,85

Table 5

Regression equations

Function	Regression	
Linear	$N_{\max} = 82{,}8299 - 3{,}1686.T^{PT}$, number of trains./day	R-squared = 96,82 % % Standard Error of Estimate = 1.64 Mean absolute error = 1.38

Fig. 7 shows a comparison of the number of trains available for the studied sections and the maximum theoretical capacity. All sections have reserve of capacity.

Fig. 8 presents a comparison of the empirical and theoretical values of the capacity of railway lines for the investigated railway sections for linear model with the factor time travel of passenger trains in restricted interstation. In the figure is also presented a forecast of 10% reduction of the travel time of passenger trains in restricted interstation to a capacity. In this case, the capacity increases to an average of 7%.

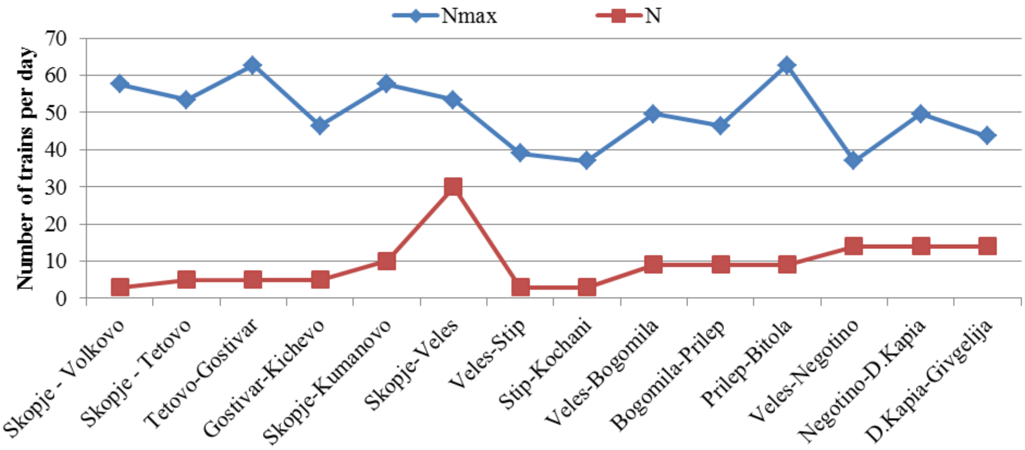

Fig. 7 Comparison of the available number of trains and the maximum capacity

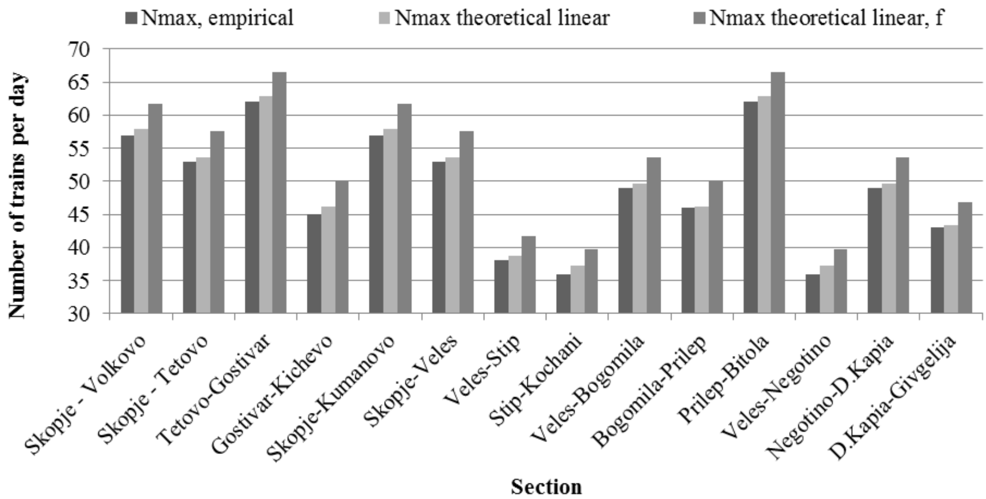

Fig. 8 Comparison of empirical, theoretical values of capacity for linear regression and forecast at 10% reduction of travel time on passenger trains in restricted interstation

5. Conclusion

- In the present study has been developed a complex analysis of capacity for the railways of the Republic of Macedonia. 14 section of Macedonia's railway network have been analyzed.
- The factors of the transport resistance have been investigated to establish regression dependencies with capacity of railway lines.
- In the paper have been studied single-factor, two-factor and multi-factor linear dependences. The linear regression models with two factors show functional dependence and equality of influence between both factors the travel time of passenger trains and the ratio of number of passenger trains and freight trains at the restricted interstation; both factors the travel time of passenger trains and the ratio of travel time of passenger trains to travel time of freight trains at the restricted interstation; both factors the travel time of passenger trains at the restricted interstation and the ratio of non-identity between stations. The multi-factor linear regression models demonstrate high dependence in the factors studied.
- It was found that the main factor that affects the capacity of the railways is the travel time of passenger trains in restricted interstation.
- The resulting regression dependencies for determining the maximum capacity allow as to quickly and accurately testing possible modifications to the organization of transport in different technological solutions.
- The resulting regression dependencies can be used to predict the maximum capacity under the changes in factors of transport resistance. The established regression models may be used for preliminary assessment and forecasting of the capacity for rehabilitation of the railway, the introduction of new types of rolling stock, and in the design of new railway lines during repair and renovation work on railroads.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Research of Passenger's Demand for Travel Companion as the Part of Sustainable Transport Solutions

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Abstract

This paper describes research of passengers demands for travel companion, in particular this paper describes one of the steps, ethnographic workshops, which were used to identify and describe passenger's demand for a travel companion and any regional differences. The paper contains results which were obtained as part of the EC funded H2020 project - 730842 Governance of the Interoperability Framework for Rail and Intermodal Mobility (GoF4R). The main objective of the GOF4R project is to define sustainable governance for the Interoperability Framework semantic technologies that are being developed under the IP4 Shift2Rail programme.
KEY WORDS: *sustainable transport, travel companion, passenger´s demand, travel services*

1. Introduction

One of the possible methods to develop a sustainable passenger transport solution is through continuous innovation and development of multimodal travel services. Passengers require access to a lot of information to prepare and manage their multimodal trip by public transport. Many of carriers offer online applications for journey planning, online ticketing, additional information, post trip info, and communication in case of problem [5, 6]. These applications are generally not compatible with each other, and therefore it is not possible to use them across all kinds of transport and for all multimodal trips. One solution to increase the attractiveness of public transport is the creation of the one application (Travel Companion) which is able to access all relevant data needed for optimal planning of a trip [3].

This research consists of analyses of the user's interaction points with the travel companion through interviews and workshops. Every step of this methodology brings interesting feedback on the design and functionality of the travel companion. Paper describes in detail the ethnographic workshops.

2. Methodology of Ethnographic Workshops

In order to collect further information on factors that could influence the uptake and use of the Travel Companion (TC) and also to detect possible cultural / ethnographic differences (East/South/West-Europe), five workshops were organised – in Gent (Belgium), Žilina (Slovakia), Milano (Italy), Brno (Czech Republic) and in Bratislava (Slovakia). The number of participants in each workshop ranged from 12 to 28. All of the workshops were organised from 30 October until 22 November 2017.

To ensure basic information, uniformity and comparability of results, workshop guidelines were developed including tips on how to select participants, how to organise the workshop, themes to be addressed, workshop methods to be used and reporting instructions [7].

The target number of participants was 15 - 20 per workshop. Participants were selected using the so-called 'purposive' or 'convenience' sampling methods. This focus group approach being a qualitative methodology, does not aim at providing results that describe how an entire population would respond to the same questions, but aims to achieve a better understanding of how users relate with a certain topic, through a discussion and a comparison between participants' personal attitudes towards the theme. In selecting participants to be invited to the workshop, attention was paid to the following criteria:

- Balance between men and women;
- Balance between younger and elderly people;
- Inclusion of at least one person with reduced mobility;
- Balance between experienced and non-experienced travellers;
- Balance between regular and non-frequent travellers;
- Balance between digital natives and digitally impaired travellers;
- Inclusion of people that travel for different purposes (business, leisure, other);

- Inclusion of people that travel both within their own country and outside their own country.

The workshops all lasted 2-3 hours and were held in the local language. The workshops all followed a similar structure:

- Introduction;
- First round: discussion of three topics (preferences, travel related & non-travel related information, disruption & feedback) using the World Café method;
- Second round: discussion on barriers and incentives to use the TC.

Each workshop started with a brief introduction of the GOF4R project, the workshop objectives and a description of the Travel Companion and its functionalities, followed by a short round of introductions and the participants becoming acquainted with each other (20 minutes in total). Then, the participants were divided into smaller groups.

During the first round of discussion (ca. 50 minutes), the World Café method was used to tackle three topics.

A "World Café" is a great way of fostering interaction and dialogue within large or small groups. It is particularly effective in drawing together the collective wisdom of large groups of diverse people. The format is very flexible and adapts to many different purposes – information sharing, relationship building, deep reflection, exploration and action planning. The host begins by putting participants at ease. The process then consists of rounds of ca. 20 minutes of conversation for each smaller group on a specific question or item that needs to be explored and discussed. At the end of each round, everyone moves to another table. The moderator summarises after every change what was said in the previous group. One group continues on and further develops the findings of the previous group. Afterwards, insights gathered by each table are shared with the larger group and presented visually, for example by means of graphics [2, 4].

The three topics discussed during the first round in each workshop were:

1. Preferences

- Do you think that the ability to indicate their preferences will be considered by users as an incentive to use the Travel Companion and/or could it be a barrier? Please explain.
- Do you think more people would use the TC if it is not necessary to set preferences first?
- Which preferences do you think are most important?
- Do you think the Travel Companion should 'remember' preferences from previous choices the user has made when planning / booking a trip?

2. Travel related info vs. non-travel related info:

- Travellers especially need information on cost, travel/transfer time, travel modes and transfer points. Are any important items missing from this list? If so, what is missing?
- Is it useful that the Travel Companion provides non-transport related information too? If so, which are most relevant?
- The Travel Companion will be able to offer context-dependent information, based on the current location of the traveller (using the GPS and possibly the accelerometer in the user's smart device). Could this be a barrier for using the TC or do you think it will more likely be an incentive?
- Should users be able to communicate with other travellers on the same route (e.g. to find out where in the vehicle there are any free seats left)? Why (not)?

3. Disruption / feedback:

- Which kind of assistance should be offered by the Travel Companion in case of a disruption? (planning an alternative route, offering the possibility to 'buy' a new ticket, offer also non-transport related information e.g. on accommodation, food/drinks, …).
- Should the TC only communicate about how the journey is going in case of disruptions or also reassure the user during the journey if everything is going according to plan?
- What kind of information should the Travel Companion offer the user after the trip has finished? (e.g. lost property, how to file a complaint, information on passenger rights)
- Which options for on-going communication should be offered by the TC? (e.g. chat – social media – hotline – personal assistance – SMS – notifications on the TC)

In the second round of discussion (ca. 40 minutes), workshop participants were asked to discuss potential barriers for the use of the Travel Companion. They were presented with a map showing the most important barriers detected in the interviews (cf. above) and asked how might these barriers be removed [8].

In a final part (ca. 15 minutes), each group was asked to think about incentives to use the TC. Which functionalities / characteristics would they highlight? How would they try to reach certain target groups? Which communication channels would they use? What type of campaign would they propose? What are the main advantages of the TC compared with existing travel apps?

The following parts of this paper describes the ethnographic workshops organised across Europe and their key results.

3. Workshop in Žilina (Slovakia)

The ethnographic workshop in Žilina was the first from 3 workshops organized by UNIZA. The workshop was

held at the University of Žilina on November 7th (3-5:30PM) and was attended by 18 external participants. Participants have been divided into three groups according to their age. To each group one moderator has been assigned [1].

Preferences

All groups agreed that the possibility to indicate preferences is a great motivator for using the TC. Besides 'fixed' preferences, it should be possible to add or edit 'variable' preferences for each new search. Some participants mentioned that they would like to have several profiles each with its own preferences, according to reason for travelling, for instance school, work, vacation etc.

Indicating preferences could become a barrier, if it is too complicated or time-consuming. It should not be obliged; the TC should allow a fast search without the user having to indicate preferences, but in this case, more alternative connections with different characteristics (time, price, vehicle changes) must be shown. The TC should be able recommend one of these, based on general habits of travellers' behaviour.

The most important preferences mentioned in all groups were: mode of transport and minimising travelling time. The 18-25 age group considered that important preferences include minimising vehicle changes and choice of the place where to change the vehicle. The 30-40 age group also mentioned environmental impact as an important preference. The 45-60 age group required a barrier-free preference in vehicles and at stops, stations and terminals.

Faster search of connections should be based on remembered preferences from previous trips. However, some people (especially from the 45-60 age group) thought that users should be able to choose whether the TC 'remembers' previous preferences and search history or not.

Travel related vs. non-travel related info

All groups agreed that besides information on price, travelling time, mode of transport and transfers, they would like to be informed about seat occupancy. Two groups agreed that there must also be information about (history of) delays. The members of the 45-60 age group (including one person with reduced mobility) required information about barrier-free access and extraordinary events during travelling, facilities (e.g. toilets) in vehicles and at terminals, and information on when to get off the vehicle (especially when travelling for the first time or in case of a delay, night connection etc.).

Non-travel related information requirements were related with actual life needs. The 'youth' group required waiting rooms with sockets and Wi-Fi, the 'middle generation' group required waiting rooms with place for moms with children, while the 'older people' group required information about barrier-free access and facilities. Other non-travel related information that could be useful include contact information for ambulance and police services, taxi services, tourist offices, car and bike rental.

All three groups agreed that offering context-dependent information based on the current location of the traveller was positive and they thought that it is a motivator for using the TC.

The possibility of communicating with other travellers on the same route was agreed by all three groups, but only when travellers want to use it, e.g. it could be useful in order to find a free seat.

Disruption and feedback

All three groups agreed that the TC should, in case of extraordinary events, inform passengers about the causes of the event and expected duration (as early as possible, if possible before the journey has even started), offer information on alternative travel options and accommodation. All three groups also recommended that travellers should be able to choose whether they want to receive information during travel (e.g. on current location and time) even if there are no extraordinary events. Always, there must be information about vehicle changes and connections.

After finishing the trip, travellers should have the opportunity to evaluate the quality of travel. There must be also information about their rights and possibilities in case of complaints. On-going communication was preferred by the 'youth' group through chat and social networks. 'Middle age' group members required simple notifications in the application. The 45-60 age group also required language assistance when abroad and simple communication through a hotline or chat in the vehicle.

Barriers

At least two of the three groups identified these fields as key barriers for using the TC:

- personal information/preferences – time-consuming,
- information provided by TC – accuracy (real-time info, up-to-date),
- communication/feedback – bad support.

Other barriers were not agreed upon by all groups, but mentioned only once:

- personal information/preferences: privacy and security, flexibility (ease of change),
- information provided by TC - complexity, reliability of providers,
- payment/transaction: trust, cyber security, complexity,
- tool/app – complexity.

The following solutions were proposed during the workshop by the participants.

Personal information/preferences:

- Ensure a choice (in one click) from more predefined alternatives.
- Possibility to turn on/off autocomplete function.
- Possibility to repeat favourite travels.
- Possibility to have several accounts each with its own preferences and settings.
- Possibility to export and import all general user parameters to another device.

- Ensure login with password (or other means, for ex. finger print). Without login, the application should only function as a timetable without personal information and preferences.

Info provided by TC:

- Ensure updates / notifications about changes the user wants to be informed about.
- Ensure monitoring the device through GPS.
- Contractually ensure reliable information from transport companies and infrastructure managers. In case of infraction (e.g. providers who – intentionally – provide false information): penalty or exclusion from the TC
- Possibility to customise the application – show only information that is interesting for the user.

Communication/feedback – bad support:

- Ensure language assistance abroad, include as many operators as possible in the system and connect to IT systems of transport companies.
- Ensure wireless internet on the whole transport infrastructure and in all towns and villages.

Payment/transaction:

- Using electronic wallet, buying credit to the application, possibility to disconnect the application with bank account or credit card.
- Covering payments and information about realised payments by independent company (similar to PayPal).

Tool/app – complexity:

- Create a campaign explaining all features in the TC application to potential customers.
- Ensure intuitive setting of basic parameters and exclude contradicting settings.

Incentives

There was a consensus among all groups that the main advantage of the TC compared to other travel apps is that it is a complex system that considers all modes of transport. Other important advantages of the TC approach, mentioned during the workshop, included:

- tickets can be bought quickly, personalisation of travel, reliability, information about transport situation in real-time, information about extraordinary events in real-time, access to additional information (accommodation, restaurant services, tourist office etc.) (18-25 age group)
- simplicity of use, complexity of information, minimises stress during vehicle changes, offers non-travel related information, up-to-date info on extraordinary events, saves the user time and money (30-40 age group)
- complexity of information, saving time, certainty of finding the best connection based on actual information, TC will be available 24/7, can be customised by users according to their own preferences (45-65 age group).

The 18-25 age group would promote the TC through live presentations, advertisements in social networks, a video presentation on how to use the application (e.g. on YouTube), information about vehicles and transport companies, possibility to use free trial version.

The 30-40 age group preferred personal contact in marketing activities, examples in vehicles, information in mass media, timetables, stations and stops. For marketing activities, they will use places in schools, stations and vehicles. Persuading should be based on personal experiences (if you don't believe me, I will show you).

The 45-65 age group preferred advertisement in vehicles, stations and mass media. Marketing activities should be based on experiences of psychologists with all generations – the campaign should be educational, not promotional. There should be QR codes in vehicles and stations, which recommend the application to travellers in case of some problems during travel. The marketing strategy should be based on coevals for personal presentation in schools and also houses for seniors. Very popular solutions also included seminars provided by independent organisations, government of villages and towns.

4. Workshop in Brno (Czech Republic)

The second workshop was organised by University of Žilina and Masaryk University and was held at Masaryk University in Brno on November 20th (3-5:30PM). The workshop was attended by 12 external participants. Participants have been divided into three groups according to their gender. To each group one moderator has been assigned [1].

Preferences

Most participants considered indicating preferences as an advantage and a motivator for using the TC. They would favour indicating preferences and creating an account at the first use of the TC. The system should remember preferences, but next usages of the application should allow users to edit their requirements according to actual conditions. A minority of participants would like to have a simple application that does not require indicating preferences. The application should find many alternative connections and recommend one of them.

The most important preferences according to all groups were: price, duration, mode of transport. There was no agreement on preferences like environmental impact, Wi-Fi, socket, wagon class etc.

Travel related vs. non-travel related info

Besides price, travel time, mode of transport and vehicle changes, the following information could also be useful: luggage, travelling with pets, on-board catering, waiting time, terminals navigation and visualisation, equipment of vehicles (comfort), (average) delays, PRM facilities, actual speed and location of vehicles, bike transport, internet connection, location of reserved seats.

All three groups agreed that non-travel related information should be about possibilities for passing time in

terminals adapted to the type / profile of the passenger (student, mum with children, PRM etc.). Other requirements were: accommodation, local tourist attractions, information offices, ATMs, exchange office, opening hours, police and ambulance services, reviews of other passengers on each transport company or terminal.

All three groups agreed that context-dependent information based on the current location of the traveller is very useful and it is a motivator for using TC. They suggested that this function should be optional (GPS module activated for a limited time, otherwise risk of empty battery)

Communication with other passengers on the same route is considered unnecessary by most participants. One group suggested to make this optional because people could use it to solve problems during the travel.

Disruption and feedback

All three groups agreed that the TC should inform passengers during extraordinary events about cause of the event, duration, alternatives for travel, accommodation and restaurant services. The majority of respondents recommended that receiving information during travel when there are no extraordinary events should be optional.

After the travel, passengers should receive information about their passenger rights, how to find lost property, how to file complaints, how to contact the transport service provider. Passengers also want to have an opportunity to write a review of the transport company and the terminal. There was disagreement about on-going communication. Suggested methods of communication with the transport service provider include: personal contact in the vehicle, a phone hotline, SMS, social networks, QR codes in vehicles and at stations.

Barriers

All three groups agreed that the most important barrier is the complexity of the tool/app.

At least two groups considered these barriers:

- info provided by TC – reliability (are all options integrated),
- info provided by TC – accuracy (real-time info, up-to-date),
- payment/transaction – (cyber) security.

These barriers were considered only once:

- personal information/preferences – time-consuming,
- personal information/preferences – privacy and security,
- info provided by TC – transparency (options you get),
- payment/transaction – trust.

The following solutions were proposed during the workshop by the participants:

Personal information/preferences:

- Require login and password when using the full version of the TC.
- Basic version should be quick and without any preference indication.

Information provided by TC:

- Information should be added only by transport companies or other stakeholders impacting transport or extraordinary events solving. Local time zone on route must be mentioned.
- Ensure update of the app based on user requirements, when the content is changed regularly.
- Ensure participation of all transport companies. Ensure online automatic updating.
- Ensure user reviews for noticing mistakes.

Payment/transaction:

- Always require authorisation code for example through phone, not only credit card number. The application should not remember the credit card number.
- Covering payments by independent organisation (similar as PayPal), ensure detection if the payment was successful.

Tool/app – complexity:

- Make a structure of the application by the process of development, consult graphics and design with potential customers, ensure intuitive and chronological use of the TC.
- The TC should not require much writing of text, using click is better choice.
- Simple colours are recommended for clarity.
- Advertisement should not cover data.
- Output of the application must be simple with possibility to click for more details.
- The application should not allow contradictory requirements. Use history of using the icons – most used icons should be first.
- Basic version of TC should be simple and easy and quick to use.

Incentives

All groups agreed that overall, the main advantage of the TC compared to other apps is that it covers all modes of transport, and that its information is reliable and up-to-date. The main advantages mentioned during the workshop included:

- (group 1) all information together in one application, simple usage, more alternative connections, online support during travel, reliability, actual information
- (group 2) clarity, actual information, reliability, optimisation of price, optimisation of travel, complex information together in one application, less stress in case of extraordinary events, elimination of language barriers

- (group 3) complexity, multimodality, simplicity of use, reliability, information about international connections, connectivity with information systems of transport companies, more alternatives according to personal preferences, actual data, possibility to buy tickets.

The TC approach could be promoted by means of billboards, social networks, personal meetings and presentations (by coevals), leaflets distributed via transport companies, information offices, advertisement in newspapers and magazines, tourist and accommodation websites, videos on YouTube, … TC users could be offered a discount for travelling. Propagation should be ensured by transport companies (ticket stores, back side of ticket). The TC should be installed in the mobile phones beforehand.

5. Workshop in Bratislava (Slovakia)

The third workshop was organised by UNIZA at the General Directorate of Slovak Railway in Bratislava (monthly meeting of Slovak Science and Technical Society for Transport Bratislava) on November 22nd (4:30-6PM) [1]. Firstly, participants have been introduced to the Shift2Rail programme, GoF4R project and to the objectives and functionalities of Travel Companion through a brief presentation about the technological tool.

Participants stay in one group with two moderators, because participants were older people and this methodology was better for moderating the workshop. The workshop was attended by 18 external participants (mainly 65+). Discussion were step by step, topic by topic. Respondents were very interested by theme, they tried to understand the problematic and help with showing their opinions.

Preferences

More than 80% of the participants preferred the TC without indicating preferences – the TC should suggest travel alternatives, then the user will choose one of these alternatives, which is most suitable. All participants agreed that indicating preferences should be voluntary and optional.

The TC should offer a broad range of alternative connections, while one of these alternatives would be recommended according to general behaviour of passengers. The user should be able to sort alternative routes based on different criteria, for instance: duration, price, vehicle changes etc. Users could choose using the TC with or without indicating preferences for a quick search.

Group members considered that the most important preferences / personal characteristics are:

- Gender,
- Health condition,
- Restrictions.

The TC should remember at least approx. 5 journeys or the most frequent journeys of travellers. This would quicken using TC therefore this application would be more attractive for users.

Travel related vs. non-travel related info

Besides information like price, travel time, mode of transport, vehicle changes, other information considered useful are also operator and carrier, waiting time, congestions, next connections and terminals navigation.

Non-travel related info: If possible, participants would like info about accommodation, restaurant services, ATMs and exchanges in transport hubs, local tourist attractions and tourist offices.

Offering context-dependent information based on the current location of the traveller can be positive and it is a motivator for using the TC. It must be only optional though; some people might object because of privacy concerns (‘big brother is watching’).

Communication with other travellers on the same route should be an optional function. People could use it for solving problems during travel or to chat with others travellers.

Disruption and feedback

Respondents would require these types of assistance in case of disruption (extraordinary events):

- alternative routes,
- alternative connection,
- alternative transport modes,
- information about delay,
- information about accommodation, restaurants etc.

Workshop members did not agree on receiving information from the TC when the travel is without any extraordinary events. Only one member wanted it in some periodic time (every half hour). Other members wanted it only as optional possibility.

After the travel, passengers should receive information about the quality of transportation, how to file complaints and final cost calculation.

Persons preferred on-going communication with audio communication (non-stop hotline) or live communication with operator’s employees. They did not consider using SMS and QR codes, because they have problems to use small devices with small words.

Barriers

Participants defined a set of 3 main barriers:

- personal information/preferences – privacy and security,
- tool/app – complexity,

- info provided by TC – transparency (options you get).

Participants recommended these possibilities to eliminate barriers:

- Require login and password when using full version of the TC.
- Graphics of the TC should be modified into form, which affect that there is not much data required. Simple colours are recommended for clarity. Advertisement should not cover data. Output of the application must be simple with possibility to click for more details.
- Make a structure of the application by the process of development, consult graphics and design with potential customers, ensure intuitive and chronological use of the TC.

Incentives

Main advantages of the TC are: complexity – all information together in one application, simple usage, online support during travel in own language.

Persons preferred for propagation: personal meetings (for seniors), showing the positives and comparing with other applications. Materials should be distributed with logos of the transport companies. Marketing activities should be based on personal presentations of the application and free testing.

The TC should consist of all modes of transport, should be easy to use and to be on top of technological level.

7. Conclusions

Ethnographic workshops brought interesting and important information about passenger's requirements. One of the most interesting conclusions was that the differences between respondent's opinions based on countries are minimal. The biggest differences between requirements of passengers are based on age of respondents and IT skills. Younger respondents were more focused on complexity and connectivity of travel applications. However, they were less interested on the solutions to problems during the journey or safety and security of personal data. Older respondents were much more focused on problem solutions during travel and personal data security.

The data gathered from these ethnographic workshops has been further developed within the GoF4R project, to identify the key requirements of the end users.

Acknowledgement

The work on which this paper is based was supported by the European Commission, H2020 project - 730842 Governance of the Interoperability Framework for Rail and Intermodal Mobility (GoF4R).

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Methods of Image Processing in Thermographic Testing of Ballistic Composite Armors

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Abstract

In non-destructive thermographic testing, defect detection is carried out by means of image (thermogram) analysis. During tests, a sequence of thermograms consisting mainly of several hundred or more individual images is recorded. An effective analysis of such a large number of images without the use of appropriate algorithms is practically impossible. The algorithms used are mechanisms of increasing the signal/noise ratio and thereby increasing the efficiency of defect detection. An increase in the signal/noise ratio can be achieved by processing separate thermograms. This can be achieved by applying standard methods used in digital image processing, the main ones being: modification of scale of shades (change of histogram); choosing a colour palette; improvement of focus of thermograms; smoothing; separating boundaries of areas; morphological filtration; reconstruction of thermograms; subtraction and division of thermograms. However, in many cases, this is inadequate, and special image processing methods must be used. These methods are: thermal tomography; Fourier transform; wavelet analysis; reconstruction of a thermographic signal; normalization in dynamic thermography; principle components analysis; neural networks; data synthesis. This paper presents how helpful special methods of image processing can be in assessing damage caused by ballistic impacts in composite materials used in ballistic vehicular armor. Selected results from these analyses are presented.
KEY WORDS: *image processing, non-destructive testing, light armor, IR thermography*

1. Introduction

The dynamic development of composites in recent years has depended on two main factors - the first of them is primarily the low weight of the structure. The second factor is excellent mechanical and strength properties of the resulting structure being high tensile factors, impact resistance, energy dissipation, fire resistance, and rigidity of the structure. In military applications, there is great demand for composite ballistic armor which is widely used to protect people and vehicles, in particular, fiber-reinforced composites [1]. Fiber-reinforced composites are currently dominant in the market for composite materials due to their superior mechanical and strength characteristics combined with minimal weight. The working principle behind fiber composites is based on the transfer of load by different types of fibers. The matrix serves only as a binder for the fibers and as direct protection against external factors. In lightweight ballistic armor, fiber-reinforced composites usually come in the form of a laminate, the basic layer of which is formed by fiber bonded with resin. A laminate is a system of interconnected composite layers (usually with different parameters) appropriately oriented towards the direction of the main load, so as to use the optimal arrangement of individual layers. The basic fiber used in these composites is aramid fiber and to a lesser extent, carbon and glass fibers [2]. In recent years, research on the use of basalt fibers has also been carried out [3].

Lightweight ballistic armor is designed to provide protection for both human life and the vehicle itself against small-caliber projectiles, fragments, and various types of mechanical impacts. During penetration by the projectile, a complex state of stress occurs in composite armor whereby the buckled material is subjected to shear, tension, compression, and twisting caused by rotary movement of the projectile. The impact of the projectile causes two-phase destruction of the composite; in the first phase, a high-velocity, high-energy projectile strikes the composite causing destruction of the fibers and matrix in the outer layers. Then, as the velocity of the projectile diminishes, some of the energy is spent on the destruction (shearing) of the matrix, and fibers under the place of impact energy concentration are subject to stretching. Delamination occurs. Stretching causes a high degree of absorption of the kinetic energy of the projectile. Most of these defects occur in the internal structure and are invisible from the outside so non-destructive testing methods are used to determine the amount of internal material destruction. Due to the specificity of the structure of multilayer fiber reinforced composites, it is believed that the most effective method is active infrared thermography. This method require the use of various types of heat sources for thermal stimulation of the tested structure. Temperature field changes on the surface of the tested object are recorded using an infrared camera and, as a result of the analysis of changes in temperature distribution on the surface of this object, sub-surface defects can be detected. In many cases, deep-lying defects are difficult to detect due to small changes in temperature over the defect on the surface of the tested object. They are often at the level of disturbances caused by the inhomogeneity of the surface. However, you can increase the probability of detecting these defects by using special image processing methods.

2. Methods for Special Processing of Thermograms

The image (thermogram), after it has been digitally entered into a computer, requires certain procedures to extract the most interesting information resulting from its processing. A characteristic feature of the image processing process is that both input of the information processing program and its output have an image. The output images should be free from interference and have clearly distinguished features of interest. After initial processing of the image, analysis takes place to produce quantitative data describing specific features of the image. In the analysis process, a full image containing hundreds of details is replaced by a limited set of distinguished features for use with recognition algorithms [4].

The algorithm used is a mechanism for increasing the signal/noise ratio and thereby increasing the efficiency of detection of defects. The increase of signal/noise ratio can be achieved by processing separate thermograms. There are several such methods, for example, thermal tomography; Fourier transform; wavelet analysis; reconstruction of a thermographic signal; normalization in dynamic thermography; principle components analysis; neural networks; data synthesis. The paper presents examples of two of these: principle components analysis and wavelet analysis.

2.1. Principle Components Analysis

In thermographic testing, the principle component analysis (PCA) method has only been used relatively recently. PCA uses a decomposition method for spatial and temporal extraction of information from a thermographic data matrix. The three-dimensional matrix (sequence of recorded thermograms) is transformed into two-dimensions, in which time values are arranged in columns and spatial data in rows. The two-dimensional matrix is then decomposed, and the resulting matrix can be represented again in the form of a sequence of images.

The most common use for the described method is reduction of the data dimension. This task consists of describing data of a larger dimension (a large number of features) using a smaller number of features, while maintaining the maximum amount of information. In the case of PCA, this information is measured by variance, which in statistics is a classic measure of variables. The principal components analysis allows describing multidimensional data by means of a small number of uncorrelated coordinates (determined by eigenvectors of a covariance matrix), preserving the spread of data. A new dimension of space will depend on how many features you want to keep.

2.2. Wavelet Analysis

Wavelet transform enables simultaneous presentation of time and frequency signals and leads to approximation of signals by isolation of their characteristic structural elements. In contrast to Fourier transform, in wavelet transformation the signal is decomposed into elementary signals called wavelets which are continuous waveforms with different durations and different spectrum [5]. The disadvantage of Fourier transform, which is the more popular method of analyzing temperature signals, is that transition from the time-value system to a frequency-value system causes loss of time information. Wavelet analysis is a useful tool in analysis of short time signals, transient data or complex images.

In thermographic tests, the basic function of Morlet is used, which is a function of form of sinusoids modulated by Gaussian functions. Distribution parameters are called translation coefficient *Tr* and scale factor *S*. So, wavelet transform equation (*W*) has the form:

$$W(S,Tr)=\int_{-\infty}^{+\infty} T(\tau)h_{STr}(\tau)d\tau\,,$$

where h_{STr} is wavelet function related to parental function of a compound:

$$h_{STr}(\tau)=\frac{1}{\sqrt{S}}h\left(\frac{\tau-Tr}{S}\right).$$

Because scaling factor is related to frequency and factor of translation with time, the wavelet function method does not lose time information necessary to assess defect depth.

3. Examples of Use of Special Image Processing

As examples of the application of special processing of thermograms, the paper presents selected results for two samples of materials that are used to construct light ballistic armor. The first example is a sample with a thickness of 10 mm made of a multi-layer composite reinforced with aramid fiber, tested by ultrasonic thermography. The sample was analyzed after destructive testing with damage from impact of a 7.62 mm caliber projectile. Figure 1 presents a thermogram after testing with the ultrasonic thermography method (ultrasound frequency - 20 kHz, recording temperature changes on the sample surface using a FLIR 7600 camera, capturing 250 thermogram sequences with a frequency of 10 Hz) with visible temperature changes on the surface of the sample over defects (both surface and inside

sample structure). The results after applying special image processing using the PCA method and wavelet analysis are presented in Fig. 2.

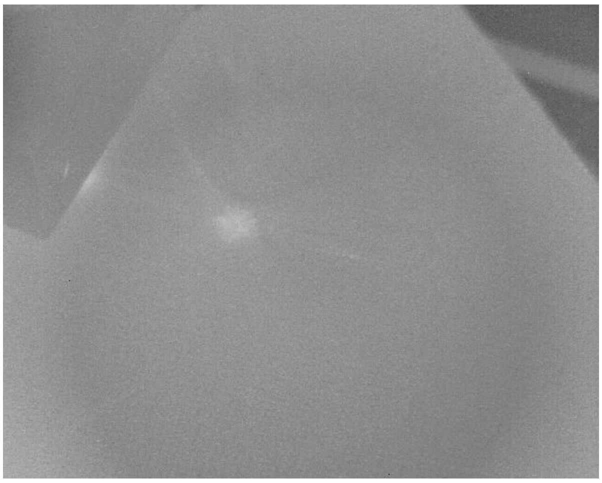
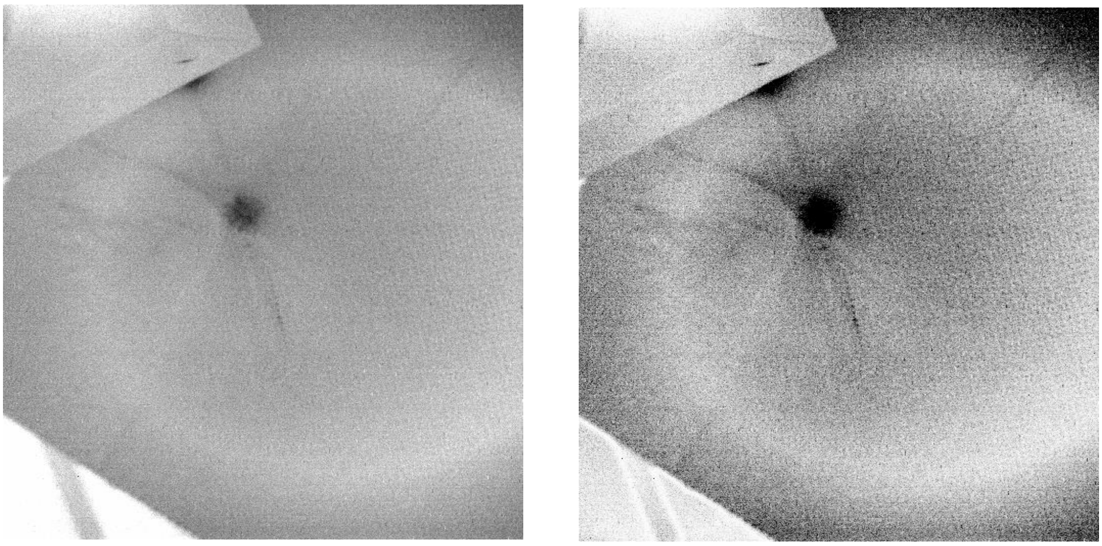


Fig. 1 Thermogram of sample after destructive testing

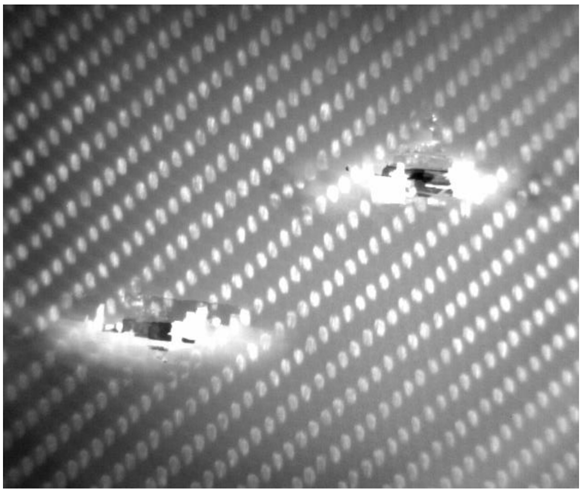


a b

Fig. 2 Thermogram (Fig. 1) after special image processing: a - PCA method; b - wavelet analysis

A second example is a sample with a thickness of 6 mm made of a multi-layer composite reinforced with carbon fibers. The sample after destructive testing (fired at with 5.45 mm caliber projectile) was tested by means of optical impulse thermography with thermal stimulation from a 2kW heating lamp and a heating time of 0.1 s. Changes in the temperature field on surface of the sample were recorded with a FLIR 7600 camera. A sequence of 750 thermograms with a recording frequency of 20 Hz was recorded. Fig. 3 shows the best thermogram with visible damage. Fig. 4 presents selected results obtained after applying special processing of thermograms using the PCA method and wavelet analysis.

Fig. 3 Thermogram of sample after destructive testing



a

b

Fig. 4 Thermogram (Fig. 3) after special image processing: a - PCA method; b - wavelet analysis

4. Summary

As can be clearly seen in Figs. 2 and 4, application of special thermogram processing methods can have an impact on improving detection of subsurface defects in composite materials reinforced with fibers. Defects are more clearly visible and invisible lesions appear on thermograms as shown in Figs. 1 and 3.

The presented examples show that in cases when internal damages of tested materials does not cause large changes on the surface of the sample, the special image processing method above them can be very useful.

Further work will be focused on use of more extensive wavelet functions for analysis of thermograms.

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Determination of the Critical Gauge Widening of the Railway Track

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Abstract

The article describes the main requirements for the railway track gauge. One of the main reasons for the derailment of the rolling stock is the widening of the railway track. The article describes the technique of determining the critical gauge widening for various conditions using modern numerical simulation methods.
KEY WORDS: *railway, track gauge widening, derailment, numerical simulation*

1. Introduction

Railway track is two parallel steel rails fixed at a certain distance to the some base (sleepers, beams, concrete slabs and etc.). One of the most important parameters of the railway track is the gauge − the distance G between the inner faces of the two rail heads (Fig. 1). It is well known that the global railway network uses a large variety of track gauges. The most popular 1435 mm track gauge is used on 65% of railways, 9% of tracks have 1000 mm gauge, 8% − 1067 mm, 6% − 1675 mm [1]. On the Lithuanian railways, as well as in other countries of the former Soviet Union, Finland and Mongolia, the track gauge is 1520 mm, or 10% of the total length of the world railway network. But even in this railway network, requirements [2, 3] permits the use of two different types of the track gauges: 1520 mm and 1524 mm.

In 1970, in the former Soviet Union republics, it was decided to reduce the railway gauge of the entire railway network by 4 mm: from 1524 mm to 1520 mm. The narrowed by 4 mm gauge reduced the gaps Δ_1, Δ_2 (Fig. 1) between the rail head and the flange of the wheels and, according to the results of numerous studies [4], the level of lateral forces between the wheels of the rolling stock and the rail head has decreased also trains resistance forces decreased and trains traffic safety level is increased.

It is obvious that it is practically impossible to maintain the exact track gauge, so certain technical track gauge tolerances should be applied (based on technical and economic criteria) and those tolerances could be different. For example, until 1996 the tolerances were +6 mm, −4 mm, and at the moment the tolerances depend on the top speed of the trains: up to 50 km/h + 10 mm, −4 mm; more than 50 km/h +8 mm, −4 mm [5].

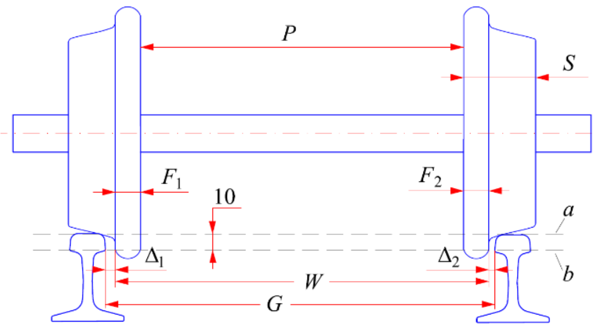

Fig. 1 Railway track gauge determination: P – distance between wheels, G – track gauge, W – wheel set gauge, S – wheels width, F_1, F_2 – wheels flange width, Δ_1, Δ_2 − gap between the rail head and the flange, a – rolling plane, b – calculated plane

The upper part of the railway track, as a complicated and complex structure, consisting of different bodies (rails, sleepers, fastenings, ballast layer), is elastically deformed by moving trains wheels and it changes track gauge. Depending on the type of the railway track and the wagons and locomotives axial load, the elastic enlargement of the track gauge can be 2−10 mm for wagons and 1 mm for locomotives [4, 6].

Depending on the profile of the wheel sets, the railway rails are placed with a certain inclination. The standard inclination is 1/20, but the tolerances for the rail track maintenance allow the use rails inclination from 1/12 to 1/60 [5], which geometrically reduces the track gauge by 6 mm and increases by 6 mm.

Finally, the real gauge of the track depends on the actual technical condition of the railway tracks, which often, especially on non-public track, do not meet basic safety requirements [6].

The interaction of the wheel and the rail depends not only on the gauge of the rail track, but also on the gauge of

the wheels (Fig. 1). Track and wheel set gauges are interrelated, because their difference determines the gap between the railheads and the flanges of the wheels.

The wheel gauge consists of the distance between the inner faces of the wheels (1440 mm), the tolerance of this distance depends on the biggest speed of the rolling stock, for example at speeds up to 120 km/h is not less than 3 mm and not more than 3 mm [2]. Also the wheel gauge includes the thickness of the flanges of wheel sets. Since the flange has a rounded profile, the thickness of the flange is measured in the calculated plane, which is located at a distance of 10 mm from the tape circle (Fig 1). At a speed of up to 120 km/h, the thickness of the new flange should not exceed 33 mm, and the worn out flange − up to 25 mm [2].

The necks of the wagons wheel sets are on the outside, the axles of the wheel sets under axel load is elastically deformed and the distance between the wheels is decreasing. For freight cars, this decreasing is about 2 mm, and for locomotives – 1 mm [4].

In the future, the number of factors (Table 1) effecting the width of the rail or wheel gauges will only increases. The increase the wagon's axle load to 265 kN and the increase in train speed increase the elastic deformations of the upper part of the railway track and the elastic deformation of the axes of the wheelsets of the rolling stock. It is also planned to change the requirements for the width of the flange of the wheels, which will affect the interaction between the wheels and rails.

Table 1

Factors effecting the gap between the wheels flanges and rails heads

Nr.	Factors	Reduce the gap, mm	Increase the gap, mm
1	Track gauge 1520 mm	0	0
2	Track gauge 1524 mm	−	+4
3	Track gauge tolerance till 1996	−4	+6
4	Track gauge tolerance from 1996 and till 50 km/h	−4	+10
5	Track gauge tolerance from 1996 and from 50 km/h	−4	+8
6	Track gauge elastic deformation	−	from +1 till +10
7	Rails inclination tolerance	−6	+6
8	Distance between the inner faces of the wheels toleration till 120 km/h	−3	+3
9	Wheel set flange thickness	−	+16
10	Wheel set axel elastic deformation	−	+2

The gauge of the railway track and the gauge of the wheel sets are one of the main results of the infrastructure and rolling stock exploitation and repair activities. The gauges of the railway track and of the wheel sets guarantee the railway transport safety with a certain level of forces between the rolling stock wheels and the rails. The gauge of the railway track and the gauge of the wheel sets are relative and constantly changing values, the influence of which on dynamic processes between the wheels and the rails is still being actively investigated [7-10]. The aim of this article is to describe the results of numerical simulation of the effect of the track gauge and the wheel set gauge on the main safety indicators. The article describes the technique of determining the critical track and the wheel set gauges for various conditions using modern numerical simulation methods.

2. Computer Simulation

The commercial simulation of dynamics of mechanical systems software „Universal Mechanism" used to simulate complex train dynamics. Program package „Universal Mechanism" intended for simulation of kinematic and dynamic of planar and spatial mechanical systems. This software automates the process of model creation and the analysis of obtained results. The software include a special module for simulation of railway dynamics (locomotives, freight and passenger wagons, EMU, DMU and etc.). Every vehicle of the train in terms of „Universal Mechanism" is a subsystem, which can be a model of any complexity [11].

2.1. Vehicle model

The 3D model of gondola wagon (Fig. 2) used for dynamics simulation. The gondola wagon model with two-axle bogies (18-100 model) consists of 11 rigid bodies (car body, 2 bolsters, 4 side frames, 4 wheel sets) and has 66 degrees of freedom (6 for each of the bodies) is presented in Fig. 3. The model is created as rigid body systems (or multibody systems), whose bodies are connected by means of force elements.

Creating a wagon model, the wheel set sub-model uses the most dangerous tolerance of the distance *P* between the inner faces of the wheels (Fig. 1 and Table 1). The interaction of the rail and wheel gauges is particularly influenced by the profile of the wheels of the model. To create the simulation conditions, two principally different types of wheel profiles were used:

− conical (1/20 and 1/7) not conformal two-point contact profile (Fig. 4);

− onformal single-point contact profile Dmeti30 (Fig. 5).

Fig. 2 Model of gondola wagon

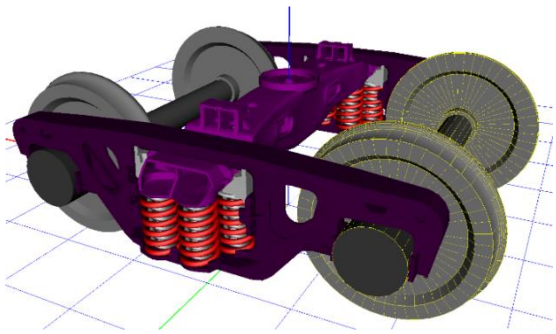

Fig. 3 Model two-axle bogies (18-100 model)

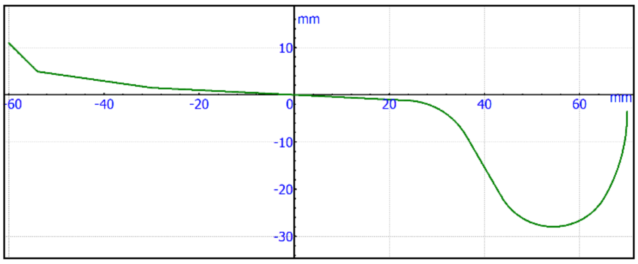

Fig. 4 Conical not conformal two-point contact profile

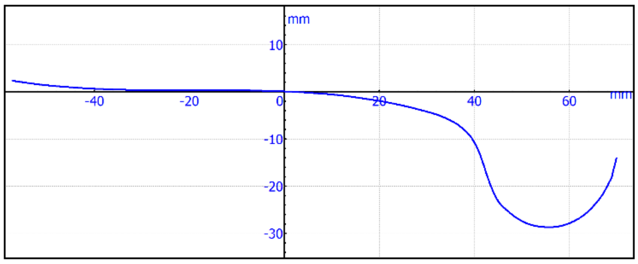

Fig. 5 Conformal single-point contact profile

2.2. Track Model

Track model presented as a massless new R60 rail track model, so only elastic and dissipative properties of a track are taken into account: vertical stiffness 40 MN/m, lateral stiffness 20 MN/m, torsional stiffness 5 MN/m, vertical damping 0,3 MNs/m and lateral damping 0,1 MNs/m. For wheel and rail contact forces estimation Fastsim algorithm was used. That algorithm for creep forces by Kalker takes into account both the spin and the geometry of the contact surfaces. Track macrogeometry presents in a tangent section of 1000 m length.

Track microgeometry (irregularities) created in accordance to experts of International Union of Railways [12]. Note that horizontal irregularities for the left and right rails are equal (Figs. 6 and 7). Spectral power density functions corresponded to railway tracks of different quality of horizontal track irregularities:

$$\Phi(\Omega) = \frac{a_h \Omega_c^2}{\left(\Omega^2 + \Omega_R^2\right)\left(\Omega^2 + \Omega_c^2\right)} \cdot \Omega > 0 \ . \qquad (1)$$

Spectral power density functions corresponded to railway tracks of half-sum of vertical track irregularities:

$$\Phi(\Omega) = \frac{a_v \Omega_c^2}{\left(\Omega^2 + \Omega_R^2\right)\left(\Omega^2 + \Omega_c^2\right)} \cdot \Omega > 0 \, . \qquad (2)$$

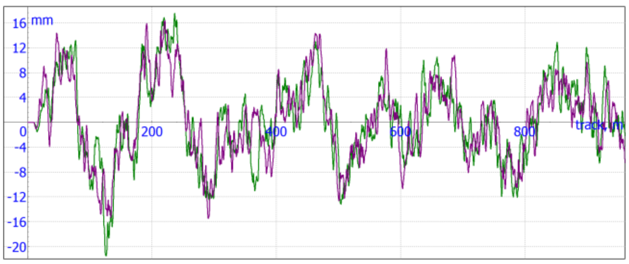

Fig. 6 Left and right rails vertical irregularities

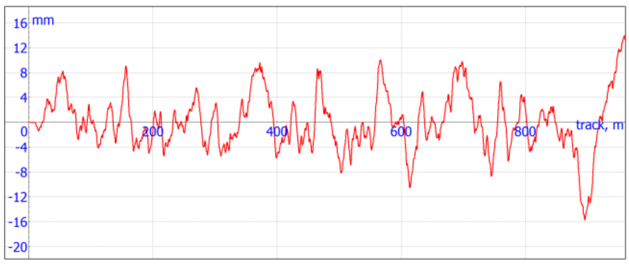

Fig. 7 Left and right rails horizontal irregularities

Spectral power density functions corresponded to railway tracks of different quality of half difference of vertical track irregularities:

$$\Phi(\Omega)=\frac{1}{b_A^2}\cdot\frac{\Omega^2}{\left(\Omega^2+\Omega_S^2\right)}\cdot\frac{a_v\Omega_c^2}{\left(\Omega^2+\Omega_R^2\right)\left(\Omega^2+\Omega_c^2\right)}\cdot\Omega>0\,, \tag{3}$$

here a_h, a_v – track quality parameter (bad/good), cm^{2}rad/m; Ω_R, Ω_c, Ω_S – track parameter, rad/m.

Instructions [5, 14] approved the procedure and evaluation criteria for the irregularities of the railway track − set the basic parameters, introduced a system of tolerance, irregularities classification system, and established qualitative and quantitative railway track validation system. In simulation software package „Universal Mechanism" the railway track condition tool is used to estimate the path condition for the generated irregularities of the track. In accordance of instructions [5, 14] track microgeometry estimated at 500 points and „unacceptable".

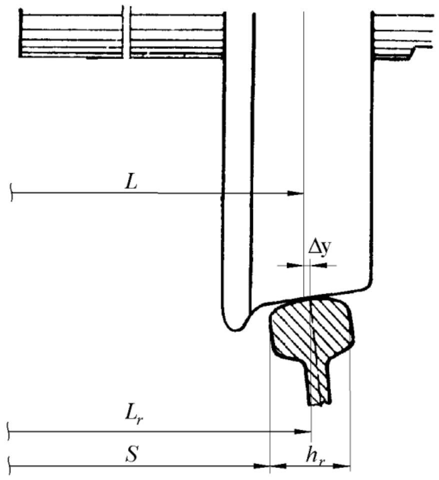

Fig. 8 Distance relative to the wheelset base Δy [13]

Table 2

Lateral position of rails

Nr.	Δy, mm	S, mm
1	6	1514
2	7	1516
3	8	1518
4	9	1520
5	10	1522
6	11	1524
7	12	1526
8	13	1528
9	14	1530
10	15	1532
11	16	1534
12	17	1536
13	18	1538
14	19	1540

In simulation software package "Universal Mechanism" lateral position of rails is set by the distance Δy relative to the wheelset base (Fig. 8). For simulation scenarios distance Δy range is from 6 mm till 19 mm was used or according (5) distance Δy equivalent to track gauge range from 1514 mm till 1540 mm (Table 2).

$$\Delta y=\frac{L_r-L}{2}=\frac{S+h_r-L}{2}, \tag{4}$$

here L_r – distance between the rail head centers; L – distance between wheel set wheel running circles; S – track gauge; h_r – width of the rail head.

2.3. Safety Criteria

To estimate a level of rolling stock derailment danger different derailment criteria is used: Nadal, criteria Weinstock criteria, Derailment quotient (Russian version), Combined safety factor and etc. Derailment quotient (Russian version) is based on Nadal's criteria, or that quotient is estimated by the „safety factor":

$$\lambda=\frac{F_z}{F_y}\cdot\frac{tg\delta-\mu}{1+\mu\cdot tg\delta}=\frac{F_z}{F_y}q_0\,, \tag{5}$$

here δ – wheel flange angle; F_z, F_y – lateral and vertical forces; q_0 – axel load; μ – coefficient of friction between rail and wheel or ratio of the lateral creep force to the normal force in the contact zone.

For wheel profiles that do not allow a two point contact, it is calculated at a contact angle $\beta > 30°$. With the values $\lambda > 5$ accepted $\lambda = 5$. If there is no contact between the wheel and the rail $\lambda = 5$. Dangerous for train traffic safety are the values $\lambda < 1{,}2$.

3. Simulation

Simulation experimental part was divided into two phases. In the first stage the movement of gondola wagon

with wheel sets with conical not conformal two-point contact profile. During the second phase the same wagon movement, but with conformal single-point contact profile, was simulated.

3.1. Wagon with Wheel Sets with Conical not Conformal Two-Point Contact Profile

After creating a model of the gondola wagon and creating all train traffic conditions train, it is possible to simulate the dynamic processes. The conditions of the first experiment assume the use of a new conical not conformal two-point contact profile (Fig. 4). Simulation was carried out for the maximum speed of freight trains −25 m/s. Train traffic safety was estimated by the Derailment quotient (6) while railway track gauge was 1532 mm (Fig. 9). The simulation results for all wheel sets prove that this track widening creates wagon derailment possibilities, because the Derailment quotient falls below the critical value $\lambda < 1.2$ (the red line in the graph).

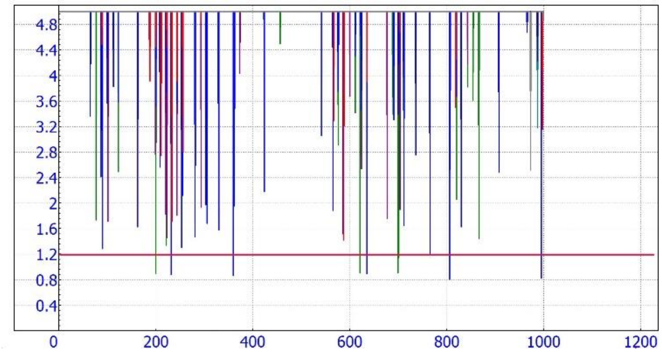

Fig. 9 All wheel sets derailment quotient for 1532 mm gauge(red line – critical level)

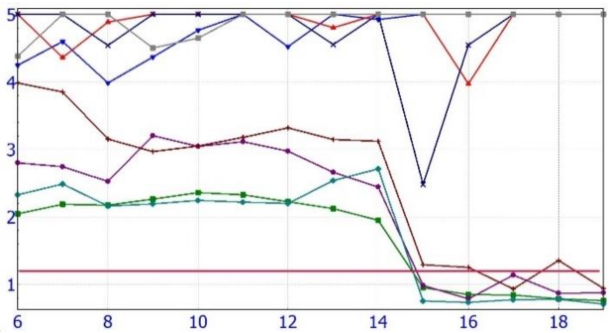

Fig. 10 Minimal derailment quotient for 1514−1540 mm range gauges(Δy from 6 mm till 19 mm))

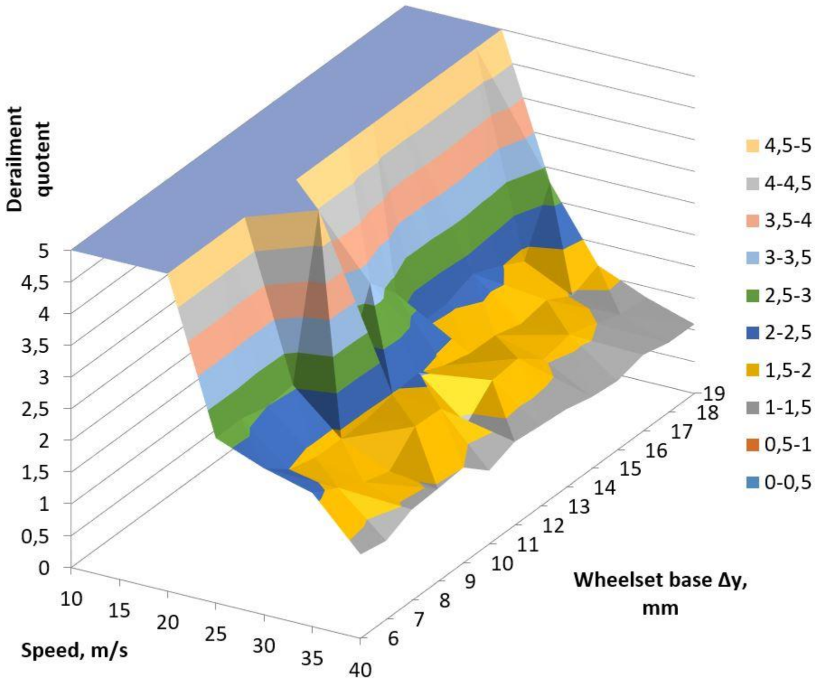

Fig. 11 Derailment quotient for different wagon speed and lateral position of rails

At the next stage of the numerical simulation, the motion of the wagon was simulated with different track gauges from 1514 mm to 1540 mm, with a widening step of 1 mm (Table 2). For all of the 14 experiments, the data was processed and the minimum Derailment quotient for all wheels of the freight car was determined (Fig. 10). The results prove that the front wheel sets of the wagon bogies are most prone to derailment and the 1530 mm widening of the track gauge is critical for the safety of the conical not conformal two-point contact profile.

3.2. Wagon with Wheel Sets with Conformal Single-Point Contact Profile

The second experiment was carried out for wheel sets with a conformal single-point contact profile (Fig. 5) with

a speed of 25 m/s. After the processing of the simulated data, the all wheel sets Derailment quotient was calculated for the different widening of the gauge and in the entire range of the gauge widening from 1514 mm to 1540 mm, the Derailment quotient did not reach the critical value. It means, that conformal single-point contact wheel profiles are more safe, in comparison with conical not conformal two-point contact profiles.

On the next step factorial experiment was created. In this experiment influence of different factors is estimated by multivariant calculations. Internal identifiers were used for variation of the corresponding conditions in numeric experiments: wagon speed from 10 m/s till 40 m/s and lateral position of rails from 1514 mm till 1540 mm (Fig. 11). The simulation results (Fig. 11, gray zone) show that the conformal single-point contact profiles at speeds of more than 35 m/s and gauge widening more than 1520 mm do not meet the safety requirements.

4. Conclusions

The railway track consists of two closely interconnected parts − a track gauge and a wheel set gauge. The difference between the rail and wheel sets gauges creates a gap between the rail heads and the wheel flanges, which directly affects the train’s traffic safety.

The railway track gauge and wheel sets gauge are not static, but dynamic parameters that, depending on the operating requirements for the rolling stock and the infrastructures and deformations of the track and wheel sets, are constantly changing.

Railway rolling stock with wheel sets that conical not conformal two-point contact profiles are prone to derail with a relatively small widening of the track gauge of 1532 mm. Wheel sets with conformal single-point contact profiles are safer and when the track gauge is widening to 1540 mm, the rolling stock can only be derail at a speed of 35 m/s, which exceeds the maximal speed of freight wagons.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

An analysis of The System Supporting Management of Railway Transport in Poland

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Abstract

The basic elements of an enterprise that improve work productivity and quality of provided services is implementation of the systems supporting efficient management of a company. The implementation of the systems supporting management allows to improve execution of the processes and goals of an enterprise. In this article, the authors conducted a comparative analysis of the quality transport services provided in Poland for two carriers: Koleje Mazowieckie and Koleje Wielkopolskie that use Quality Management System. The analysis was conducted with reference to Koleje Dolnośląskie that does not use this system. Conducted analysis showed that constant improvement of the systems supporting management in an enterprise is a basis for development, of a company.
KEY WORDS: *Railway transport, Quality Management System*

1. Introduction

In Poland, there are 13 carriers that have acquired, in the Railway Transport Office, necessary licenses, certificates and decisions allowing to conduct passenger transport activity.

Every railway carrier conducting passenger transport activity is obliged to implement Security Management System. [5, 6]. It is a basic condition of obtaining Security Certificate by the railway company, therefore, all carriers base their transport activity on the implementation and improving the system. The conditions of maintaining Security Certificate by a railway carrier include:

- observing the regulations in national and European law concerning railway traffic;
- reporting the change of activity or types of rolling stock every time to the Chairman of the Railway Transport Office;
- carrying out audits and inspections on the Security Management System by the people appointed by the Chairman of the Railway Transport Office;
- in accordance with the Order of the Minister of Transport [7], any carrier is obliged to submit every year a *Report on security* and *Program of security improvement;*
- in accordance with article 18, letter b, sec. 8 of the Act of March 28, 2003 on railway transport, the Chairman of the Railway Transport Office has the right to partially or fully withdraw Security Certificate. The condition of withdrawal of Security Certificate is non-observance by a carrier of the conditions of maintain Security Certificate.

2. Quality Management System in the Transport Processes

The initiation of the process of improving the quality is the activity connected with quality planning, as well as determination of quality pattern [3, 4]. The better image of transport process can be achieved by implementation of quality control system that allows to find the segments and employees that bear the blame for lowering the quality level.

Railway transport is one of the elements of transport system [1],[16]. The quality of passenger transport services considerably affects standard of living of the society. People travelling by train have some expectations that, depending on the stage of dislocation and check-in of the passengers, can be divided into:

1. The stage of check-in of the passengers – the state of a railway station is very important at this stage: appearance of the areas nearby, uncomplicated access to the platforms, the possibility of sheltering from the rain, state of the toilets (if they exist), waiting room, comfortable access to the railway station, the possibility of parking cars, monitoring, which makes people feel safer, left-luggage offices, station information and clear train timetable;
2. The stage of dislocation – the most important at this stage are: quick travel, finding free space in a train, which isn't always possible, convenient connections while changing the train, low price for transport service, clean seats and carriage, clean toilets, sense of security during travel, professional train service and lighting;
3. The stage of final check-in – this stage is of technical character, in which empty carriages are taken from final

station to the stabling tracks.

Railway transport should be integrated with other branches of transport and environment [11, 12]. The criteria determining integration include:

- accessibility of the stops;
- spatial and functional integration with other means of local, regional and national public transport;
- service at night-time;
- frequency;
- the connections with the lowest possible number of changes;
- the reliability of transport, that is, cyclicality, punctuality, finding the best seat, reaching target place on time and possibility of communication with other means of transport;
- flexibility, that is, the choice of alternative connection;
- time of travel;
- the conditions of reaching the stop, that is, collision-free and security;
- the conditions at the stop, that is, the possibility of sheltering from bead weather conditions, aesthetic railway station and its crowding and services in its proximity;
- the conditions while getting on and getting off the train, including facilitations for the disabled;
- comfortable travel, that is, the degree of train crowding, ride fluidity, heating and air-conditioning in a train, lighting and cleanliness [14];
- polite staff;
- convenient changes;
- reduction of noise and vibrations [13, 15];
- convenient ticket system, that is, user-friendliness, large ticket offer and validity of a ticket in different carriers;
- travel and personal safety.

Every railway passenger, depending on his/her financial capabilities, transport conditions and time of travel, would like to have the opportunity to choose the best offer. The railway enterprises should adjust their offers to the preferences and expectations of the passengers. The criteria that should be taken into account during implementation of new transport offers include:

- short time of travel, including options of working or resting;
- frequent train runs, particularly in regional and agglomeration traffic;
- transport in door-to-door system;
- the costs of travel adequate to offered quality and financial means of a client;
- providing access to information through the Internet, electronic medium or free helpline;
- implementation of a sound system that would inform not only about next stations, but also about the possibility of changing a train;
- diversity of information, that is, not only train timetable, but also bus timetable in the cities that the train go across and information about the fares and tickets;
- well-organized arrangement of connections and constant hour ends of departures in cyclical traffic;
- an option of buying tickets on the Internet and paying by credit card;
- high comfort of travel and aesthetic appearance inside the train;
- travel and personal safety;
- additional services in the trains, for example, luggage or gastronomic services;
- providing travel continuity [8].

Improving quality of transport services requires many technological, technical, financial and organizational actions. It is also necessary to implement a special quality control system providing information about the quality of provided services and suggestions of the passengers. Fig. 1.

The first step toward improvement of quality is the activity connected with quality planning and determination of its pattern. The better image of transport process can be achieved by implementation of quality control system that will allow to find the segments and employees that bear the blame for lowering the quality level in an enterprise. Finding critical (with reference to quality) trains, elements of technology and sections is one of the elements of improving quality that railway enterprises may use for constant improvement of transport.

All employees at all levels of organizational structure of the management of a given carrier are involved in improvement of passenger transports and solving qualitative problems since activation of quality control system.

Management Systems are not mandatory for railway passenger carriers. However, most of them have implemented Quality Management System.

The carriers that possess such systems conduct regular analyses, the assessments of the passengers and their satisfaction with using transport offer of a carrier. The whole system includes planning and execution of passenger railway transport, therefore, every carrier determines directions of action improving its company in the Quality Management System.

Quality Management System has been implemented in many carriers in Poland, for example, Koleje Mazowieckie and Koleje Wielkopolskie. Koleje Dolnośląskie does not have such system. The reports on quality norms are worked out on the basis of the Directive no. 1371/2007 [9], and not on the basis of quality norms, procedures and quality policy, like in the companies that implemented Quality Management System.

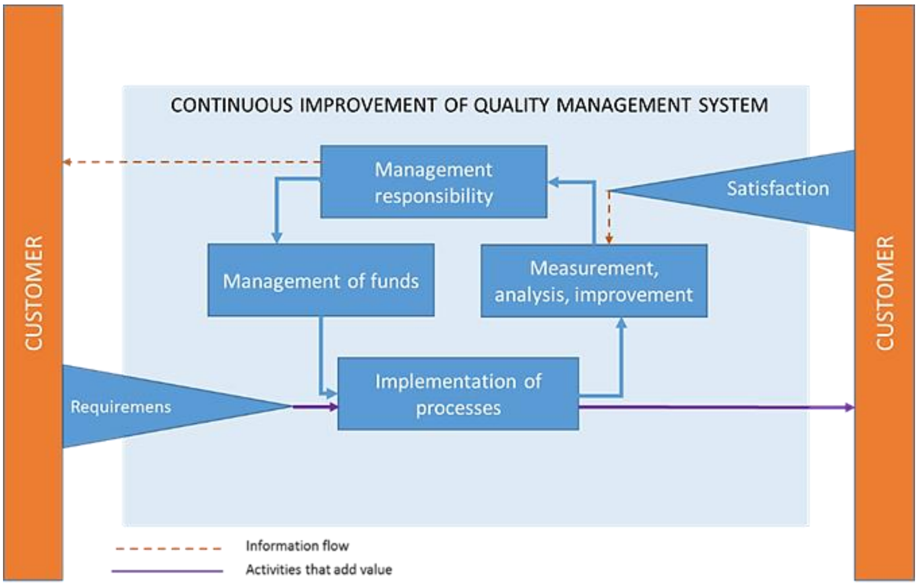

Fig. 1 A model of process approach

2.1. The Passengers Participating in the Railway Transport

One of the factors affecting the quality and its particular elements is the number of the passengers within a year who made use of the services provided by particular carriers. Fig. 2 shows the number of the passengers using the trains of the carriers that comparative analysis is conducted for, that is, Koleje Mazowieckie, Koleje Wielkopolskie and Koleje Dolnośląskie.

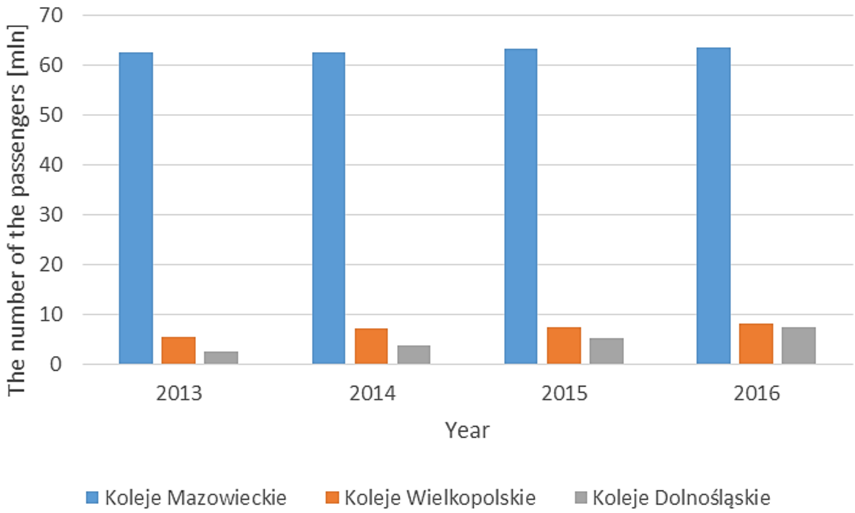

Fig. 2 The number of the passengers who made use of services provided by selected carriers [2]

Koleje Mazowieckie had 9 times passengers more than two other carriers (Fig. 2). In the years 2013 – 2016, it was about 63 million passengers. The highest increase in the number of the passengers had Koleje Dolnośląskie – the number of the passengers increased three times in the years 2013 – 2016.

2.2. Train Punctuality

Another factor that determines appropriate quality in the railway passenger carriers is train punctuality. However, due to the growing number of new trains, train punctuality is not the most comparable element of quality. Fig. 3 shows train punctuality in Koleje Mazowieckie, Koleje Wielkopolskie and Koleje Dolnośląskie. Train punctuality in Koleje Mazowieckie is increasing every year, whereas, it is decreasing in Koleje Dolnośląskie every year. The cause may be the fact that Koleje Dolnośląskie does not possess the Quality Management System and increasing number of the passengers and growing number of new trains.

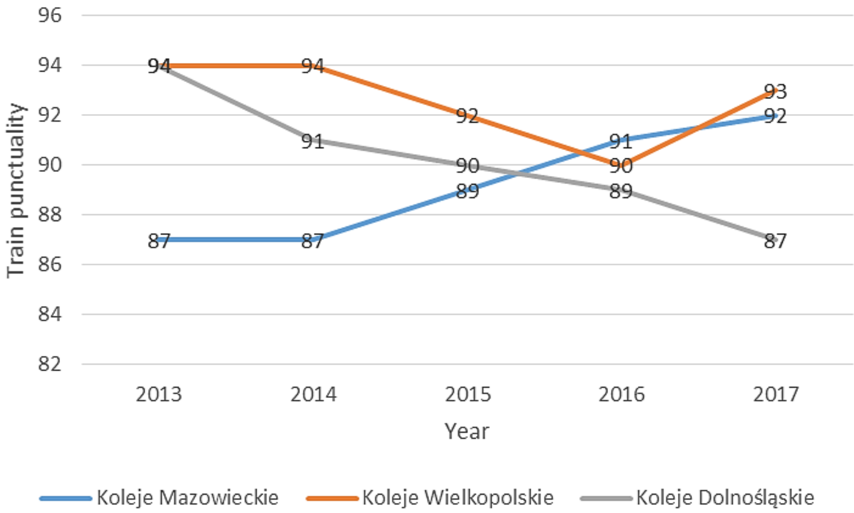

Fig. 3 Train punctuality in selected carriers – the author's own study on the basis of data obtained from the Railway Transport Office [2]

2.3. Complaints

Another factor that determines appropriate quality in the railway passenger carriers is the number of complaints submitted by the passengers to particular carriers [10]. Fig. 4 shows the number of complaints and applications submitted to the carriers in the years 2013-2016.

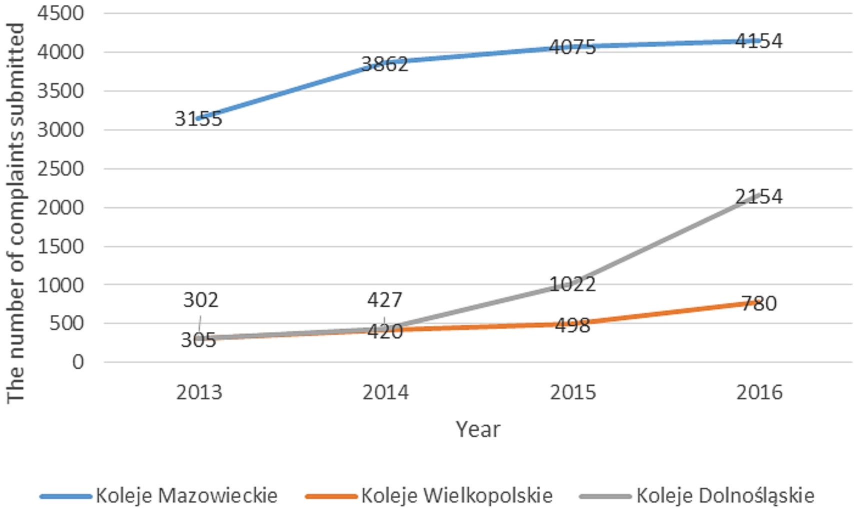

Fig. 4 The number of complaints submitted to particular carriers – the author's own study on the basis of annual reports of the carriers [2]

The highest increase in the number of complaints occurred in Koleje Dolnośląskie (Fig. 4). Within three years, the number of complaints increased seven times in the years 2013 – 2016, that is, increase by 610%. For comparison, in the same period, this growth in Koleje Mazowieckie was by 30%, and by 155% in Koleje Wielkopolskie.

Taking the number of the passengers in three carriers from Fig. 2 into account, in Koleje Mazowieckie, there is one complaint to 15 262 passengers, in Koleje Wielkopolskie, one complaint to 10 512 passengers, in Koleje Dolnośląskie, one complaint to 3 390 passengers. Statistically, Koleje Mazowieckie has the lowest number of complaints, and Koleje Dolnośląskie the highest number of complaints [2].

3. Conclusion

Based on the example of the carriers and analysed three factors determining the quality of provided services, we can see that a carrier, which hasn't implemented the Quality Management System achieves worse results that considerably affect the quality of provided services. Thanks to the implementation of ISO 9001 system in Koleje Mazowieckie, these factors, in comparison with other analysed carriers, are constantly improving.

It is caused by the fact that Koleje Mazowieckie provides high-quality services and regularly conduct customer satisfaction surveys. On the basis of these surveys, the regulations are amended and the suggestions of the passengers

are used to improve the quality of the services.

The implementation of Quality Management System based on international norm ISO 9001 and trade standards provide, apart from quality of provided services:

- efficient communication with the passengers through customer satisfaction surveys and considering the expectations expressed in these surveys;
- increase in sale;
- improvement of company's prestige;
- reduction of operating costs;
- improvement of work productivity.

Constant improvement of the systems supporting management in a enterprise is a basis for development of a company.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Sustainable Development Indicators of Selected European Countries in the Field of Transport Sector

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Abstract

Sustainable development is based on three pillars: economic pillar, environmental pillar and social pillar. EUROSTAT defined two important indicators of sustainable development which are related to transport sector. The first indicator is the share of collective transport modes in total passenger land transport. The indicator measures the share of collective transport modes (buses, coaches, trolley-buses and trains) in total inland passenger transport performance, expressed in passenger-kilometers. The second indicator is the share of rail and inland waterways activity in total freight transport. The indicator measures the share of rail and inland waterways in total inland freight transport, expressed in tonne-kilometers. The aim of the article is to analyse the development of these indicators between 2005 and 2015 in selected European countries and compare the states among themselves and with the average of 28 countries of European Union.
KEY WORDS: *sustainable development, sustainable development indicator, transport sector, EUROSTAT, European Union*

1. Introduction

Olawumi & Chan [1] stressed the importance of Brundtland Report for the World Commission on Environment and Development in 1992 where the term of "sustainable development" was introduced. The concept of sustainable development nowadays increasingly gained importance among organizations and their stakeholders around the world [2]. The concept of sustainable development encompasses three dimensions of welfare – economic, environmental and social – and involves complex synergies and trade-offs among them [3-6].

Stevens [3] differentiated six effects in relation to sustainable development areas, there are: effects of economic activity on the environment (e.g., resource use, pollutant discharges, waste); environmental services to the economy (e.g., natural resources, sink functions, contributions to economic efficiency and employment); environmental services to society (e.g., access to resources and amenities, contributions to health, living and working conditions); effects of social variables on the environment (e.g., demographic changes, consumption patterns, environmental education and information, institutional and legal frameworks); effects of social variables on the economy (e.g., labour force, population and household structure, education and training; consumption levels, institutional and legal frameworks); effects of economic activity on society (e.g., income levels, equity, employment).

Transport has significant economic, social and environmental impacts and represents a significant factor of sustainability [7]. Sustainable transport is characteristic by the fact that it does not represent any threat to public health or to ecosystems, but at the same time it provides for transport needs in such manner that competitiveness and regional development are supported [8].

It is worth to trace and evaluate the development in transport sustainability on the international, on the national and on the regional levels; sustainable transport indicators can be utilized for this [9, 10]. Calderon, Pronello and Goger [11] define sustainable transport indicators as variables by means of which it is possible to monitor target values in the area of sustainable transport; such indicators also represent an important tool for decision-making. According to Litman [7] they are variables selected and defined to measure progress towards an objective. Joumard and Gudmundsson [12] consider indicators to be statistical measures that give an indication of the sustainability of economic, environmental and social development.

The article analyses the development of two indicators (*the share of collective transport modes in total passenger land transport* and *the share of rail and inland waterways activity in total freight transport*) between 2005 and 2015 in selected European countries and compares the states among themselves and with the average of 28 countries of European Union.

2. Materials and Methods

The United Nations Conference on Sustainable Development (Rio+20) resulted in a nonbinding document in which the governments of various countries declared their commitment to create a set of sustainable development goals [13]. These goals were integrated into the framework of the Millennium Development Goals after 2015 [14]. EUROSTAT [15, 16] defined seventeen groups of sustainable development indicators, there are: Group 1 – No poverty; Group 2 – Zero hunger; Group 3 – Good health and well-being; Group 4 – Quality education; Group 5 – Gender equality; Group 6 – Clean water and sanitation; Group 7 – Affordable and clean energy; Group 8 – Decent work and economic growth; Group 9 – Industry, innovation and infrastructure; Group 10 – Reduced inequalities; Group 11 – Sustainable cities and communities; Group 12 – Responsible consumption and production; Group 13 – Climate action; Group 14 – Life below water; Group 15 – Life on land; Group 16 – Peace, justice and strong institutions and Group 17 – Partnership for the goals. Each group of indicators consists of several sub-indicators that are focused on a particular area of sustainable development.

In this article attention is given to two selected indicators by means of which it is possible to monitor and to evaluate transport sustainability. These are the following indicators: *share of collective transport modes in total passenger land transport* and *share of rail and inland waterways activity in total freight transport*. Both indicators are put into a group of indicators characterizing sustainability of industry, innovation and infrastructure (Group 9). The characteristic of both of these indicators is stated in Table 1.

Table 1

Selected sustainable development indicators [15, 16]

Indicator	Description of indicator
Share of collective transport modes in total passenger land transport by vehicle	The indicator measures the share of collective transport modes in total inland passenger transport performance, expressed in passenger-kilometers (pkm). Collective transport modes refer to buses, including coaches and trolley-buses, and trains. Total inland transport includes transport by passenger cars, buses and coaches, and trains. All data should be based on movements within national territories, regardless of the nationality of the vehicle. The data collection methodology is voluntary and not fully harmonized at the EU level. Other collective transport modes, such as tram and metro systems, are also not included due to the lack of harmonized data.
Share of rail and inland waterways activity in total freight transport	The indicator measures the share of rail and inland waterways in total inland freight transport, expressed in tonne-kilometers. Inland transport includes transport by road, rail and inland waterways. Road transport is based on all movements of vehicles registered in the reporting country. Rail and inland waterways transport is generally based on movements on national territory, regardless of the nationality of the vehicle or vessel, but there are some variations in definitions from country to country. Neither sea nor air freight transport are currently represented in the indicator.

This article analyses the development of these indicators in selected European countries and compares these countries among themselves and also with the EU-28 average. The development of these two selected indicators is traced and evaluated for the period 2005-2015. The analysed data are taken from reports published by the statistical office of the European Union (EUROSTAT) [15, 16].

The standard deviation is used for the calculation of the amount of variation or dispersion of a set of data values. Standard deviation σ is usually defined as the square root of the variance $D(X)$ of a random variable X – (Eq. 1); standard deviation σ can be also calculated using the mean value $E(X)$ or $E(X^2)$ – (Eqs. 2 and 3) [17]:

$$\sigma = \sqrt{D(X)}; \quad (1)$$

$$\sigma = \sqrt{[E(X^2) - (E(X))^2]}; \quad (2)$$

$$\sigma = \sqrt{[1/n \,.\, \sum (x_i - (1/n \,.\, \sum x_i))^2]}. \quad (3)$$

Average values of both analysed indicators I_{ij}, where i is the number of indicator and j is the number of country, are compared with the average values of 28 countries of European Union $\emptyset_{ij}$. Countries that meet the following condition (Eq. 4) are best rated, because these countries have average indicators values higher than average values of 28 countries of European Union $\emptyset_{ij}$. Countries that meet the condition (Eq. 5) have a middle rating, because these countries have only one average indicator value higher than average values of 28 countries of European Union $\emptyset_{ij}$. Countries that meet the condition (Eq. 6) have the worst rating, because these countries have average indicators values lower than average values of 28 countries of European Union $\emptyset_{ij}$.

$$I_{1j} > \varnothing_{I1j} \wedge I_{2j} > \varnothing_{I2j}; \tag{4}$$

$$I_{1j} < \varnothing_{I1j} \wedge I_{2j} > \varnothing_{I2j} \vee I_{1j} > \varnothing_{I1j} \wedge I_{2j} < \varnothing_{I2j}; \tag{5}$$

$$I_{1j} < \varnothing_{I1j} \wedge I_{2j} < \varnothing_{I2j}. \tag{6}$$

In the following chapter there are summarized and discussed the results from presented research.

3. Results and Discussion

The first analysed indicator is the *share of collective transport modes in total passenger land transport by vehicle*. The results are presented in Table 2.

Table 2

Values of indicator *share of collective transport modes in total passenger land transport by vehicle* (% of total inland passenger-km) [authors based on 15, 16]

State	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	σ
EU-28	16.70	16.80	16.90	17.30	16.40	16.60	16.70	17.20	17.00	16.90	16.90	0.246
Belgium	20.20	20.80	21.20	20.50	20.50	20.40	20.50	20.70	20.40	19.80	19.20	0.501
Bulgaria	29.10	27.40	26.20	24.80	20.50	20.00	19.40	17.90	16.90	17.70	16.80	4.305
CR	24.50	24.80	24.30	24.00	23.70	27.00	25.60	26.00	26.40	26.90	25.90	1.115
Denmark	20.90	20.90	20.50	20.20	20.00	20.40	20.10	20.00	20.10	19.90	19.20	0.457
Germany	14.20	14.40	14.30	14.40	14.00	14.00	14.10	14.60	14.20	14.30	14.40	0.177
Estonia	23.00	24.00	22.80	20.60	18.30	18.60	18.20	18.60	19.00	18.40	21.80	2.112
Ireland	17.90	17.70	17.60	17.70	17.80	17.40	17.50	17.20	16.80	20.20	19.70	0.990
Greece	21.70	20.80	20.10	19.20	18.10	18.40	18.40	18.40	18.70	18.60	18.50	1.122
Spain	18.00	17.20	19.00	19.80	18.70	17.70	19.10	19.30	19.70	17.30	18.60	0.873
France	14.30	14.70	15.10	15.80	14.60	14.60	14.70	14.90	14.80	14.90	15.20	0.377
Croatia	16.20	16.20	17.10	17.90	16.30	16.30	15.40	14.20	14.60	14.90	14.10	1.158
Italy	18.20	18.50	18.40	18.40	17.20	18.30	18.90	21.10	20.40	19.90	19.20	1.068
Cyprus	:	:	:	:	:	:	:	:	:	:	:	x
Latvia	23.80	21.10	18.50	19.50	18.50	19.80	21.70	21.00	20.60	19.00	17.70	1.675
Lithuania	10.20	9.10	9.00	8.80	7.70	8.30	9.10	8.00	8.60	11.80	10.80	1.183
Luxembourg	14.50	14.70	15.20	15.70	15.70	16.60	16.90	17.00	17.20	16.50	17.10	0.940
Hungary	35.80	34.40	32.50	32.50	30.90	31.50	31.70	32.40	32.50	32.50	31.80	1.318
Malta	:	:	:	:	:	:	:	:	:	:	:	x
Netherlands	11.80	12.30	12.50	12.80	12.70	13.10	13.50	13.80	14.00	14.50	13.80	0.787
Austria	20.70	20.70	21.10	21.70	21.10	21.60	21.70	22.20	22.50	22.40	22.20	0.625
Poland	30.60	30.00	29.30	28.10	25.30	23.90	23.40	23.20	22.00	21.80	21.50	3.324
Portugal	10.70	10.30	10.60	10.70	10.60	10.90	10.80	10.50	10.60	10.20	10.60	0.193
Romania	24.50	23.60	22.60	27.80	23.50	21.90	21.50	21.80	21.10	21.50	20.10	2.008
Slovenia	14.30	14.40	14.00	13.60	13.30	13.30	13.30	13.40	13.70	13.70	13.90	0.376
Slovakia	30.70	29.20	28.00	27.00	22.40	22.00	22.70	22.70	22.20	22.50	24.20	3.075
Finland	15.10	15.10	15.00	15.50	15.10	15.10	14.80	15.10	15.10	14.80	15.00	0.177
Sweden	14.40	14.90	15.10	15.70	15.80	16.00	16.10	16.40	16.60	16.50	16.80	0.730
UK	11.70	11.70	12.10	12.80	12.90	13.70	13.80	13.90	13.90	13.90	14.00	0.885
Iceland	:	:	:	:	:	:	:	:	:	:	:	x
Norway	11.60	11.50	11.30	11.50	11.40	11.70	11.50	10.20	10.30	10.30	10.60	0.569
Switzerland	21.60	22.10	22.50	22.30	22.50	22.70	22.70	22.30	24.30	24.30	24.80	0.999
FYRoM	20.80	19.60	22.20	24.70	24.40	25.40	25.10	22.70	20.00	16.00	16.90	3.109
Turkey	47.60	46.00	45.10	43.70	43.10	40.70	40.80	38.30	36.30	35.10	32.30	4.639
Maximum	47.60	46.00	45.10	43.70	43.10	40.70	40.80	38.30	36.30	35.10	32.30	4.639
Minimum	10.20	9.10	9.00	8.80	7.70	8.30	9.10	8.00	8.60	10.20	10.60	0.177
Median	19.20	19.05	18.75	19.35	18.20	18.35	18.65	18.50	18.85	18.05	18.10	x
Explanatory notes	σ (standard deviation), EU-28 (28 countries of European Union), CR (Czech Republic), FYRoM (Former Yugoslav Republic of Macedonia), UK (United Kingdom), : (not available), x (not calculated)											

The average value of the first indicator (*share of collective transport modes in total passenger land transport by vehicle*) of 28 countries of European Union increased by 0.2 percentage point in comparison years 2015 and 2005. Turkey has the highest standard deviation (4.639) between 2005 and 2015. This means that there were the biggest

fluctuations during the years 2005-2015 in the analysed indicator. On the other side, Germany (0.177) and Finland (0.177) have the lowest standard deviation values of the analysed indicator. This means that Finland and Germany have the most constant values. Turkey reached the highest indicator values in all analysed years (2005-2015). Lithuania reached the lowest indicator values between 2005 and 2013 and Portugal reached the lowest indicator values between 2014 and 2015. Switzerland achieved the greatest increase of indicator value between 2015 and 2005; it was a growth of 3.2 percentage points. Turkey achieved the largest decline of indicator value between 2015 and 2005; it was a decrease of 15.3 percentage points.

The second analysed indicator is the *share of rail and inland waterways activity in total freight transport*. The results are presented in Table 3.

Table 3

Values of indicator *share of rail and inland waterways activity in total freight transport* (% of total inland freight tonne-km) [authors based on 15, 16]

State	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	σ
EU-28	24.30	24.50	24.50	24.50	23.10	24.30	25.00	25.30	25.10	25.10	24.80	0.576
Belgium	26.10	27.20	27.20	27.30	23.20	26.60	27.00	27.80	26.90	27.00	27.80	1.210
Bulgaria	49.80	50.50	51.90	51.80	49.60	50.60	43.90	47.10	44.00	45.10	45.30	2.978
CR	31.60	32.00	32.50	32.20	30.60	30.20	30.20	30.60	28.40	28.30	26.50	1.791
Denmark	:	:	:	:	:	:	:	:	:	:	:	x
Germany	30.10	30.20	30.20	30.00	28.30	29.50	28.70	29.20	29.30	28.70	28.70	0.664
Estonia	:	:	:	:	:	:	:	:	:	:	:	x
Ireland	:	:	:	:	:	:	:	:	:	:	:	x
Greece	:	:	:	:	:	:	:	:	:	:	:	x
Spain	:	:	:	:	:	:	:	:	:	:	:	x
France	14.40	14.10	14.10	14.00	13.50	12.50	13.70	13.80	13.60	13.70	14.60	0.527
Croatia	26.10	27.60	28.80	28.60	28.40	31.00	28.80	29.50	27.00	27.30	27.20	1.296
Italy	10.00	11.30	11.90	11.30	9.20	9.30	11.30	12.80	11.90	13.20	13.50	1.393
Cyprus	:	:	:	:	:	:	:	:	:	:	:	x
Latvia	:	:	:	:	:	:	:	:	:	:	:	x
Lithuania	74.10	71.70	71.00	73.10	70.40	72.80	73.70	70.30	66.60	68.10	65.90	2.674
Luxembourg	28.10	30.20	31.50	22.90	19.60	24.50	21.60	16.00	17.80	14.50	14.70	5.806
Hungary	33.50	33.30	32.00	30.80	29.80	34.50	34.20	36.20	36.80	36.60	34.90	2.195
Malta	:	:	:	:	:	:	:	:	:	:	:	x
Netherlands	49.20	49.30	51.80	50.90	47.00	51.60	51.90	53.30	51.70	51.90	52.00	1.693
Austria	39.00	39.20	38.40	37.10	35.60	37.00	36.50	36.40	35.90	36.40	35.10	1.298
Poland	36.60	37.20	36.40	34.00	28.90	29.60	30.00	27.70	26.40	26.60	25.60	4.216
Portugal	:	:	:	:	:	:	:	:	:	:	:	x
Romania	48.40	47.50	46.50	48.60	47.60	63.10	62.80	60.60	59.70	59.20	62.00	6.837
Slovenia	:	:	:	:	:	:	:	:	:	:	:	x
Slovakia	47.50	49.20	46.70	45.10	40.40	44.10	42.70	41.20	43.60	42.90	39.80	2.848
Finland	25.40	29.60	28.10	27.40	26.00	27.00	27.90	29.00	30.50	31.10	27.40	1.699
Sweden	:	:	:	:	:	:	:	:	:	:	:	x
UK	11.40	11.40	10.80	11.30	11.80	11.00	11.80	11.70	12.90	13.00	10.50	0.746
Iceland	:	:	:	:	:	:	:	:	:	:	:	x
Norway	:	:	:	:	:	:	:	:	:	:	:	x
Switzerland	:	:	:	:	:	:	:	:	:	:	:	x
Maximum	74.10	71.70	71.00	73.10	70.40	72.80	73.70	70.30	66.60	68.10	65.90	6.837
Minimum	10.00	11.30	10.80	11.30	9.20	9.30	11.30	11.70	11.90	13.00	10.50	0.527
Median	31.60	32.00	32.00	30.80	28.90	30.20	30.00	29.50	29.30	28.70	27.80	x
Explanatory notes	σ (standard deviation), EU-28 (28 countries of European Union), CR (Czech Republic), UK (United Kingdom), : (not available), x (not calculated)											

The average value of the second indicator (*share of rail and inland waterways activity in total freight transport*) of 28 countries of European Union increased by 0.5 percentage point in comparison years 2015 and 2005. Romania has the highest standard deviation (6.837) between 2005 and 2015. This means that there were the biggest fluctuations during the years 2005-2015 in the analysed indicator. On the other side, France has the lowest standard deviation value (0.527) of the analysed indicator. This means that France has the most constant values of the indicator. Lithuania reached the highest indicator values in all analysed years (2005-2015). Italy and United Kingdom reached alternately the lowest indicator values between 2005 and 2015. Romania achieved the greatest increase of indicator value between 2015 and 2005; it was a growth of 13.6 percentage points. Luxembourg achieved the largest decline of indicator value

between 2015 and 2005; it was a decrease of 13.4 percentage points.

The results of the assessment of both indicators are presented in the Fig. 1 in accordance with the Eqs. 4-6. The best rated countries that meet the following condition (Eq. 4) are: Hungary, Slovakia, the Czech Republic, Poland, Belgium, Romania, Bulgaria and Austria. All these countries have made greater average values than the average values of 28 countries of European Union in both analysed indicators. The worst rated countries that meet the following condition (Eq. 6) are France, United Kingdom and Luxembourg. These countries have made lower average values than the average values of 28 countries of European Union in both analysed indicators. Other countries have a middle rating in accordance with Eq. 5, because these countries have only one average indicator value higher than average values of 28 countries of European Union.

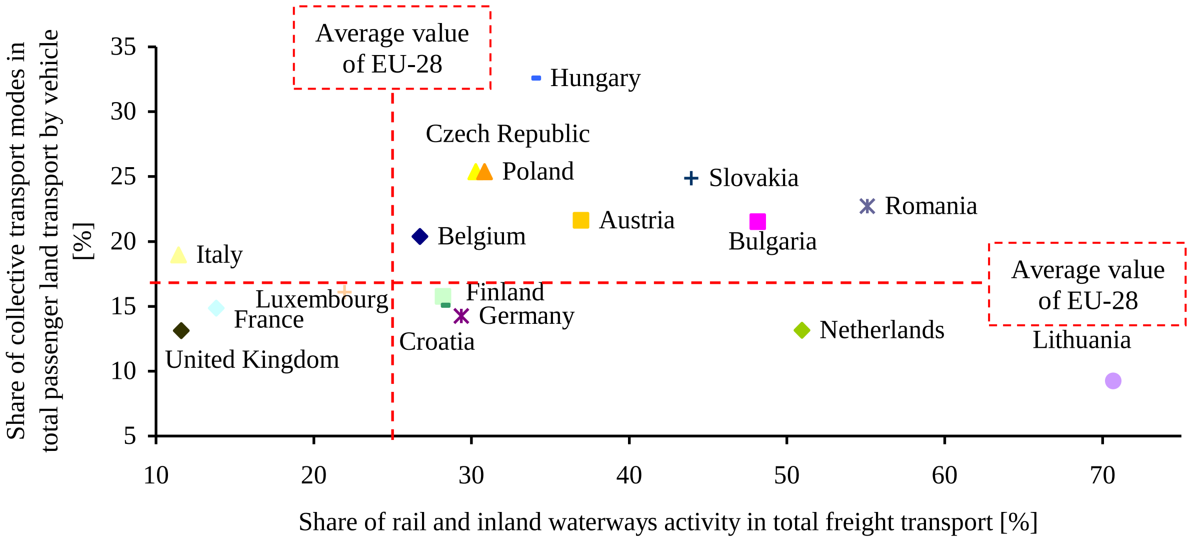

Fig. 1 Comparison of average indicators values [authors]

4. Conclusions

The issue of sustainable development is a very current topic because many subjects are involved in this area. EUROSTAT had defined seventeen groups of sustainable development indicators, but this article focused only on a group of selected indicators in the transport sector; those were: *the share of collective transport modes in total passenger land transport* and *the share of rail and inland waterways activity in total freight transport*. These indicators are closely related to the issue of sustainable transport.

Both indicators' values were analysed between 2005 and 2015 in selected European countries. Both the development of the value of these indicators and the development of the average of the indicators' values for EU-28 were evaluated. Based on this analysis the Visegrad Group countries (V4), Belgium, Austria, Bulgaria and Romania were the best countries in this rating; all of these countries reached greater values than the average value of EU-28 countries in both of the analysed indicators. The average values of both indicators of EU-28 countries between year 2015 and year 2005 had a positive trend. The average value of the first indicator (*the share of collective transport modes in total passenger land transport*) increased by 0.2 percentage point in comparison with years 2015 and 2005. The average value of the second indicator (*the share of rail and inland waterways activity in total freight transport*) increased by 0.5 percentage point in comparison with years 2015 and 2005.

The values of both indicators are affected by the quality of transport infrastructure and transport means, by macroeconomic situation, mobility requirements, by political environment and by legislative bodies and other specific factors in each country. For the future, it would be advisable to increase the indicator values. That would be in agreement with the principles of sustainable development and sustainable transport.

Acknowledgement

This article is published within the solution of project no. SGS_2018_023 „Traffic Engineering, Technology and Management".

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Mathematical Analysis of Factors Affecting the Road Safety in Selected Polish Region

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Abstract

The most important element of effective road safety management is to get to know the factors that influence it. If their influence is determined, then it is possible to describe this stochastic process mathematically and to make predictions about its evolution, which can contribute to more effective prevention of accidents and collisions on the road.
The article presents a detailed analysis of selected Polish region (Mazovian Voivodeship) in which not only the average number of accidents in recent years was the highest, but also the highest number of fatalities was recorded. Due to the complexity of this problem and considerable diversity of the country, such a selective analysis may prove to be more effective compared to the overall national model. On the basis of empirical data obtained from the Polish Road Safety Observatory, a mathematical model was proposed, allowing not only for mathematical description, but also prediction of future phenomena. Such models can be helpful in supporting rescue systems, shaping safety policy and raising awareness among road users.
KEY WORDS: *road safety, road traffic accidents, factors affecting the road safety, mathematical model*

1. Introduction

In 2017 in Poland there were over 32 thousand accidents in which 2 831 people died and 39 466 were injured, including 11 103 severely. These figures are very alarming and show how important it is to ensure an appropriate level of road safety. It is conditioned by many factors, and therefore the risk is variable within the country. The region in Poland, where the number of accidents in 2017 was the highest, is the Mazovian Voivodeship (Fig. 1), where there were the highest number of victims.

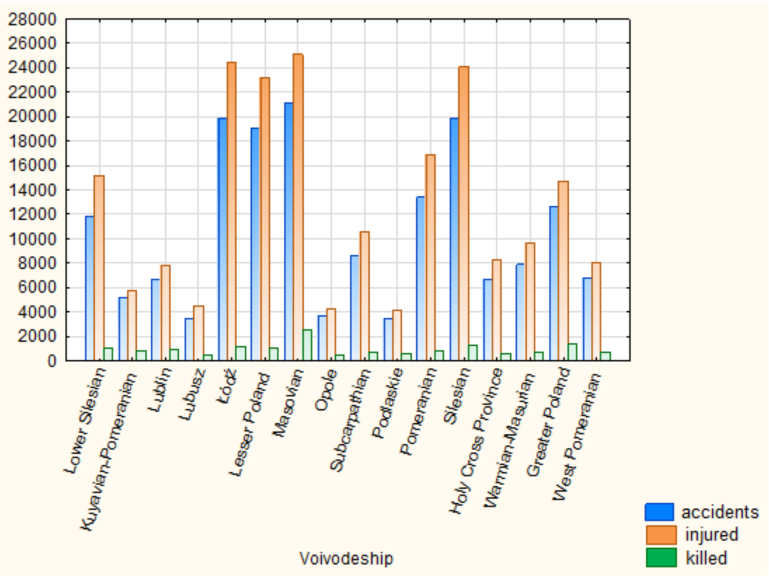

Fig. 1 Number of accidents in 2017 with division into voivodships

Detailed information on the road situation is collected by the Polish Road Safety Observatory (POBR) [5], functioning at the Motor Transport Institute in Warsaw. They enable to conduct an accurate analyze of accidents, as well as their causes and consequences. In this article, on the basis of available data, a detailed analysis of events that took place in the Mazovian Voivodeship was carried out.

2. Research Subject

The general characteristics of this phenomenon show that in 2017 the highest number of accidents in the Mazovian Voivodeship took place in October, which constitutes almost 10% of all events, and in December –

9.8% [5]. This is a result not only of worsening road conditions due to the difficult autumn and winter weather, but also of increased road activity in the holiday season around Christmas, which is the most dangerous time in the whole year. High indications (over 9% for each month) were also recorded from June to September, which is a result of increased traffic related to vacation period. January and February turned out to be the least conducive to accidents with about 5% result each. As regards weekdays, Friday has the highest indications (17% of total), and Sunday has the most favorable indications (11%). A great migration of the population is conducive to Friday's accidents, mainly for economic purposes (returns from the workplace to home) and educational purposes (trips to and from universities). These statistics are a part of national trends, which are shaped in a similar way for the whole country.

Therefore, we can see that the number of accidents can be influenced by many different aspects. Some of them result from the calendar – dates and these are dependencies related to the weekday or calendar month, caused by the variable intensity of road traffic. Another factor is deterioration of road conditions, which may be caused by poor condition of the road surface, weather or lack of road lighting. And it was the second group that underwent a detailed study.

3. Shaping Road Accidents – Mathematical Model

In order to perform a mathematical analysis, selected factors were grouped and in each set elements were distinguished, which were assumed to have a significant impact on the number of accidents. They were described in Table 1. Such a division coincides with the way of collecting data by the Polish Road Safety Observatory.

Table 1

Characteristics of analyzed factors

Weather conditions	**Lighting**	**Condition of the surface**
Good weather conditions	Nighttime – unlighted road	Holes, bumps, ruts, humps
Cloudy weather, fog, smoke	Nighttime – lighted road	Wet and/or polluted surface, puddles, floodplains
Rainfall, snow, hail	Daylight	Icy, snowy surface
Blinding sun	Dusk, dawn	Dry surface
Strong wind		

Due to the qualitative nature of factors, the mathematical description is based on multiple regression method, which enables forecasting on the basis of this type of variables [3]. For this purpose they were converted into binary variables (dummy variables). A large number of potential predictors decided to use the step regression method, which is a very useful tool in order to find the best possible model. Its undoubted advantage is also the elimination of collinearity problem, which occurs during the traditional construction of multiple regression model based on binary variables [1, 3].

The procedure of step regression can be automated and rely on gradual (step by step) introducing or removing variables from the model until a satisfactory determination factor of R^2 is obtained. Progressive regression involves the gradual addition of statistically significant explanatory variables to the model until improvement of R2 reaches the target level. Backward step regression assumes introduction of all analyzed predators at the same time and then gradual, single removal of insignificant variables from the model. The process ends if removal of a variable does not lead to fixed slope of R^2. A common feature of both methods is the fact that a given variable cannot be included in the estimation process more than once, which may affect the final quality of model and make it sub-optimal [4].

With reference to the above, the estimation of multiple regression function was carried out in three ways. Using the Statistica program, variables were selected based on progressive and backward method, and then manually, following the statistical significance of estimated parameters.

4. Research Methodology

The first stage of study was a visual inspection of the variable course. The diagram presented in Fig. 2 shows the existence of a trend.

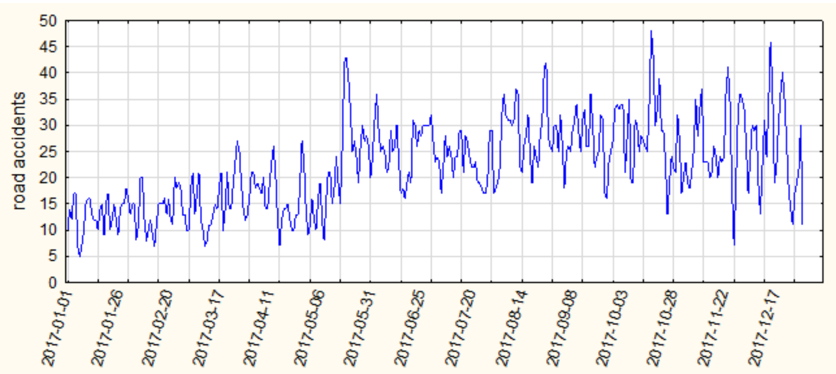

Fig. 2 Accidents in the Mazovian Voivodeship in 2017

Since the form of function characterizing the developmental trend of series is not unambiguous, it was extrapolated by studying the dependence of variable on the linear, square and logarithmic trend. The obtained determination coefficients for individual models are presented in Table 2.

Table 2

Determination factors for the trend function

trend	$y = \alpha\, t + \beta$	$y = \alpha 1t2 + \alpha 2t + \beta$	$y = ln(t)$
R^2 [%]	35%	42%	34%

All estimated parameters turned out to be statistically significant, but the highest determination coefficient value of 42% was obtained for the polynomial trend, and therefore its form was considered to be the best. The next step was to estimate parameters of multiple regression model. As mentioned above, it was carried out using two automatic methods available in Statistica program: progressive regression and backward regression [2]. In addition, two manual estimation models were proposed. The obtained results were presented in Table 3.

Table 3

Parameters of estimated multiple regression models

	automatic methods		manual methods	
	backward regression	progressive regression	model 1	model 2
absolute term	1.78	-2.24	2.76	1.44
t	0.17	0.16	0.17	0.11
t^2	-0.000328	-0.00031	-0.00035	-0.000202
Good weather conditions				
Cloudy weather, fog, smoke			-2.03	
Rainfall, snow, hail		1.99	1.44	2.44
Blinding sun	4.61	4.81		5.66
Strong wind				
Nighttime – unlighted road	2.32	2.28	2.31	2.33
Nighttime – lighted road	2.42	2.31	2.59	
Daylight		5.03		5.39
Dusk, dawn				
Holes, bumps, ruts, humps				
Wet and/or polluted surface, puddles, floodplains				
Icy, snowy surface	4.63	3.79	4.58	
Dry surface				
Multiple correlation coefficient R	0.73	0 .74	0.71	0.72
Adjusted coefficient of determination R^2	0.52	0 .54	0.49	0.51
Standard error	5.72	5.61	5.90	5.79

Conducted analysis shows that not all analyzed factors significantly influence the number of accidents. Aspects such as strong wind, driving at night or dawn, or damaged, wet or polluted surfaces have not been taken into account during any estimation, because of their lack of determined impact. All the above models achieved quite a high correlation coefficient of multiple R, informing about the strength of relations between explained variable and explanatory variables. However, a better assessment of the model is conducted by corrected determination coefficient. It expresses the percentage of variability of the dependent variable, explained by model. The obtained R^2 coefficients oscillate around 50%, which means that proposed regression functions explain the studied phenomenon only in 50%. This is due to the fact that number of road accidents is also affected by many other factors, which are not included in the model, such as technical condition of the vehicle, individual predispositions of the driver or road traffic intensity, which vary depending on the time, day or month in which the journey takes place.

The best result was obtained by the estimated model using progressive step regression. It is able to explain more than 53% of variable variance: number of accidents. The average difference between empirical values and model's predicted values is about 6 accidents (SE = 5.71). High value of statistics $F(9,355)=44,900$ and obtained probability $p < 0,0000$ confirm that the model is statistically significant. The final stage of its diagnosis is analysis of residues, which should have a normal distribution. This condition has been fulfilled, as confirmed in Fig. 3. Therefore, the obtained model can be considered as correct.

However, the correct construction of model does not change the fact that obtained determination coefficient is not high, and therefore significantly affects the adjustment of forecast function to empirical data. The function follows the series satisfactorily, but does not fully reflect the large deviations, both positive and negative (Fig. 4). It is caused by the recalled impact on the number of accidents of other important factors, which were not included in the model.

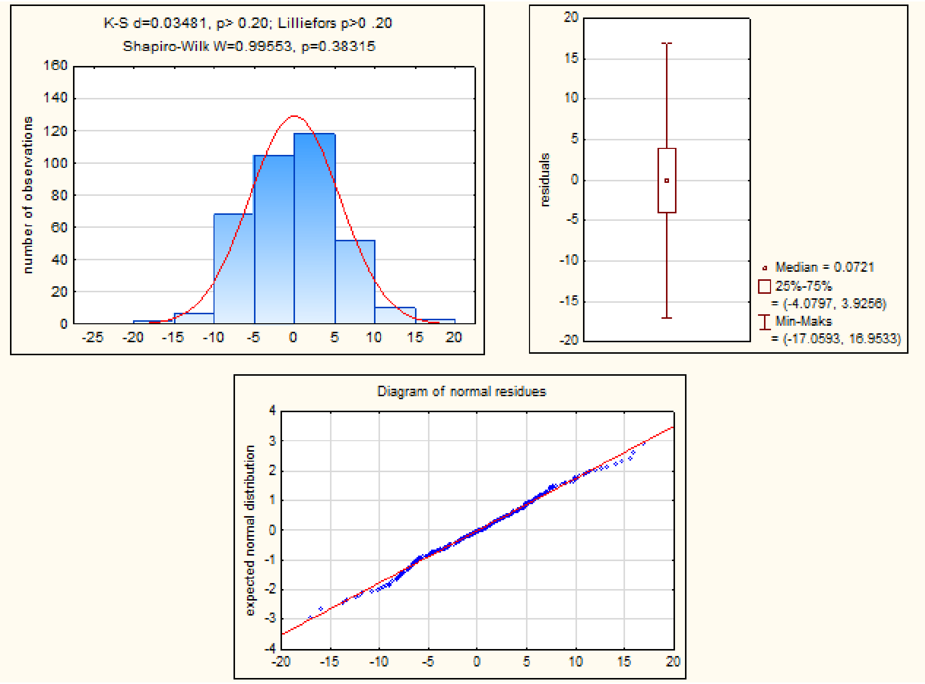

Fig. 3 Study of model residuals

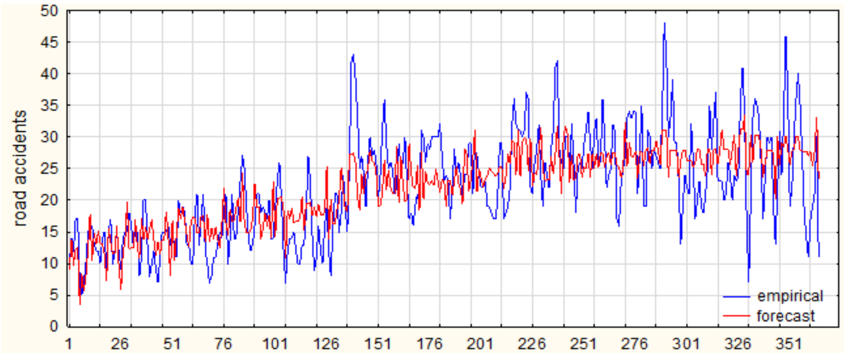

Fig. 4 Diagram of empirical values and forecasting functions

5. Conclusions

The aim of estimating a multiple regression model based on selected factors was to investigate which of them influence road safety and to what extent. It turned out that the number of accidents is higher during the day and they are often caused by blinding sun. This is also due to bravado of drivers, who in favorable weather conditions increase their speed of ride, lose vigilance and are not careful enough. Night driving is also conducive to an increase in the risk on road, particularly if the road is not lighted and if it is icy or snowy in winter.

Developed model may be helpful in shaping the level of road traffic safety. Although not all of these aspects can be modified by the man, as they are unable to change the weather, but it is possible, for example, to provide adequate protection in case of blinding sun. The condition of roads also depends on people. According to the study, it is worth focusing on their proper lighting, as well as snow clearance and de-icing at low temperatures. It turns out that such measures are more important in terms of safety than repairing a surface, which poor condition does not increase the number of undesirable events, probably because of driver's concern for their own vehicles and reducing speed on roads of doubtful quality. The results of analysis may also provide guidance for driving schools, suggesting a greater focus on shaping the right habits during the ride on slippery surfaces.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Utilization of Adams for Evaluation of Tracked Vehicle Vibration

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Abstract

Presented article deals with the problematics of tracked vehicle vibration when a vehicle crossing an artificial obstacle. Knowledge of evaluation of vibration due to human health according to ISO 2631 is mentioned in the introduction. Tracked vehicle simulation model in multi-body system MSC Adams has been suggested. Simulation data has been evaluated with respect to ISO standard. Partial outcomes and conclusions are given in the final part of the article.
KEY WORDS: *Multi-body system, tracked vehicle, vibration, modelling*

1. Introduction

Vibrations occur all around us and have a negative effect on human health. Therefore, it is necessary to examine the vibration levels that affect a human body already during a design of vehicle itself. By increasing vehicle comfort, we will reduce a crew fatigue and thus also increase combat capability Soldiers which are using tracked vehicles are exposed to vibration significantly higher than that of wheeled vehicles due to vehicle construction. In addition, there is high probability of kinetosis (motion sickness) [1].

Standards are beginning to emerge due to reasons mentioned above. They take into account the effect of vibrations on human body mostly in civilian area. Limits of exposure of human body to vibrations and methods of vibration measurement are found in these standards [2]. Majority standards are found under ISO standards – most of them that take into account the effect of vibrations on human body is referred to ISO 2631. The most important still valid standard is ISO 2631-1:1997 Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration – Part 1: General requirements [7].

However, there are still other standards issued by the European Committee for Standardization. These standards are related to WBV – EN 13490: 2001, EN 14253: 2003, CEN / TR 15172-1: 2005.

Although those ISO standards provide very extensive information, some foreign institutions have issued their own standards based on ISO. Namely we can mention The British Standard BS 6841, German Standard VDI 2057-1: 2017, US Standard ANSI S3.18: 2002 and US Defense Standard MIL-STD-1472G. All of these mentioned standards are based on ISO 2631-1, but some of them supplementing and modifying it.

2. Vibration Evaluation According to ISO 2631

Standard defines the ways how to evaluate the vibration with regards to sitting or standing figures. The norm uses frequency-weighted curves to evaluate vibrations on human body. Three basic methods are defined – weighted root-mean-square acceleration, the running r.m.s. method and the fourth power vibration dose method. Diagram on Fig. 1 shows methods of evaluation and assessment defined by ISO 2631. [3]

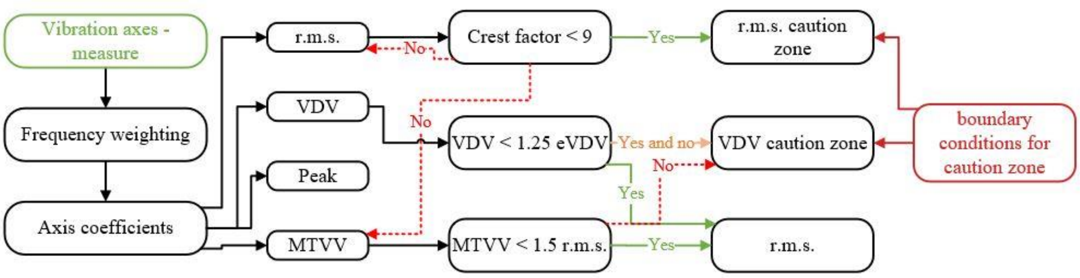

Fig. 1 Diagram of methods according to ISO 2631

Method of weighted root-mean-square acceleration

The assessment of vibrations in relation to human health must always include a weighted acceleration value. This effective value is given by the equation [3]:

$$a_w = \left[\frac{1}{T}\int_0^T a_w^2(t)\,dt\right]^{\frac{1}{2}}, \tag{1}$$

where a_w – weighted acceleration [m/s^2]; T – duration of measurement [s].

The suitability of the method is determined by crest factor. The crest factor de termines whether the basic method is sufficient for vibration evaluation. In case that crest factor is greater than 9, complementary approaches are chosen. The value of crest factor is determined by equation [3]:

$$\frac{MTVV}{a_w} = CF \ , \tag{2}$$

where a_w – weighted acceleration [m/s^2]; $MTVV$ – maximum transient vibration value [m/s^2]; VDV – vibration dose value [m/s$^{1.75}$].

The running r.m.s. method

This method takes into account the random shocks and transient vibrations very well. Using very short integration time constant is a condition. The calculation is given by equation [3]:

$$a_w(t_0) = \left\{ \frac{1}{\tau} \int_{t_0-\tau}^{t_0} \left[a_w(t) \right]^2 dt \right\}^{\frac{1}{2}} , \tag{3}$$

where $a_w(t)$ – instantaneous frequency weighted acceleration [m/s^2]; τ – integration time [s]; t – time of measurement [s]; t_0 – observation time.

Fourth power vibration dose method

This method, similarly as the running r.m.s. method, is more shock-sensitive than the basic method. The fourth power of vibration (Quartz vibration dose in [m/s$^{1.75}$]) is used instead of the second the power of vibration. This method is also applicable when time intervals are not the same and have different sizes. It is given by the equation [3]:

$$VDV = \left\{ \int_0^T \left[a_w(t) \right]^4 dt \right\}^{\frac{1}{4}} . \tag{4}$$

All three methods are very important, because vibrations are not only about the acceleration in time domain but also in frequency domain. Therefore, we also need to add frequency weighing.

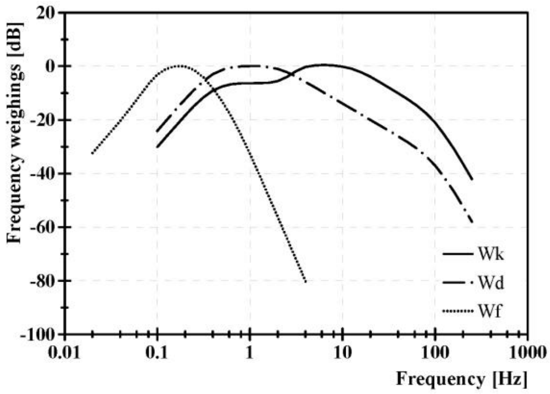

Fig. 2 Frequency weighing curves

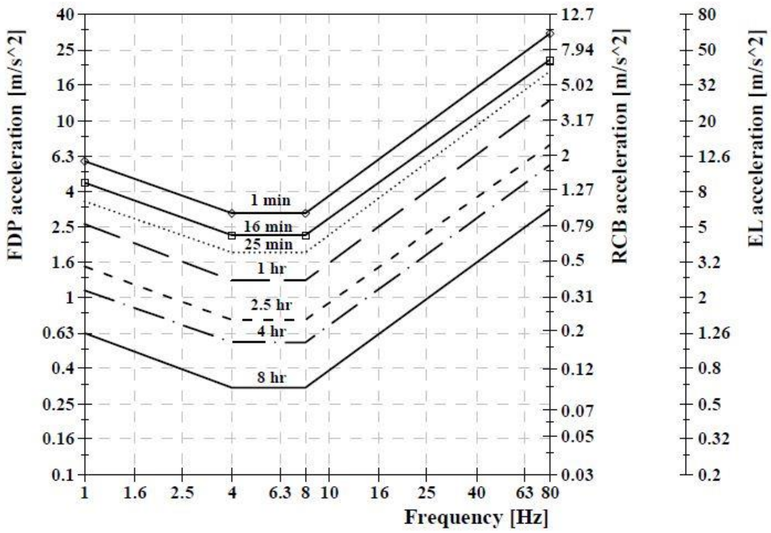

Fig. 3 Exposures limits

Using the frequency weighing we can evaluate the effect of vibrations on health, comfort, perception and motion sickness. Frequency weighing curves are shown in the Fig. 2.

The standard distinguishes three basic criteria determining limits for the assessment of vibrations in relation to human health – Exposure limit (EL), reduced performance limit (FDP) and limit of reduced comfort (RCB). [4] Mutual relationship exists between the WBV boundaries. The acceleration values for individual limits are shown in Fig. 3.

In most cases, the so-called vibration acceleration level in decibels and the 1/3 octave band is used for evaluation. The conversion is performed according to ISO 1683 [5] where the equation is:

$$L\left(a_{db}\right) = 20 \cdot log\left(\frac{a_{ef}}{a_0}\right), \tag{5}$$

where $L(a_{db})$ – vibration acceleration level [dB]; a_{ef} – acceleration effective value [m/s^2]; a_0 – acceleration reference value - 10^{-6} [m/s^2].

3. Simulation in MBS

MBS software MSC Adams has been used for simulation of tracked vehicle movement [6, 8]. The vehicle model of BMP-2 has been constructed, see Fig. 4. The vehicle overtakes a defined artificial obstacle of 150 mm high and 800 mm wide, at speeds of 30 and 40 km.h^{-1}. Simulations were made for the proposed path, which will also form the basis for experimental measurements.

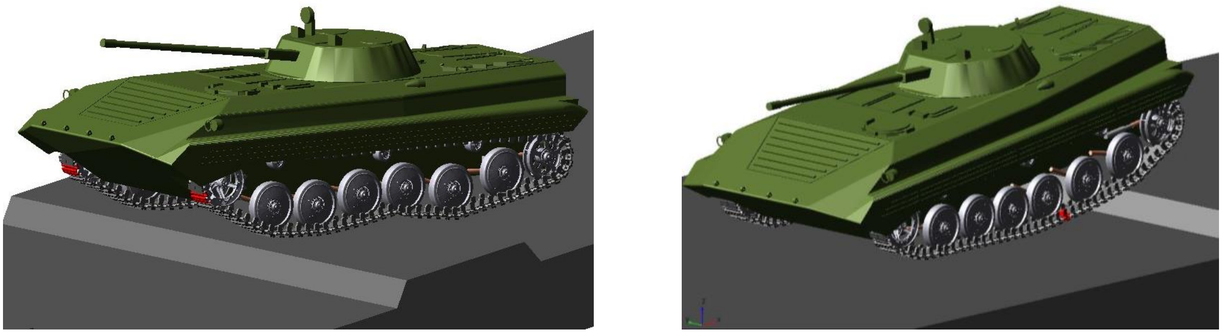

Fig. 4 BMP-2 model in MSC Adams

Simulation outcomes are accelerations in the driver compartment for different vehicle speed condition. Frequency weighting of simulation signal has been done in DIAdem software according to z axis of seated person. A comparison of simulated and frequency-weighted signals can be seen in Figs. 5 and 6.

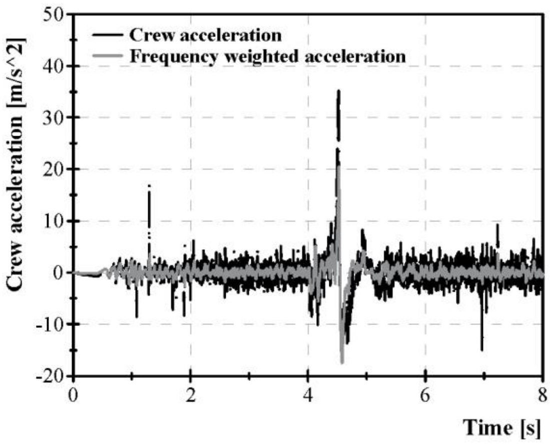

Fig. 5 Crew acceleration 30 km.h^{-1}

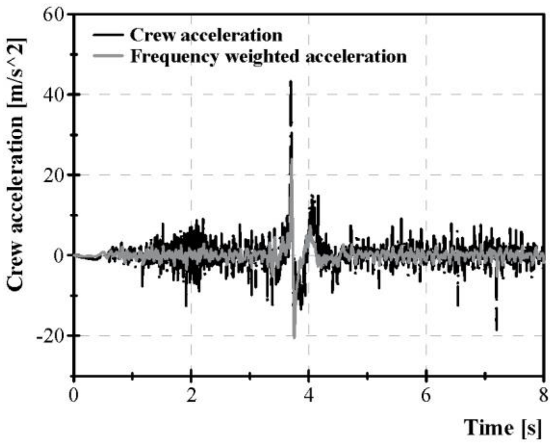

Fig. 6 Crew acceleration 40 km.h^{-1}

Spectral analysis of frequency-weighted signal needs to be performed for evaluation the effect of vibration to human organism. Spectral analysis has to be plotted in third octave band spectrum. By combining the curves on Fig. 3 and spectral analysis, the graphs of the effect of vibrations on human organism with respect to time intervals are obtained.

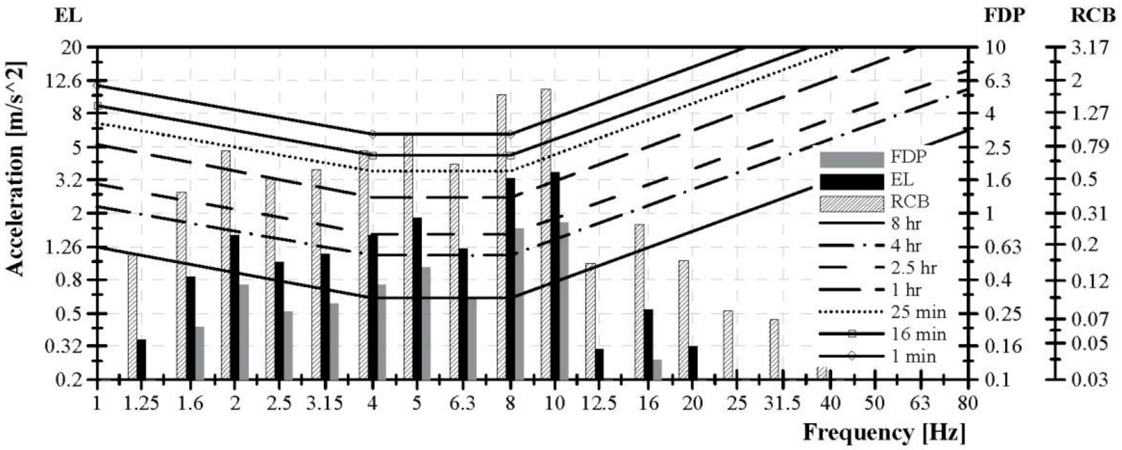

Fig. 7 Crew acceleration at 30 km.h^{-1} – FDP, EL, RCB

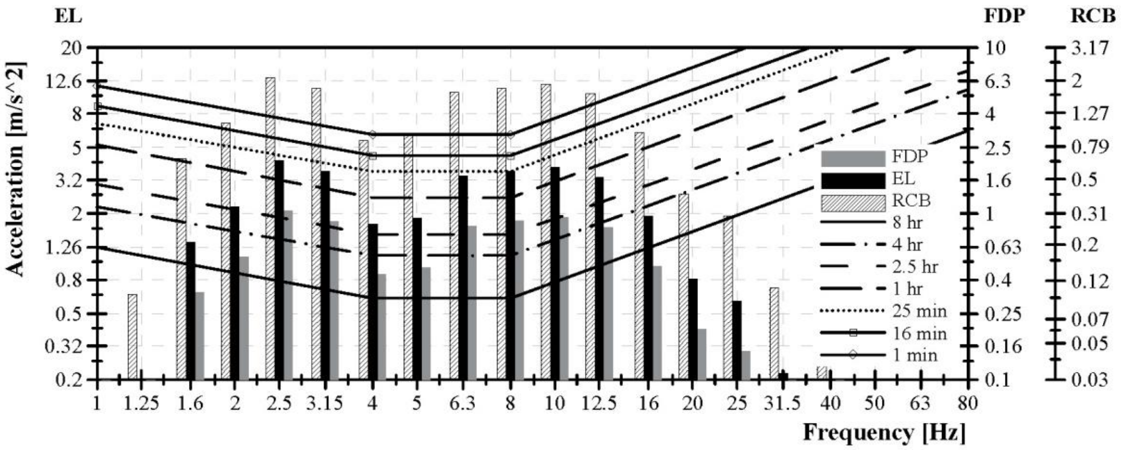

Fig. 8 Crew acceleration at 40 km.h^{-1} – FDP, EL, RCB

4. Conclusions

Human body is directly exposed to vibration in all means of transport. There are a number of standards that define approaches and indicate the boundary conditions of impact of vibrations on human body. Selected approaches are presented in the first part of the article. A significant disadvantage is that WBV standards are obsolete and are not subject to regular updates.

Combat and special vehicles have a specific usage. Thanks to these specifics, a crew of vehicle is subjected to considerably higher vibration effects that affect not only its comfort but also its health. The Norm ISO 2631 defines three basic criteria for evaluation of human vibrations – EL, FDP, RCB.

Simulation model of combat tracked infantry vehicle, which is currently in use by the Czech Army has been suggested. The model of vehicle was simulated on the proposed track, which is an artificial barrier – a perpendicular degree of 150 mm high. Measurements were made at crew and driver compartment and evaluated against the WBV.

For evaluation, the frequency weighing according to ISO 2631 and spectral analysis in the 1/3 octave band has been used. Outcomes for vehicle speeds of 30 km.h-1 (Fig. 7) indicate that the crew already felt the reduced comfort when the vehicle started operating, after approx. 1 hour of operation may endanger human health due to vibration. At the speed of 40 km.h-1 there is a gradual increase in acceleration that affect on the crew (Fig.8). The crew is experiencing a significant reduction in comfort, the safe operating time is reduced to about 25 minutes. Outcomes also shown that there is a risk of damage to health earlier than a reduction in the performance of human body itself in a combat tracked vehicle. It has to be added that each human body is different (weight, height, physical fitness etc.) and therefore every human body will feel the vibration effect a little differently. Therefore, the universal standards mentioned in the introduction of the article are introduced. Although the influence of vibration on combat tracked vehicle is considerable, comfort of the crew is in the last place after mobility, armored resistance and firepower.

Acknowledgement

The presented paper has been prepared with the support of the Ministry of Defence of the Czech Republic, Partial Project for Institutional Development, K-202, Department of Combat and Special Vehicles, University of Defence, Brno.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

LNG Bunkering Stations Location Optimization on Basis Graph Theory

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Abstract

As an alternative to traditional fuel and energy source LNG (Liquefied Natural Gas) has many advantages, such as lower emissions while providing a means of energy for trucks, trains and ships. In focusing on the maritime transport sector the reasons for using LNG make a convincing business case, but lead to many discussions on LNG investments. The key issue has been is: “should investment be implemented first on LNG bunkering stations and then wait for the market to build ships to use the facilities or should investment wait until there is a demand?” Obviously, this creates a “chicken-and-egg” situation on when and where to invest for LNG use to take place. The initial experiences in using LNG in maritime and road transport suggest that the transport firms often take the risk themselves by not only investing into the transport units (ships, trucks) themselves but also invest into the infrastructure as well, e.g., developing LNG bunkering facilities. At the same time with these large initial investments for developing LNG bunkering networks there are more and more requests for identifying optimal solutions, often are based on real LNG fuel demand in ports and on the roads.

This paper is oriented on the study for optimal bunkering network creation, which is argued to help with improved efficiency in the supply of LNG fuel to transport users. In addition, optimal investments for LNG bunkering networks can be realized.

KEY WORDS: *LNG fuel, LNG bunkering, transport corridors, optimization LNG bunkering network*

1. Introduction

Liquefied Natural Gas – (LNG) as energy source has been used since 1941 when it was derived from the first LNG liquidation facility located in the USA. Currently, more and more industries and transport means suck as sea ships, heavy road transport units, railway locomotives, and inland waterway ships, are using LNG as fuel. Concurrently with the increasing use of LNG there is a lack of LNG bunkering stations, which can hinder or slow down the progressive or wider use of LNG as fuel in the different transport modes [7, 8].

In developing an optimal network of LNG bunkering stations, a number of factors need to be considered in to the decision-making. Some of the major factors are: a link is required to a main transport corridor(s) that includes the following: (a) sea ports, (b) LNG import and LNG small scale terminals, (c) existing and/or planned transport vehicles or ships (d) bunkering capacities, (e) ability to deliver LNG to the bunkering stations, (f) fuel price differences between typical (oil) fuel and LNG fuel.

Transport means, such as trucks, locomotives and ships are using more and more LNG since there has been a rapid increase in LNG development, which requires more research in order to understand the situation [7]. Today more than 100 large ships are using LNG as fuel with a further 100+ large ships, including container ships with a capacity 22,000 TEU (twenty-foot equivalent unit), such as those ordered by CMA-CGM. Also, large manufacturers of heavy road truck, such as, VOLVO, MAN, DAF and others have started to produce trucks that have engines running on LNG fuel.

The demand for LNG bunkering and fueling station networks for the various transport modes is highly dependent on location or the distances to be traveled for bunkering or refueling. The physical distances between bunkering and fueling stations along with the economic costs or benefits can be identified and evaluated by the use of graph theory. A number of articles by [1-3, 6] indicate that the application of graph theory is a robust technique for evaluation and for modeling, for example the fueling stations are modeled as a set of vertices while the distances between fueling stations are modeled as a set of edges. In applying graph theory, we argue that it is an efficient means for analyzing the optimal location or investment for building facilities into a LNG bunkering and fueling stations network.

2. LNG Bunkering and Fueling Stations Situation Analysis

As more and more LNG powered ships are in use or on order the demand for developing bunkering facilities for the ships and fueling stations for the road and railway transport vehicles takes an important position. In the chart presented in Fig. 1, the demand for LNG can be identified from the number of ships in operation with more than 100 ships running on LNG. According to DNV LG, (9) there are currently 250+ confirmed LNG fueled ships, and about 120 additional LNG ready ships.

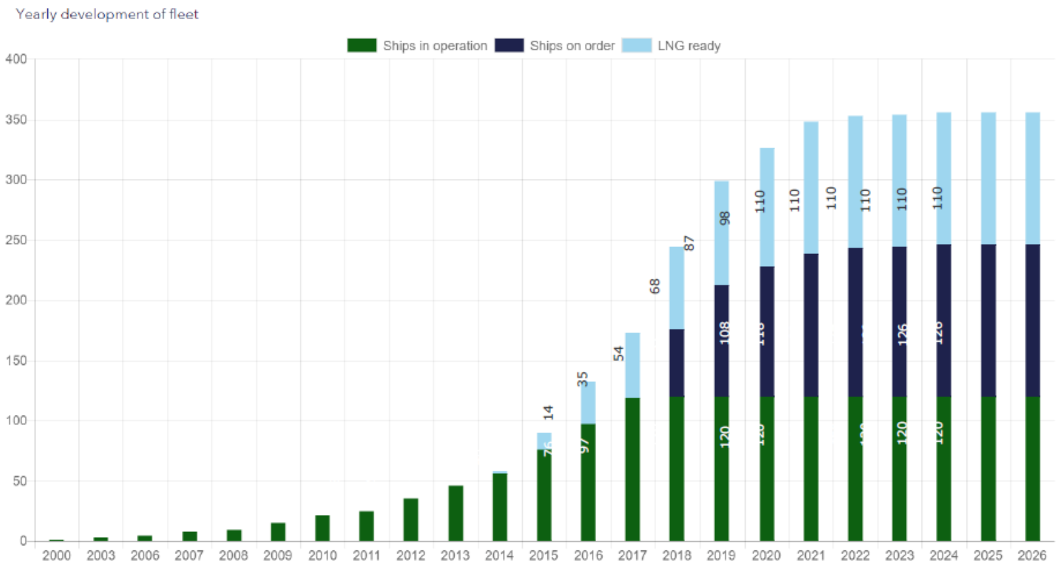

Fig. 1 Existing and planning LNG fueled ships (DNV LG information [9])

Currently, there exist several LNG bunkering stations in Norway, as well a few bunkering stations located in other countries in the Baltic Sea area. The map of LNG bunkering facilities is presented in Fig. 2 and identifies both existing bunkering stations and planned LNG bunkering stations.

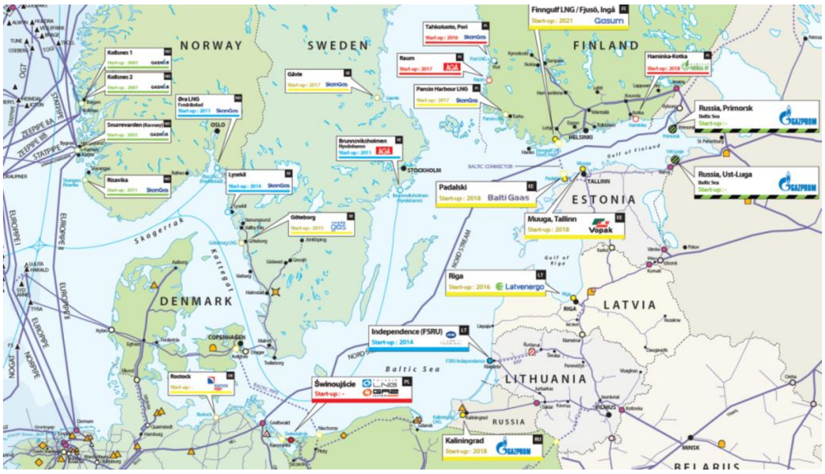

Fig. 2 Existing and planning LNG bunkering for the ships stations in Baltic Sea area (Kosan Crisplant information [9])

The East Baltic sea area has noticeably developed LNG bunkering stations and fueling stations in comparison to rest of the BSR very rapidly and are planning by 2025 to have an additional 8 – 10 LNG bunkering stations. Unfortunately, there is a lack of LNG liquation plants and small-scale LNG terminals in East and South Baltic areas, which are able, supply LNG according today requirements. The map in Fig. 3 illustrates the number and location of these facilities.

At the same time, often in many cases, Trucks that are powered by LNG are delivering LNG to users. Various studies have indicated, that the best economical use of LNG supply by trucks is when considering distances up to 350 – 500 km [8]. As example 500 km distance from Klaipeda small scale LNG terminal shown on Fig. 4.

For the viability of LNG to be used in the road network, the importance of LNG fueling stations is paramount along with their locations in LNG fueling stations network. According to an EU directive in 2025, members of the European Union must have LNG fueling stations operating on distances not more than 400 km from the main European transport corridors. As an example, Poland has installed 30 LNG fueling station with another, 20 LNG fueling stations to be built by 2018 and by 2022 up to 200 LNG bunkering stations on main roads. The map of LNG fueling stations is illustrated in Fig. 5 and shows their locations and status.

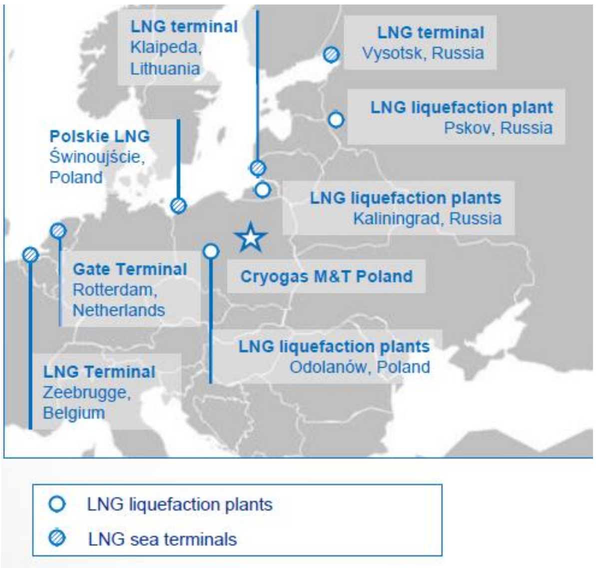

Fig. 3 Today able LNG liquefaction and bunkering facilities in East Baltic area (Cryogas information [9])

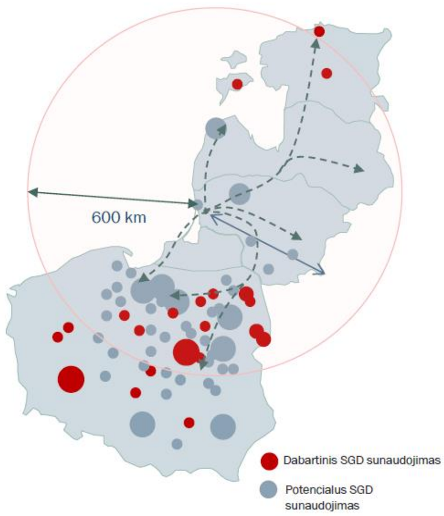

Fig. 4 500 km distance around Klaipeda small scale LNG terminal [9]

Fig. 5 LNG fueling stations plans in Poland (Barter S.A. information [9])

It is possible to conclude that LNG bunkering and fueling stations are very rapidly being developed in the Baltic Sea area and that an optimization of this process is very important for the optimal LNG supply for the transport means network creation.

3. Theoretical Basis and Practical Ways for the Optimal LNG Supply Network Creation

For developing an optimal LNG supply network the application of graph method is used in which a model is built that incorporates a set of vertices representing fueling stations and a set of edges that represent the distances between fueling stations. The optimal LNG supply network modeled as a graph is expressed as follows [5, 6]:

$$G = (V, E)\,, \tag{1}$$

where V - the set of vertices; E - the set of edges.

As an example, the LNG fueling stations network could be created in the East Baltic countries including Poland, as shown in Fig. 6.

Fig. 6 LNG fueling stations network as graph tree

For the graph tree, presented on Fig. 6, the sets of vertices and the set of edges can be expressed as follows [4, 6]:

$$V = \{v_1, v_2, v_3, v_4, v_5, v_6\}\,; \tag{2}$$

$$E = \{(v_1, v_2)(v_2, v_3)(v_2, v_4)(v_2, v_5)(v_5, v_6)\}\,. \tag{3}$$

The all-vertex incidence matrix of a non-empty and loop less directed graph for the presented graph tree G is [3, 5]:

$$A = a_{ij}\,,\ \text{where}\ \ a_{ij} = \begin{cases} 1\,\text{if}\ v_i\ \text{is the initial vertex of}\ e_j \\ -1\,\text{if}\ v_i\ \text{is the terminal vertex of}\ e_j \\ 0\ \text{otherwise} \end{cases}. \tag{4}$$

In this study for LNG bunkering and fueling stations networks the incidence matrix can be explained as follows [6]:

$$A = \begin{pmatrix} v_1, v_2, v_3, v_4, v_5, v_6 \\ v_2 \\ v_3 \\ v_4 \\ v_5 \\ v_6 \end{pmatrix}. \tag{5}$$

For the graph tree covering East Baltic countries including Poland, which is explained on Fig. 6, mentioned matrix in formula (5) could be computed as follows:

$$A = \begin{pmatrix} 010000 \\ 101110 \\ 010000 \\ 010000 \\ 010001 \\ 000010 \end{pmatrix}. \tag{6}$$

Finally for the optimum distances between fuelling stations or optimal price in the LNG bunkering and fueling network could be used next optimization formula [3, 6]:

$$f : E \Rightarrow R^{+} \tag{7}$$

and it is necessary find graph tree $T = (VE)$ price or optimal distance $F(T)$ like

$$F(T) = \sum_{xy \in E'} f(xy), \tag{8}$$

where $f(xy)$ - minimum price or optimal distance.

In study case the edges $e = xy \in E$ as minimum price or optimal distance could be find as follows [3, 4, 6]:

$$f(e) = \min_{xy \in E} f(xy). \tag{9}$$

Based on the work of graph theory, we argues that it is possible to design LNG bunkering and fuelling stations networks, and to consider LNG fuel demand forecast, since it is possible to identify the sets of vertices and the set of edges weights. In considering weights of the sets of vertices and edges it is possible to improve or identify the optimal location of planned LNG bunkering or fueling stations and supply system of the LNG fueling stations network.

4. Conclusions

This paper introduces the problem of LNG adoption in the Baltic Sea Region, like elsewhere; there is a gap in the knowledge for investing on bunkering and fueling stations. We argue that with the rapid developments on the demand side, such as larger ships being built using LNG as a fuel and with truck manufacturers introducing more and more LNG powered vehicles that the supply of LNG is weak. By adopting the concept of networks, we model a number of bunkering and fueling stations that are located in the Baltic Sea Region. The use of graph theory has shown to be a good method for modeling the problem and in evaluating various scenarios, such as optimal location of LNG bunkering and fuelling stations, Calculating costs based on distance between LNG bunkering and fueling stations. This method is argued to be suitable for investigating the situation of LNG supply and demand in the Baltic Sea Region and elsewhere. Graph theory (by considering such factors as capacity, location, distance) helped to obtain results that indicated that a minimum of 6 LNG fuelling stations are required in the East Baltic States and East part of Poland based upon location of fueling stations possessing distances between them at100 – 350 km.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Specifics of Rail Transport Safety in Condition of the Czech Republic

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Abstract

The paper deals with the issue of safety on railway communications in the Czech Republic. The primary goal is to analyze the specific features of safety on railway communications and its guarantee. The thesis identifies and analyzes the risks and the probable causes of emergencies. The secondary goal is focused on the safety of traffic regarding ČD Cargo, a. s. and suggests regulations to improve the current condition. The thesis studies the safety on railway communications, analyzes the railway sections that are necessary for the safe railway operation as well as the causes of emergencies and their consequences.
KEY WORDS: *Emergency cases, security device, railway*

1. Introduction

Rail safety is a serious issue. Given its social and economic importance, it is thus a priority for the state to ensure the highest possible safety and security of rail transport. [9] Therefore, authorities and institutions are established to oversee safe operation and ensure proper conditions for fulfilling these goals [1]. In practice, this means using modern technologies and processes. In terms of the operational aspect, emphasis is placed on ensuring that the information is fully provided, as well as, consequently, the necessary training of the employees involved in traffic management [12]. At present, the most common concept of social sciences has become the concept of safety. In a comprehensive understanding of safety, the departure from the predominantly military point of view of state security is currently important. This departure from the traditional perception of security is caused by the predominantly increasing consequences of non-military risks [11]. One of these risks is the risks related to rail transport safety.

Rail transportation safety is the primary task of all effected entities, starting with Správa železniční dopravní cesty (the Railway Infrastructure Administration) and carriers, to administrative authorities and railway organizations. It is a priority for the state to set the legal framework and to supervise its observance, and to work on its modifications given by the current circumstances, developments or regulations of the European Union. Rail transport is specific by the conditions under which it is carried out, and ensuring its safety must always be maximal, regardless of the amount of funding invested in the infrastructure. [15] In terms of the density of their network (0.12 km/km^2 of the area of the Czech Republic), together with Belgium, railways in the Czech Republic are among the largest in Europe. In total, about 9.5 thousand km of tracks are operated here. From the point of view of the capacity of the railway network, if we ignore its poor state due to poor and slow renewal of essential resources, lack of maintenance and delays in general technological developments (see the issue of high-speed lines), the existing rail network would suffice for significantly more transportation of people and cargo volumes than are currently being achieved. Some of the devices are as old as when the railway began to build and expand in the 19th century. Today's rail network in the Czech Republic is virtually identical to the railway network from the beginning of the last century. J. Dušek informs more about the issues of economy, transport and infrastructure [4-6].

2. Materials and Methods

The main aim of this work is to analyse railway transport safety in the Czech Republic and its specifics, e.g. operational securing and management of rail transport and railway tracks. Analysing emergency situations in rail transport and its corrective and preventive measures at present. A secondary aim is to highlight the positive and negative aspects of rail transport safety solutions in selected case studies. The work is based on available professional literature, internal materials (České dráhy, a.s., state organization Railway Infrastructure Administration, ČD Cargo, a. s., Railway Inspectorate) and legislation.

A collection of information that was systematically organized was used as a methodological approach to the implementation of goals, and the quantitative indicators of extraordinary events and their causes were evaluated. The research of literary, electronic and legislative sources was used to write them. This paper highlights the legislative aspects of rail safety in a broader context. The correctness of the outlined issue was verified by the synthesis and secondary analysis of the statistical data from state organization Railway Infrastructure Administration (hereinafter

"SŽDC") and the Railway Inspectorate (hereinafter "DI"). For a more precise introduction into the issue, case studies of selected railway incidents and their analysis from the point of view of ČD Cargo, a. s. were used.

3. Safety Equipment

Since the beginning of the railroad, there has been significant progress in safety equipment, from mechanical, electromechanical and relay to today's electronic security [3]. These systems are gradually replaced by newer and more modern ones, so the different types have to communicate with one another and, most importantly, faultlessly secure the operation of railway traffic. More safety is the goal of all decisions when planning new machines and complex equipment, but also different types of activities. In order to achieve this goal, it is important to pay attention to all of the components of the "human-machine-environment" system [10].

The purpose of this equipment is, first and foremost, to ensure the correct positioning and secure switches lying in the tracks for the entire duration of the train's trip and avoid the positioning of other routes that would interfere with the already-developed route. The safety and reliability of rail transport is conditioned by the trouble-free activity of safety equipment [7]. Furthermore, it must ensure that there is no other rail vehicle on the rail route (with the exceptions of shunting, where it is permitted to enter the occupied track), and it significantly reduces the human factor failure [8]. Safety equipment then greatly contributes to reducing the need for human resources, increasing the speed of trains and the throughput of stations and tracks. The progressive upgrading of safety equipment leads to the centralization of operational control from service facilities. Segmentation of safety equipment according to the secured area:

- station safety equipment;
- track safety equipment;
- crossing safety equipment;
- train safety equipment;
- catchment area safety equipment.

According to the safety level, safety equipment is then divided into three categories:

- category I equipment – this is the easiest securing, where the line speed does not exceed 60 km/h and where only the serving staff is responsible for the train running and shunting;
- category II equipment – includes equipment for lines where the speed does not exceed 100 km/h. Train running and shunting is provided by securing equipment, and other matters are the responsibility of the equipment staff;
- category III equipment – this is equipment intended for a line speed over 100 km/h, and only securing equipment without the co-responsibility of the serving staff secures train running and shunting.

4. Rail Transportation Safety

The railway network in the Czech Republic is very extensive, and with its nearly 9,500 kilometres, it is one of the densest in the world. Its reconstruction and modernization are carried out in full operation, making the process more complicated. In the event of closures, the requirements of building contractors and those of carries for utilization of infrastructure must be combined. These requirements are sometimes contradictory, and complications cannot be avoided. During construction, the latest securing equipment and safety components are being applied, in particular on transit corridors as part of the construction of the Trans-European Transport Networks, TEN-T. Even the securing of regional routes is not taken lightly and modern safety systems such as Radioblok or transition to remote control are used. Through gradual modernization, safety is being rapidly improved on these lines. The introduction of new electronic and computer-controlled systems further eliminates errors caused by the human factor.

Rail transport has its advantages and disadvantages compared to other modes of transport. It has the potential to move large numbers of people and goods over long distances in a relatively short time, while its limitation is the density of railway infrastructure, which is largely placed over more populated areas and larger urban agglomerations. This results in its worsened availability with the necessary connection to another mode of transport.

Another limitation stems from the nature of the movement of the railway wheels along the rail. This connection is extremely effective in terms of the energy required to drive vehicles. On the other hand, it has worsened braking conditions, which are several hundred meters depending on speed and weight. For fast train sets with a maximum speed of 160 km/h, it can be up to 1,200 meters before the train completely stops, and thus the railway needs its own specific control and marking system.

The number of emergencies on railways is a monitored indicator, and its thorough analysis is a paramount aspect in preventing these undesirable situations. Year-on-year there is a slight variation in the number of emergencies, but over time the tendency is slightly decreasing and the situation in terms of the number of emergencies is improving [2]. The decrease in emergencies indicates that rail transport can be well-utilized for the transport of dangerous substances [13]. The largest number of accidents in rail transport comes from collisions of rail vehicles with persons, and these cases are responsible for the highest number of killed and injured persons. Pursuant to Section 4a, paragraph 2, Act No. 266/1994 Coll., on Rail Systems, as amended, with the exception of intersection of the track with roads, platforms, etc., all of the locations on the track and in the track zones are inaccessible to the public. However, this is neglected by the public and people often risk their lives. Accidents with rail vehicles also include railroad employees and persons acting with suicidal intent, who are the most involved in this. Fires and collisions of rail vehicles are not as frequent of a

phenomenon and are rarely encountered.

There were a total of 153 rail vehicle collisions with obstacles in 2015, and there were 16 injuries and no deaths in these cases. The conditions under which rail transport is operated with respect to other laws, such as Act 114/1992 Coll., on Nature and Landscape Protection, which is in some provisions contrary to the Rail Act, are largely responsible for these extraordinary events. The track manager can not sufficiently apply the provisions on the track protection zone and there is insufficient treatment of the surrounding area. For this reason, there are frequent collisions with fallen trees. Another cause is vandalism when various objects are placed on the rails [14].

Incidents at railway crossings are largely responsible for creating emergencies [16]. It is evident that the trend in the number of these situations is gradually declining. While 190 emergency situations occurred in 2011, two years later there were 180 and in 2015 there were 165 of these incidents, the lowest number in the reference period. Upon doing more detailed research, we find that persons killed were approximately the same in 2011 (34) compared to 2015 (32). An exception in this respect was 2014 when 43 persons were killed. Compared to 2014, there was a 69% increase in the number of injured persons during collisions on crossings in 2015. This can be explained mainly by the fact that there were more accidents in which more injured persons were involved. A large proportion of these accidents were collisions with lorries and trucks, and a considerable amount of the increased number of injured persons in 2015 involved a bus accident at the railway crossing in Studénka, where a total of 25 persons were injured.

In 2015, the highest proportion of collisions was at crossings with light signalling without gates in 71 cases, during which there were 13 fatalities and 81 injuries. With regard to crossings secured only by warning crosses, there was one incident less, but the composition of the killed and injured persons is significantly lower. It can be assumed that there are lesser securing measures on less frequented regional routes, where the line speeds in the vicinity of crossings are significantly reduced, so even if an incident occurs, the consequences of the accident are not as fatal.

The fewest accidents are on crossings with light-signalling and gates. The disparity is mainly in the number of emergencies and their consequences, when 11 people died in 24 incidents and 30 were injured. This is mainly due to the fact that such secured crossings are on the main lines with fast line speed. Most of the accidents in this case were caused by pedestrians and cyclists who overcame the gates and found themselves on the track that the train passed through.

5. Conclusion

This paper deals with the specifics of rail transport safety. It focuses not only on the well-known problems associated with rail transport, but rather on the specifics of practice. Attention was primarily focused on safety in terms of operational securing. With rising track performance, especially in a situation where an emergency occurs, high demands are placed on employees, as well as the need to resolve problems immediately in the shortest possible time. The principles of the operation of train safety at stations and on the track were characterized. Safety equipment is designed to prevent erroneous manipulation of operational staff and eliminate the possibility of accidents. Modernization includes the implementation of newer safety equipment that enhances safety on railway lines, and in general, railways as a whole are one of the safest types of transport.

Emergencies and the prevention thereof is a key topic of rail issues. On the basis of their analyses, there are subsequent changes in the regulations and technological procedures that lead to the minimization of the causes leading to extraordinary circumstances. This is why rail transport safety was reflected and the structure and dynamics of emergencies was analysed. It is evident that the implementation of new technologies and processes in operation is gradually decreasing incidents. The cooperation of the bodies involved in the provision of specific transport and mutual cooperation in dealing with and preventing emergencies is exemplary, and given that ČD Cargo is among the five largest railway carriers in Europe, it is a prerequisite for ensuring safe transport in large volumes.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Investigation of the Harmonic Response on the Simple Structure in Structural and Acoustic Domain by Experimental and Numerical Approach

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Abstract

Nowadays the vibro-acoustic issues are to the foreground and these questions are often topics in transport engineering. Largely in sphere of automotive, there is daily discussed particularly the passenger safety, car performance and speed, driving comfort which is significantly influenced by vibrations and emitted noise. At first stage, before the harmonic response analysis could be investigated, the modal parameters need to be determined. According of gained modal parameters it is possible to continue in the next stage. In terms to examine the critical places on the structure, experimental measurement and numerical simulation based on the finite element method (FEM) are proposed. This paper primarily includes investigation of operating deflection shape (ODS) and sound pressure level (SPL) on simple structure. Mutual validation of two approaches is required in text below.
KEY WORDS: *Vibration and noise, Harmonic analysis, Experimental and numerical approach*

1. Introduction

Vibration and noise are clearly physically demonstrable from the point of view of the interconnection between machinery and humans. In this case, for example some utility machines - tractors, cranes, as well as transport vehicles - ships, trains, aircrafts and, of course, cars. The main issues that are directly related to vibro-acoustics are performance requirements, user safety and currently increasing interest in comfort.

In current praxis, all new technical products on the market are being developed through experimental measurements and computer simulations. In terms of eliminating vibration and noise from the investigated machinery, the ODS, the SPL, sound intensity and sound power are primarily investigated.

Prior to the very beginning of the analysis, investigation and evaluation of data, several appropriate steps are taken. At the very beginning, the geometry of the investigated component is considered. Especially there are considered possibilities of laboratory tests: available space capacity of the workplace, hardware and software equipment.

The first step is to validate structure from the geometry, weight, volume, most often through 3D scanning. The main benefit of this stage is more accurately specifying the material density of the component. In the first phase of the investigating, an experimental modal analysis is performed, from which the resulting custom modes of the component are obtained in the desired frequency range [1]. Simultaneously with this step, a numerical model is also created. The knowledge of these two approaches allows the validation of individual results of their own shapes and so possible partial modification of material properties such a Young's module, Poisson's constant. This approach is standardly applied in engineering practice. After sufficient validation of the modal properties, it is possible to proceed in a harmonic analysis. Experimental setup and numerical model for harmonic analysis is different compared to modal analysis according of the knowledge of the equation of motion. In case of harmonic response analysis, the specific load is applied at the particular place of the structure. In many times, the forced oscillation with harmonious excitement is used.

This article illustrates two approaches of investigating ODS and SPL on a simple specimen from the gearbox. The examined part was a rectangular planar plate made of the cast iron steel [2]. The paper describes how to set up an experimental measurement and also requires the creation of numerical model using FEM.

In the final part of the article, the comparison of the eigen frequencies is shown in two considered variations including with percentage differences. Subsequently, the values of normal acceleration of the selected shape are dominantly investigated. The results also include comparison of the sound pressure level from the experimental measurement and the numerical simulation for the selected own shape of the plate.

2. Experimental Measurement

The entire measurement setup has a lot of important aspects. From the preparation of the investigated structure, through the hardware and software equipment, to the final analysis of the obtained data. It is necessary to proceed

progressively on the basis of certain requirements. For this reason, the whole laboratory measurements were divided into several successive steps [3]:

1. Verification of main geometric dimensions (length, width, thickness), weighing and subsequent determination of material density.

2. Experimental modal analysis - For the determination of modal properties, a modal hammer was used at this stage, which is normally used for vibro-diagnostics. Before the tests, points were marked on the surface of the specimen with sufficient density. These points served in this case as places in which the structure was excited (application of impact signal). The structure was placed on a low-rigidity foam to provide free boundary conditions. At one of the points, an acceleration sensor was applied to which the structure response signal was recorded. Thus, the frequency response functions (FRF's) could be evaluated. According to the frequency range, the modal properties were expressed - eigen frequencies, eigen shapes and modal damping of the investigated structure [4, 5].

3. Experimental harmonic analysis – The measurement focused on the investigation of ODS and SPL took place in a special anechoic chamber (see Fig. 1). In this type of analysis, a modal vibration exciter was used as the source of vibration excitement. The structure was hung by silk lines (P7) on iron struts (P1). The vibration exciter was firmly attached on the lodge (P3), wrapped in special non-reflective material (P2). The excitation was applied from the vibration exciter to the structure via the excitation rod (P5). A force sensor (P6) was used to record the excitation signal. In this case, a contactless measurement of the response signal was applied through the laser vibrometer (P4). Based on this type of signal scanning, a special reflective tape was glued to the surface. The SPL was recorded by two condenser microphones placed in front of the investigated structure (P8). The 5-channel Bruel & Kjaer analyzer together with the PULSE Reflex computer software was included in the measurement equipment for mediation, processing and subsequent evaluation of the measured signals [6].

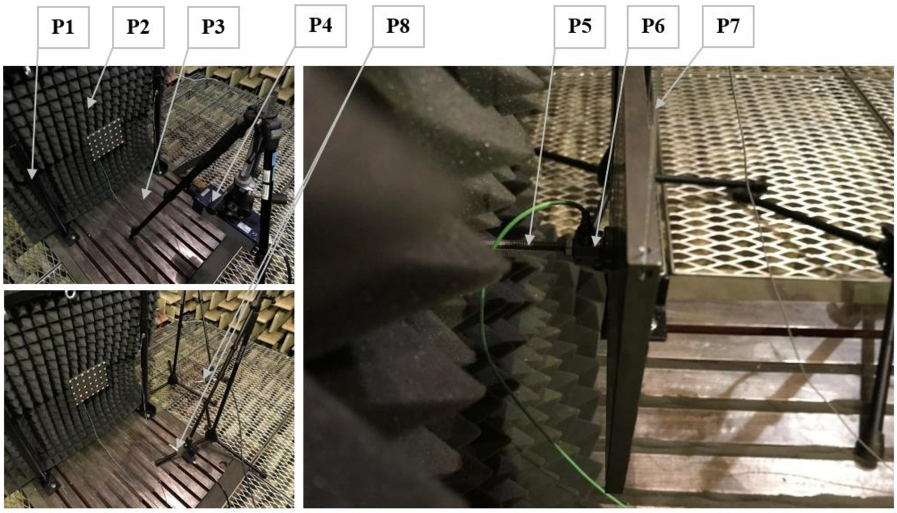

Fig. 1 Measurement setup

3. Numerical Model

The possibility of comparing and mutual verification of results between experiment and numerical simulations is nowadays a standard issue. In compiling the computational model, it is necessary to keep as close as possible to laboratory measurement.

In numerical simulations, it is important in the first step to validate material properties through modal analysis. In the first variant, an engineering data based on the specifications of used material was included in the numerical model. In Table 1 it can be seen, that after backward validation of geometry and the modification of material density and Poisson's ratio, values of the natural frequencies from simulation are more similar to the experimental data. In next step, it was possible to perform harmonic structural analysis. The numerical model with the applied force and the “Response point 1” with the normal acceleration progression is shown in Fig. 2. In the numerical model was applied:

- Free boundary conditions;
- Frequency range setup;
- Applied load in place of the force sensor according of measurement;
- Damping from experimental modal analysis;
- Geometry of the plate was sliced based on the measuring points placement.

When composing a numerical model in the acoustic domain, the possibility of linking with the structural analysis (harmonic response solution to the setup of harmonic acoustics) was used. Thus, normal surface velocities were imported into the acoustic model. In the models, the spherical enclosure of the acoustic space was included, the radiation boundary condition was applied on the surface. This condition ensures the experimental conditions of the anechoic chamber.

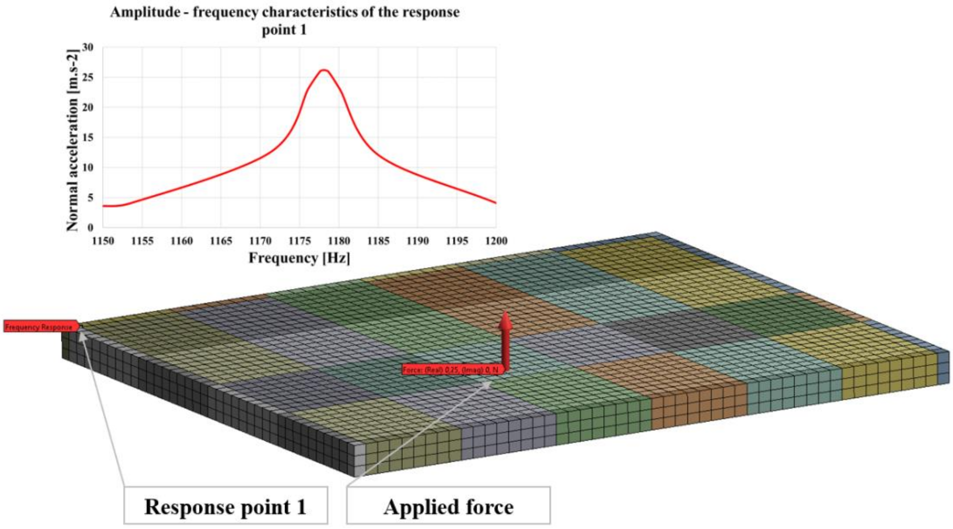

Fig. 2 Mathematical computational model

4. Results

Through two approaches, the modal properties of the investigated planar plate were verified at the initial phase. In Table *1*, the values of the eigen frequencies are compared before and after the material modification in numeric models. Based on the validation of geometry and the subsequent determination of real weight, the material density was primarily modified. After re-comparison of the experimental and numerical data, a significant percentage improvement occurred. It can be seen in Table *1* in the last column.

Table 1

The comparison of the eigen frequencies [Hz] obtained from the experiment and numerical simulation

	Experimental data	Material data according specification	Difference [%]	Material data according real mass	Difference [%]
Density	-	7107 kg.m^{-3}	-	6880 kg.m^{-3}	-
Young‘s modulus	-	169 Gpa	-	169 Gpa	-
Poisson's ratio	-	0,275	-	0,285	-
Mode number					
1	920	909	-1,2%	920	0,0%
2	1180	1160	-1,7%	1178	-0,2%
3	1926	1884	-2,2%	1922	-0,2%

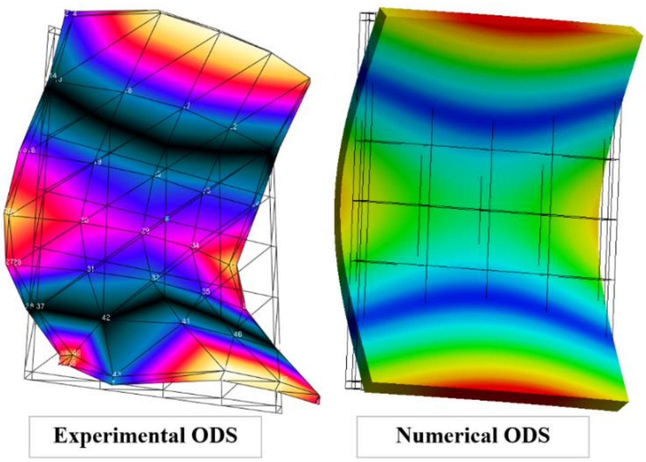

Fig. 3 ODS‘s of the 2nd eigen mode

Investigating harmonic analysis was a next level of vibro-acoustic diagnosis compared to modal analysis. From FRF's, real amplitudes were examined, as the response on the external loads. In the structural domain, the amplitudes of normal acceleration of the specimen surface were evaluated at 35 points. On Fig. 3 the ODS’s are shown from experimental measurement and numerical simulation. In this case, the bending eigen shape of the investigated component was excited. There is some agreement on the picture between two rendered eigen shapes. Real values of normal surface acceleration are depicted in Fig. 4. These results show the differences that occurred between two

approaches. It should be mentioned that the numerical calculation is significantly affected by the given damping. In several cases, the damping input could be inaccurate, which leads to wrong results. Therefore, it is good to consider either setting the entire experiment or modifying the damping value itself which enters to simulation.

The SPL results from harmonic acoustic analysis are evaluated eventually. Based on the microphone placement in the anechoic chamber, the SPL's were evaluated by the numerical simulation at the given locations. SPL's comparison is shown in Table *2*. The percentage differences from both approaches are also included in this table.

Experimental data						
26,3	0,6	21,8	29	20,1	2,27	28,3
33,1	8,48	12,9	20,4	12,1	9,06	34,5
36,6	11,8	9,16	17,1	9,13	11,3	36,7
33	8,04	12,3	20	12,1	7,5	34,6
26,3	1,25	19,9	29,1	20,5	0,728	27,7
Numerical data						
27,0	0,4	20,9	28,9	20,9	0,4	27,0
33,3	7,5	12,4	19,9	12,4	7,5	33,3
36,2	10,4	9,3	16,8	9,3	10,4	36,2
33,3	7,5	12,4	19,9	12,4	7,5	33,3
27,0	0,3	20,9	28,9	20,9	0,4	27,0
Differences						
2,7%	-36,1%	-4,1%	-0,2%	4,0%	-82,7%	-4,6%
0,6%	-11,4%	-4,1%	-2,2%	2,2%	-17,0%	-3,5%
-1,2%	-11,5%	1,5%	-1,8%	1,8%	-7,6%	-1,5%
0,9%	-6,5%	0,6%	-0,3%	2,2%	0,2%	-3,8%
2,7%	-74,5%	5,0%	-0,6%	2,0%	-51,1%	-2,5%

Fig. 4 Amplitudes of normal acceleration [$m.s^{-2}$] in marked points of the 2nd mode shape

Table 2

SPL's of the 2nd mode shape from two different approaches

SPECIMEN SPL						
	Experiment [dB]		**Ansys [dB]**		**Difference [%]**	
Frequency [Hz]	**Mic1**	**Mic2**	**Mic1**	**Mic2**	**Mic1**	**Mic2**
1180	67,8	70,48	65,49	65,694	-3,4%	-6,79%

5. Conclusions

As has been briefly explained in this article, it is necessary to verify the experimental and numerical data. From the modal analysis, own frequencies and own shapes are expressed, on the basis of which it is possible to predict the critical places on the structures. Experimental modal analysis also characterizes the modal damping, which is one of the input parameters of harmonic analysis. From the point of view of determining the real amplitudes, the forced oscillation with harmonious excitement is preferably used in vibro-acoustics. This initial study of simple specimen explains the approaches that are used in vibroacoustic diagnostics. Usually, more complex mechanisms are tested in real practice, such as gearboxes, engines, chassis, which we will deal with later on. Obviously, the complexity of the structure increases difficulty of the whole diagnostics, also from an experimental point of view, as well as preparing of the computational model. A therefore the whole procedure is solved on a simple structure at first.

Acknowledgement

The research leading to these results has received funding from the project FV18-56 granted by specific university research of Brno University of Technology, Faculty of Mechanical engineering. The authors gratefully acknowledge this support.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Benefits and Efficiency of the Use of Navigational Simulators in Marine Navigation Studies

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Abstract

It is extremely important that their ship handling practice starts on the navigational simulators that enable to re-create the handling of ships in different situations while applying all the necessary procedures and using appropriate equipment because of the recent enormous technological progress. Marine navigation program students do have the opportunity to perform various simulated tasks, participate in different situations, communicate and ensure safe navigation from point A to point "B" in the modern twelve bridge common network class training simulator while studying on the fourth, third and even lower courses. Students are taught by highly experienced instructors they do perceive the information in different ways. Besides this there are no precise and defined methods for learning, what to begin with and whether the actions performed are useful and are not subjective instructions from one or more lecturers, provided. Therefore, the aim of our research is to find out the minds and impressions of students on the effectiveness of the navigational simulator, its pros and cons, the sufficiency of provided for learning time and so on.
KEY WORDS: *Marine navigation studies, training, simulators, students' opinion*

1. Introduction

Learning in various and unusual ways has always been the key to the person's success and the promotion of his interest. "It is quality rather than the quantity that matters" as for the famous Roman philosopher Lucius Annaeus Seneca quote. But is it true that the fact you know that all the possible tools and potential are used helps us in developing the skills and becoming the professional in the field of the interest? We do think so, that examples from the Lithuanian Maritime Academy gives some explanations to the research. There are marine navigation students amongst them that must obtain sufficient knowledges and experience to manage different seagoing ships safely and effectively [6]. It is extremely important that their ship handling practice starts on the navigational simulators that enable to re-create the handling of ships in different situations while applying all the necessary procedures and using appropriate equipment because of the recent enormous technological progress [7]. Marine navigation program students do have the opportunity to perform various simulated tasks, participate in different situations, communicate and ensure safe navigation from point A to point "B" in the modern twelve bridge common network class training simulator while studying on the fourth, third and even lower courses [3]. Despite the fact, that worldwide used TRANSAS software package with the latest update called *Navi - Trainer Professional 5000* is used, it does not always come liked and useful for the students and experienced navigators that have both positive and negative feedback [16, 17]. That's why though students are taught by highly experienced instructors they do perceive the information in different ways [9]. Besides this there are no precise and defined methods for learning, what to begin with and whether the actions performed are useful and are not subjective instructions from one or more lecturers, provided. Therefore, the aim of our research is to find out the minds and impressions of students on the effectiveness of the navigational simulator, its pros and cons, the sufficiency of provided for learning time and so on. It is worth mentioning that the researches of similar nature are quite uncommon in the overall necessity to result ratio context while assessing the student's practical training on the simulator [12, 13]. Analysis of references resulted to some preliminary conclusion stating that usually papers or online comments give the opinion of professional scientists and researchers studies [1, 2, 4, 5, 10; 11]. The present paper is issued in order to give some position of students and very young professionals regarding simulation training within Marine Navigation studies. This idea is partly touched in some researches [14, 15]. Perhaps this will encourage taking thought on changing the whole learning process, so as to increase the efficiency and let students spend sufficient time on the simulators rationally and develop the appropriate skills before the big seas.

2. Materials and Methods

The methodology of present research is the assessment and interpretation of the various course students' presumptions on certain suggested topics. For this purpose, in order to find out the students' opinions on the use of a navigational simulator, a total of fifteen different questions covering various aspects of the use of the navigational simulator were raised and formed the basis of the questionnaire. There were two ways of providing the answers suggested, the first one allowed to choose from the four options where it was possible to fully or partly agree or not, and the second way let the respondents leave their own comment. Due to the fact that the researches of similar nature are

quite uncommon in the overall necessity to result ratio context, in order to create the widest possible range of divergent views, it was decided to interview not only the students of different courses but also those who graduated from the LMA not long ago and successfully work according to their education as the watchkeeping officers on the ships of different types and characteristics. Thus, the study auditory was divided into four groups and for each of them a minimum criterion or a research sample size of at least 15 respondents was established. Most of the respondents were suggested to fill the anonymous questionnaire and for some others there was provided a possibility to fill up created with the help of "Google Forms" online questionnaire, due to the fact that some students and graduates were at sea at the moment of the responses' collection. In general, 124 respondents were interviewed within the period of 1 month. This amount included 30 2nd course students, 30 3rd course students that had already had their first sea practice, and it is worth mentioning that they presented the largest group of the respondents due to the fact they were completing some courses programs. Also 24 students of the 4th course that are graduating from the LMA this year were interviewed, and the last part of the respondents' amount was formed by 40 LMA graduates of recent years that successfully work in different shipping companies as the watchkeeping officers. It should be noted that the significant numbers of respondents in different groups depended on the diversity of circumstances and the peculiarities of marine navigation studies, that is why this research should be perceived as a pilot version. But this should not affect its significance, but conversely determine the relevance of the problem and create the necessity for a more serious research work.

3. Discussion

It's not a secret that young, energetic, and hard-working students are always thinking of the greater number of practical classes they are dreaming about. This position gets distinctly expressed at the moment the first sea practice approaches. As soon as the second course of studies begins students have to meet subjects dealing mostly with navigation and ship handling, what creates inevitability of use of navigational simulator in the process of studies. The use of navigational simulator provides the 2nd course students the possibility to estimate, and preliminary calculate the principals for handling of different ships using chart plotting method on the paper charts, what takes place during the navigation lectures. In this context actually students are familiarized with the navigational simulator, and the fact that the training is carried out in accordance with the currently existing provided training program should be emphasized. But as for the opinion of the students such a beginning of the learning path is not enough clear, and they express the need for knowledge and confidence growth in the provided to the following question answers.

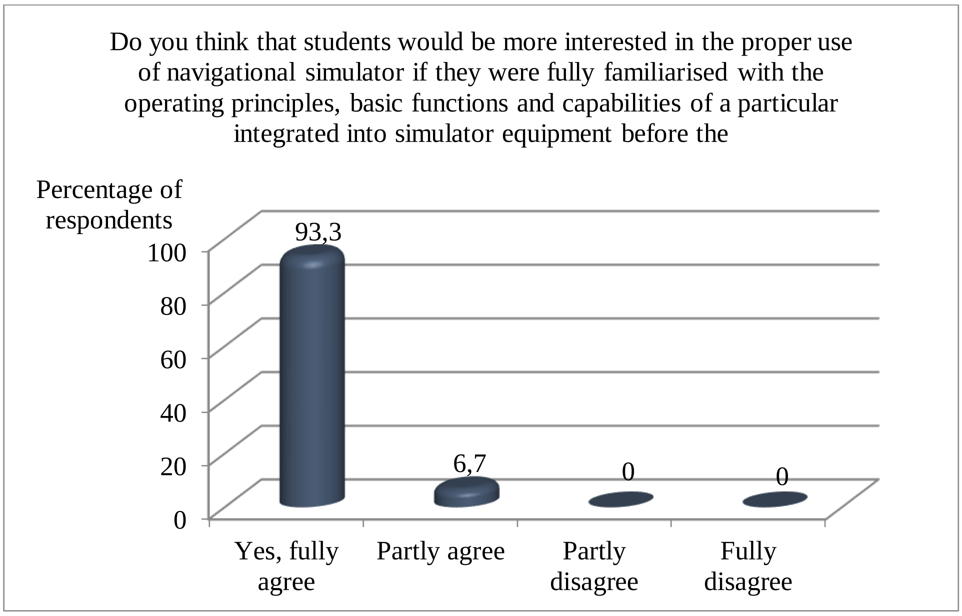

Fig. 1 Question and opinion of 2nd course students (LMA)

It is no secret that the groups of studying marine navigation students are often presented with a great number of students, and the organization process that is carried out for practical classes, should be smooth, fast and even requiring students' concentration and self-consciousness. This is to say that they do not always work by one and are the only responsible for their simulated bridge. Usually there is workplace provided for a pair of students. The first idea of this fact may seem quite simple – the lack of workplaces and time throughout the learning system. However, far more meaningful goals are being solved this way – navigators are taught to be both individual and working in team professionals, so they must learn to solve complicated tasks cooperating their colleagues. Besides this, it is quite difficult to perform a simulated task and control the ship's route by chart plotting for one person, as this would be non-qualitative, hurrying and someway dangerous handling of the ship, as even proper look-out wouldn't be ensured. This kind of experience is achieved by the mentioned already 2nd course students, even they are not properly prepared for such way of performing tasks, they do manage to work in pair so, as to control each other and successfully complete the task

(Figs. 1 and 2). The answers variation reflecting such a tendency for the discussed question are provided below.

It is worth mentioning that the general level of skills and knowledges of the 3rd course students that have already had their first sea practice is a bit wider (Fig. 3). They must safely and effectively handle different ships through various complicated routes with the help of the navigational simulators during the navigation lectures while achieving the necessary skills for the rank of the watchkeeping officer.

The program for their studies is provided by the International Maritime Organisation participants created and ratified STCW (International Convention on Standards of Training, Certification and Watchkeeping for Seafarers) [6], which requires students to complete the following courses programs: *Radar navigation, radar plotting and use of ARPA, radar at operational level* [7] and *Operational use of Electronic Chart Display and Information Systems* [8], and the achieved skills and knowledges are being practiced on the navigational simulators performing suggested tasks. Besides this, students continue studying navigation subject, and in general try out much more of the navigational simulators functions and explore some new both positive and negative aspects. But as far as so serious and necessary subjects are discussed it is naturally that students start thinking of spending as much time on the navigational simulators early as possible. Though this may appear quite strange, but it is possible only during the courses or lectures that do have pretty complicated and overloaded programs, and there is no possibility for additional „on your own“ practices provided. Moreover, the additional refresh courses for side people that are organised and held in the same auditoria do reduce the amount time that may be used for the purposes of students' practicing. It is obvious that in order to fulfil all the needs great financial and material resources are required, but all the respondents and especially the 3rd course students are assured that additional (free) hours for the practicing are really necessary. The principle model of simulators' exercises distribution within the marine navigations study program given in Fig. 4.

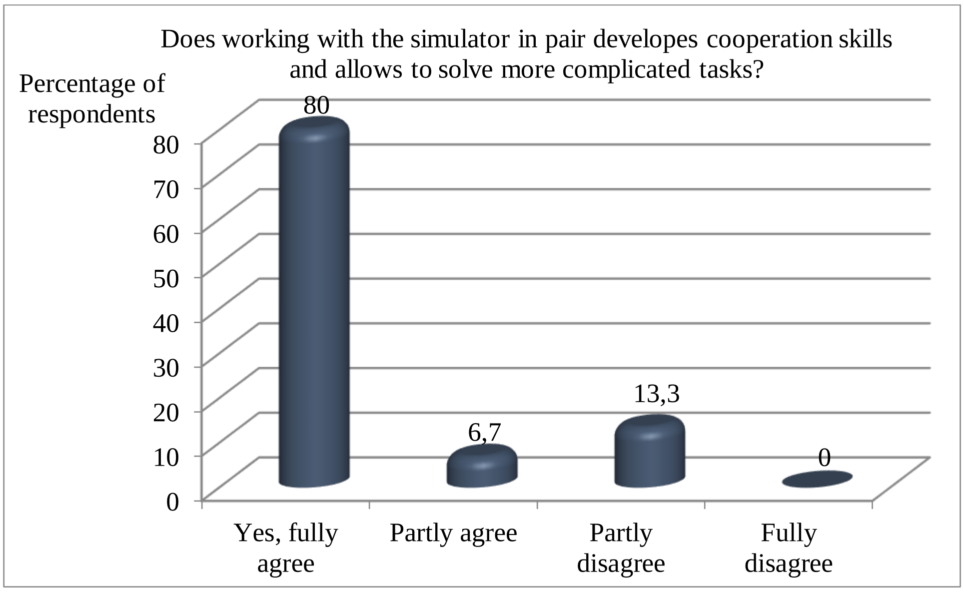

Fig. 2 Question and opinion of 2nd course students (LMA)

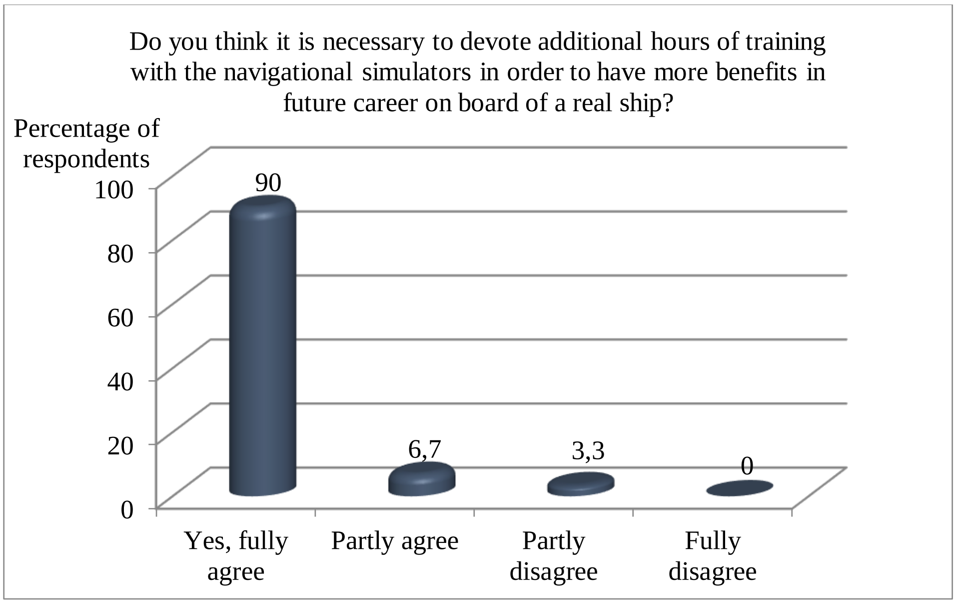

Fig. 3 Question and opinion of 3rd course students (LMA)

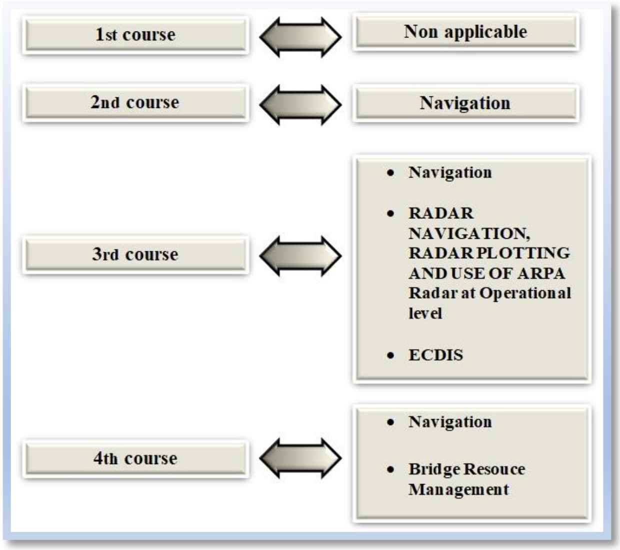

Fig. 4 Short resume about subjects, in which navigational simulators are practically used

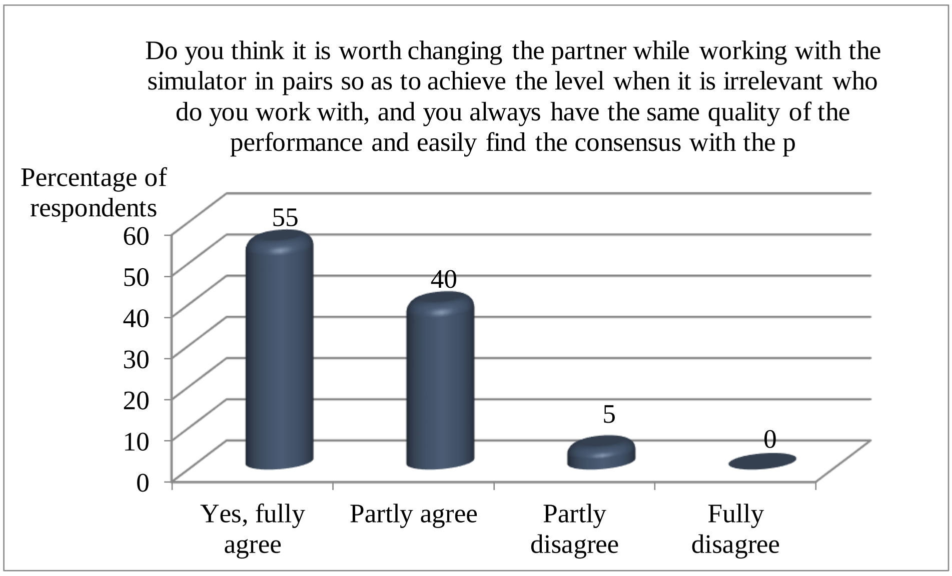

Fig. 5 Question and opinion of 4th course students (LMA)

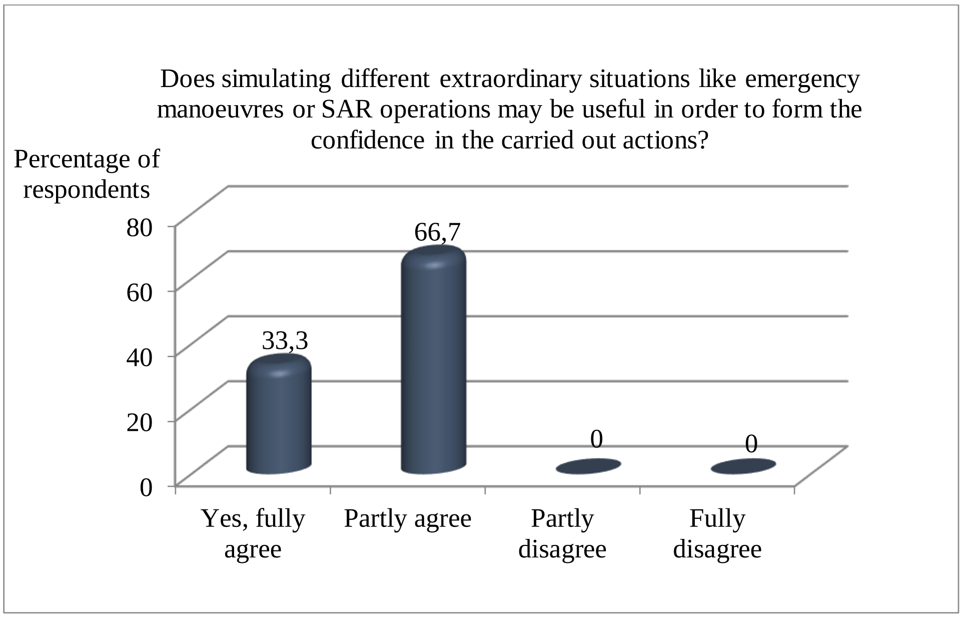

Fig. 6 Question and opinion of graduates (LMA)

The third group of the respondents is presented with students of the 4th course that are graduating from the LMA this year, and their answers are also important in the context of their highest level of experience and longest amount of time spent working with the navigational simulators, and the 4th course doesn't become an exclusion as a program of Bridge Resource Management courses is to be done this year (Fig. 5). At the same moment the lectures of navigation are provided as to prepare for the state qualification exam. The fact they have spent quite a lot of time on the navigational simulators makes them suitable for defining the competent opinion on the partners' exchange during the teamwork practices and the ability to get used to working in cooperation with any person. But it should me mentioned that this opinion expresses students' wish to be well-qualified specialists and awareness of the fact that you should be able to work and reach a compromise that will lead to a safe passage in any situation and with any person.

And the last group of respondents is presented with graduates that have recently finished their studies in LMA (Fig. 7) and successfully work in different shipping companies in the rank of watchkeeping officers. They have already had a chance to compare the experience they gained during the process of studies to the real work and various navigational tasks completion. The main aspects attention was paid to are the benefits of these skills applying (Fig. 6). The respondents were asked in the following question if the use of navigational simulator is useful, and almost all the respondents find the use of simulators useful, some of them even noted in the comments graph that such an experience helps forming the self-confidence.

Fig. 7 Lithuanian Maritime Academy navigational simulators

4. Conclusions and Remarks

Despite the fact the majority of studying marine navigation students are mostly satisfied with their educational process they do still find some imperfections in the current navigational simulators usage methods. They do think that students must get acquainted with the basic ship handling functions presented in the conning console and general interface of the simulators while completing the tasks like maintaining a proper watchkeeping, learning the helmsman's duties, chart plotting, etc. as early as it is possible. Besides this, the program of the ship handling technical issues subject strongly requires some practical classes on the simulators, as this would allow students to try out all the functions, deal with all the necessary settings and don't waste the time provided for practical passing of various routes during the navigation lectures for long preparations when students are first time trying out any technical issue and finding out how to set it up so as it works correctly. When at the same moment most of the respondents are assured that there isn't enough time provided for these practical classes, and sometimes only one lecture is provided for performing a passage of any route during navigation lectures. Almost all the respondent's do support the idea of providing more lectures for these practices and also recommend combining a minimum of two lectures in a row so as to have enough time not only to prepare and perform the passage but also to discuss it after. A great part of the respondents even declared a wish to attend additional classes of the facultative format (if only such an exist) as the benefits of the use of the navigational simulators are obvious, are regarded quite positively and even the simulators in general do intrigue the 1st course students.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Designing and Investigating of Electric Tricycle

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Abstract

Surat city, Gujarat, India has a huge vehicle population over its area and human population. Moreover, two wheelers, including gasoline powered bikes and mopeds are leading category by population of 17 lakhs out of 22 lakhs hence, this category of vehicles is one of the biggest factor for noise and air pollution as they emit a huge amount of CO_2, CO, NOX. Thus, Delta type Electrical tricycle is proposed as an alternative to replace gasoline powered two wheelers. Parts such as battery, motor, motor controller, wheels and braking systems are adopted from the electric bike and calculated for dynamic and kinematic conditions. Along with calculation, study carried forward to Computer Aided Design model of electrical tricycle is made with SOLIDWORKS. Furthermore, it has been imported and analysed by Finite Element Analysis method in ANSYS (v18.1). The FEA methodology included the tests of several loading case such as bending, torsion, lateral-braking operation, longitudinal-steering operation and natural frequencies. Succeeding with the satisfactory results gained with FEA method; Prototype (practical working model) was made and tested on the roads of the Surat City (Study Area).

KEY WORDS: *Electric Tricycle, Computer Aided Design, Finite Element Analysis, Green Mobility*

1. Introduction

Electric Tricycle has been made as a sustainable transport solution for the city areas of India. Surat city of Gujarat State has been selected as an area of study. The transportation system is divided in two parts which are Transport vehicles and Non-transport vehicles. Transport Vehicles are categorized in goods vehicles and passenger vehicles in which goods vehicles includes trucks/lorries, tankers, three wheelers light goods vehicles and other goods vehicles where as passenger vehicles includes buses, maxis, school buses, private service vehicles, taxis, auto rickshaws and ambulance. The Non-transport vehicles includes police vans, motor cars, jeeps, motor cycles/scooters, mopeds, tractors and others.

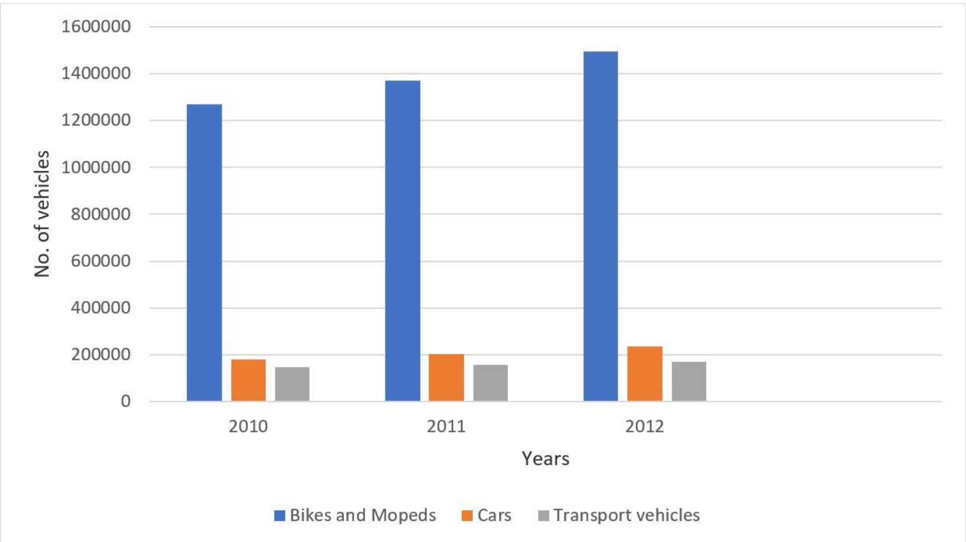


Fig. 1 Vehicle Population in Surat City

According to the records of regional transport office of Surat, population of two wheelers including motor cycles/scooters and mopeds were 1270400 in 2009-2010, 1370899 in 2010-2011 and 1495610 in 2011-2012 when total vehicle population was 1922382 in 2011-2012 (Fig. 1) [1].

This records states that the population of two wheelers includes motor cycles/scooters and mopeds were highest. Moreover, report of Times of India published in 2013 had predicted the population of two-wheeler in year 2015 would be 1700000 from total vehicle population of 2600000. [2] As a leading category of vehicle population it is a major Air pollutant too. Thus, alternative green mobility sustainable transport solution is highly needed for motor cycle/scooter and mopeds. To avoid the private vehicles government has provided different public transport modes such as City buses and Bus Rapid Transit Service which are very effective and cheap transportation mode however, not convenient for all as less frequency in rural areas, non-convenient for old age people and handicaps as walking can not be eliminating to get in the bus and reach the destination by get off the bus. Therefore, Eliminating of Two wheelers category of vehicles is not possible.

Electric Tricycle is proposed as an alternative sustainable transport solution to replace the gasoline powered two-wheeler vehicles. Electric tricycle runs on electricity and there is no use of gasoline engine thus, it does not exhaust CO_2, CO and NO_x in the air. Moreover, it is safer and provides more ergonomics than two wheelers as it is self-balanced vehicle because of three wheels. The Electric tricycle contents electric motored wheels, batteries, motor controller and accelerator system to provide the drive. Drum brakes, Shock absorber systems and the main powertrain parts are adopted from standardized parts which has been traditionally used in other electric vehicles. The frame of the vehicle has been designed and tested via Computer Aided Designing and Finite Element Analysis then it has been made for prototype model of the vehicle.

2. Designing and Investigating of Electric Tricycle

There are different types of tricycle such as delta type, tadpole type, sidecar tricycle type, but the delta type tricycle is most suitable because of its parameters dynamic stabilities, braking operation, turning operation, acceleration, comfort, visibility angle, height such are better than any other type of tricycle [3]. By Computer Aided Modeling and Finite Element Analysis method, Electric tricycle is made and tested.

CAD model is made with Software named SOLIDWORKS. 2D and 3D models can be made with SOLIDWORKS. Design of component starts with Part design as a first step followed by assembly. The model of component in SOLIDWORKS contents 3D geometries could be made with surfaces, edges, faces [4]. The model of tricycle is made with 3D geometries tools includes beams, weldment joints, surfaces and edges.

Fig. 2 Isometric View of CAD model of Electric Tricycle

CAD model of tricycle made with SOLIDWORKS is shown in the Fig. 2. Model contains Frame structure, steering, wheel hubs, braking space, wheels, tires motor space, and shock absorbers. Motor, Batteries, Motor controller and other operational wiring parts are not made in CAD model. Some parts simply adopted from old model of electric moped are Motor, Batteries, Motor Controller, Wheels with brakes, steering geometry and shock absorbers for all wheels. The focus of the research methodology is to modify the frame of old electric moped of two-wheeler into frame for three-wheeler vehicle.

Frame of the tricycle is made with hollow pipes connected with welded joints. The front pipe which will provide inside space for steering pipe has to take more load than other thus, the size of the pipe is take bigger than other. Also, the vertical pipes connected to at the rear side of the vehicle which would have load of rider is also taken bigger than other pipes. All other pipes are smaller in size which would be proven enough strong by further analysis. The design of frame is shown as below Fig. 3.

In the frame geometry there are two types of hollow pipers are used as follows:

1. ø 26.9 × 3.2 mm;

2. ø 33.7 × 4.0 mm.

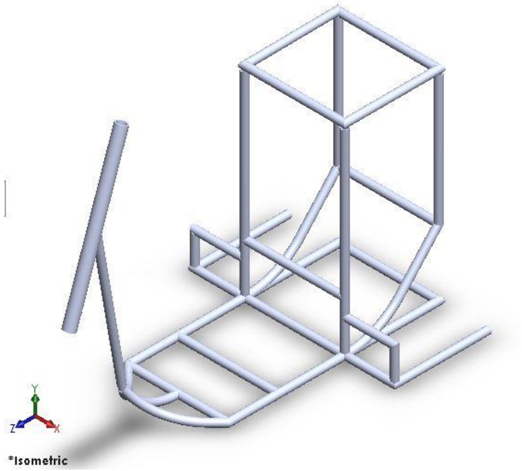


Fig. 3 Frame of the Vehicle

Both types of pipes are standardized by International Organization for Standardization. In the 1st pipe 26.9 mm is the outer diameter and 3.2 mm is the thickness of the pipe hence 20.5 is the inner diameter of the pipe. This type of pipes has been used for most of the geometry where there is a rider's foot space, as all connecting pipes, connecting pipers as rear side which will be further connect with shock absorber.

The 2nd type of pipe has 33.7 mm outer diameter. 4.00 mm inner diameter thus, it has calculated 25.7 mm inner diameter. This type of pipe has been used in the construction of frame which area has to work with more load compared to other area. Such heavy load carrying area could be area which provides space for steering geometry and the pipes which directly holds the rider's weight. The hollow pipes relate to welded joints as it is the most suitable joining process for such geometry.

3. Material for Frame

Aluminum Alloy has been chosen for construction of Frame. Aluminum alloy is most used metal for frame construction like. Other major used material used for component is steel. However, Aluminum Alloy could be cheaper in price, lighter in weight, more reliable in comparison of structural steel [5]. Frame must withstand loads such as bending load, torsion load, lateral load while braking, remote load while steering operation. The material properties of Aluminum Alloy and Structural Steel is compared below (Tables 1 and 2).

Table 1

Properties of Aluminum Alloy [6]

Property	Value	Unit
Density	2770	Kg*m^-3
Coefficient of Thermal Expansion	2.3E-05	C^-1
Young's Modulus	7.1E+10	Pa
Poisson's Ratio	0.33	
Bulk Modulus	6.9608E+10	Pa
Shear Modulus	2.6692E+10	Pa
Tensile Yield Strength	2.8E+08	Pa
Compressive Yield Strength	2.8E+08	Pa
Tensile Ultimate Strength	3.1E+08	Pa

Table 2

Properties of Structural Steel [6]

Property	Value	Unit
Density	7850	Kg*m^-3
Coefficient of Thermal Expansion	1.2E-05	C^-1
Young's Modulus	2E+11	Pa
Poisson's Ratio	0.3	
Bulk Modulus	1.6667E+11	Pa
Shear Modulus	7.6923E+10	Pa
Tensile Yield Strength	2.5E+08	Pa
Compressive Yield Strength	2.5E+08	Pa
Tensile Ultimate Strength	4.6E+08	Pa

Density of Structural steel is higher than Aluminum Alloy thus, the weight of structural steel is also higher. However, Values of Properties such as Co-efficient of Thermal expansion, Young's Modulus, Poisson's ratio, Bulk modulus, shear modulus, tensile yield strength, compressive yield strength and tensile ultimate strength are higher in Aluminum alloy in comparison of structural steel. Thus, Aluminum Alloy is taken as it is the best suitable material for the frame of the electrical tricycle.

4. Boundary Conditions of CAD Model of Frame for Finite Element Analysis

Finite Element Analysis of frame of electrical tricycle is done with ANSYS 18.1 where five analyses are done on the CAD model of frame which is directly imported to ANSIS 18.1 from SOLIDWORKS. All five analyses are named as Bending, Torsion, Lateral, Longitudinal case and natural frequencies. Different analysis performed with different forces and different fixtures (Tables 3 and 4).

Table 3

Notations for forces and fixtures to the model

A	Remote steering force 1	500 N
B	Remote steering force 2	500 N
C	Bending force 1	981 N
D	Bending force 2	294.30 N
E	Lateral force	50 N
F	Torsion force 1	650 N
G	Torsion force 2	650 N
H	Fixed Support	At Front wheel
I	Fixed Support 2	At rear wheel

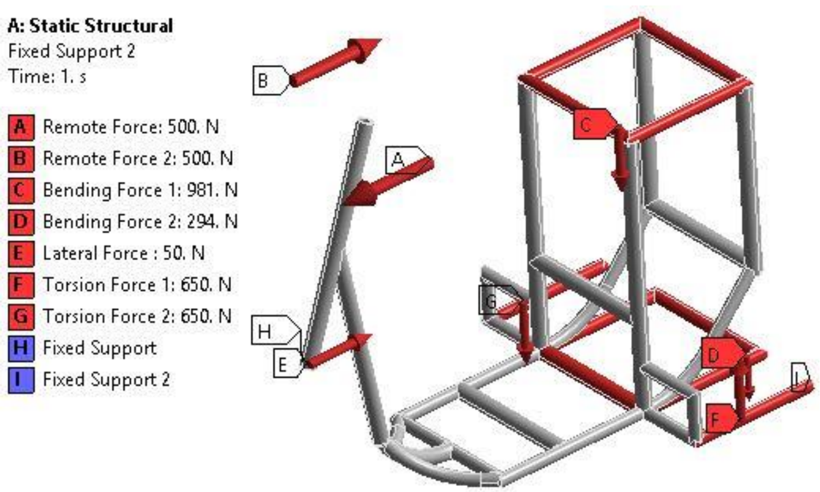


Fig. 3 Boundary Condition for Finite Element Analysis of Frame

Table 4

Force application of Loading cases

Loading cases	A	B	C	D	E	F	G	H	I
Bending case			✓	✓				✓	✓
Torsion case						✓	✓	✓	
Lateral case					✓				✓
Longitudinal case	✓	✓							✓
Natural frequencies								✓	✓

5. Finite Element Mesh of Frame

By applying programable mesh and adaptive meshing tool, fine accurate mesh is resulted as shown in the Fig. 4. Element size of the mesh is 1.00 mm, however where there was small section made because of edges or joining arears, adaptive mesh tool had regenerate the element mesh size enough fine so that all the analysis result will be accurate. In the zoom view of the mesh element result it is sown that joints have been meshed with different suitable fine element size and other portion of the frame has been meshed with uniformed element size by adaptive meshing tool.

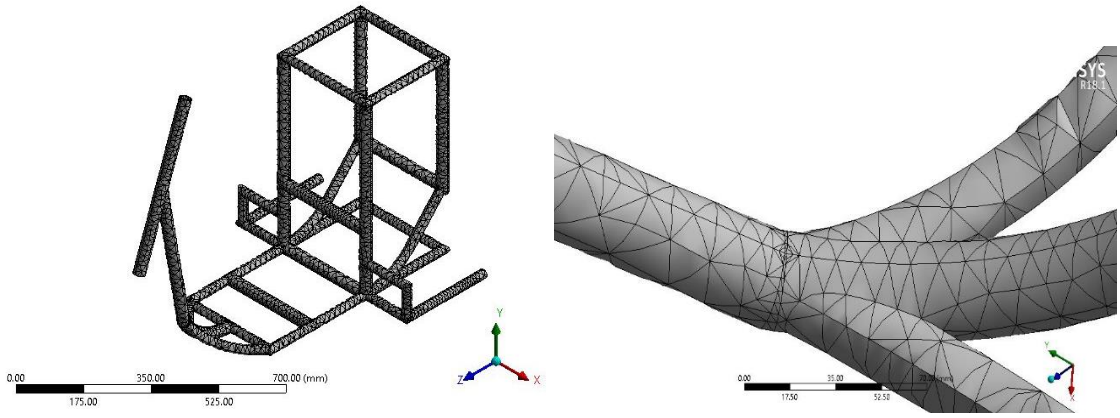
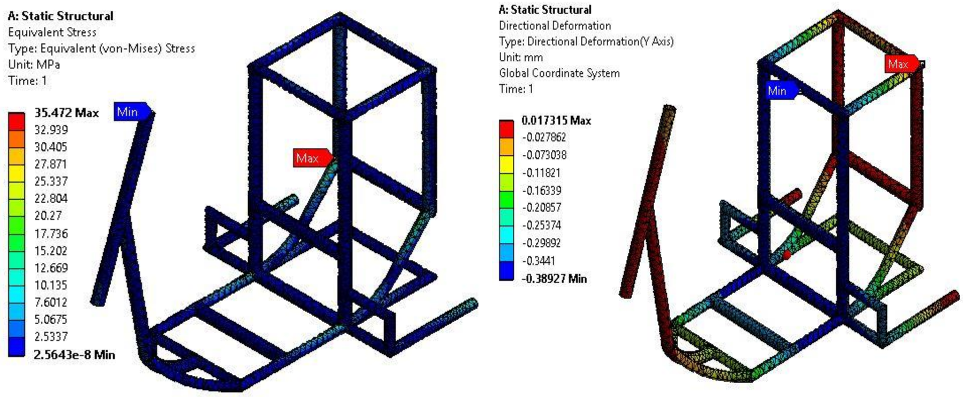


Fig. 4 Finite Element Meshing of Frame model

6. Results

6.1. Bending Case



a b

Fig. 5 a - Result of Equivalent Stress; b - Result of Deformation in Y direction

The stress result shown in the Fig. 5, a by applying the bending force, frame felt maximum stress of 35.472 MPa on the both joints which are connecting rear support pillar and curved pillar. The minimum stress of 2.5*10^-8 MPa which is almost equal to zero (negligible) is felt on the area where the steering handle connects with the bearing. The deformation result in Y axis is shown in the Fig. 5, b. The max. deformation is 0.3892mm and the minimum deformation is 0.0173. The tag of max and min shown in the Fig. 5, b should be taken as vice versa as direction of deformation is negative according to the co-ordinate system. The bending stiffness $KL = F/b$; here F - force acting on the frame, b - displacement in Y axis. So, KL = 1275.30/0.3892 = 3276.72 N/mm = 3.27 N/m.

6.2. Torsion Case

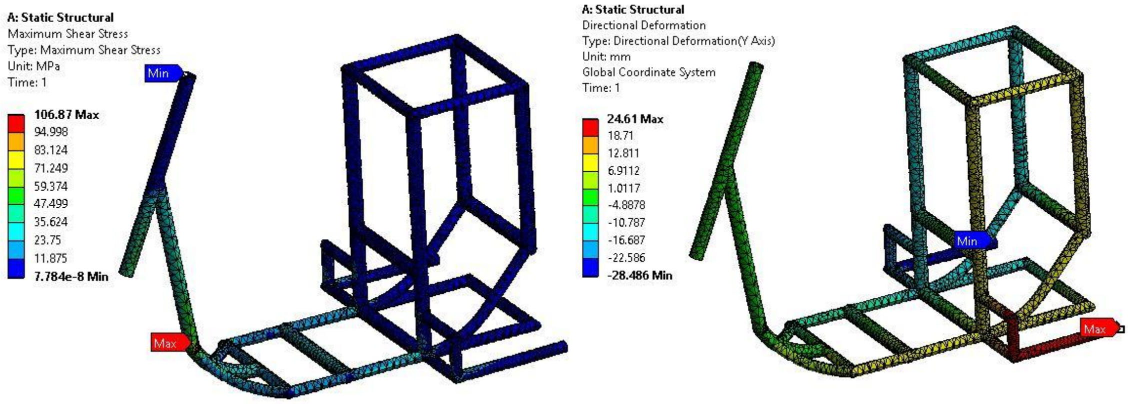


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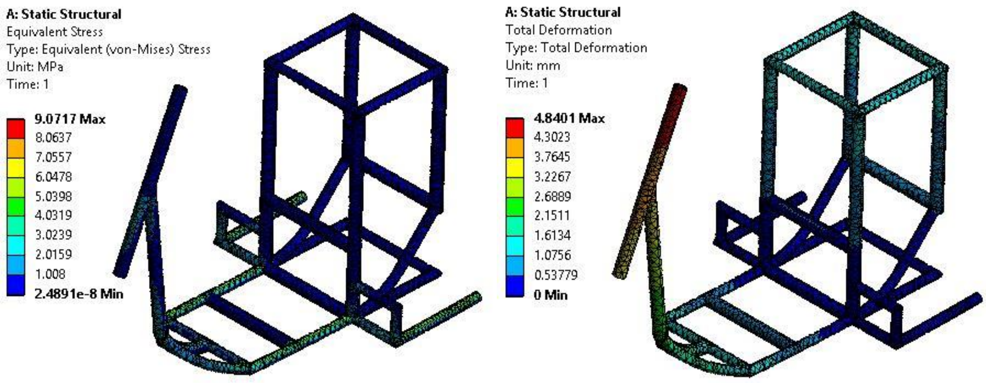
Fig. 6 a - Result of Maximum Shear Stress; b - Result of Deformation in Y direction

The result obtained by the analysis of torsion force is shown in Fig. 6. In Fig. 6, a max shear stress is 106.87 MPa which occurs on the joint of two pipes which is denoted by tag of max. where the min. tag shows the

location where min. shear stress is occurs of 7.784*10^-8 which is almost equal to zero hence negligible. The resultant deformation is checked in Y direction as forces acting on the y direction only. The max deformation is 28.486 mm which in upward direction and at the same time max deformation on other side is 24.61 in downward side. The tag of Min. in Fig. 6 shows the location of element where the max. deformation is occurred, and the direction is upward or positive direction. torsion rigidity $Ks = M / \alpha$; $M = F * L$; α = arctg [b / (L/2)]; where M-moment; α - angle a distance from the axis; b - displacement in Y axis. L = 450 mm; $M = F*L$ = 650*450 = 292500 N.mm = 292.5 N.mm; b = 28mm; α = arctg[28/ (450/2)]; α = 7.0936°; Ks = 292.5/7.0936 = 1.2339 Nm/°.

6.3. Lateral Case

During the braking operation, when front brake is used to stop the vehicle, force is acting on the opposite longitudinal direction of the vehicle moving direction. The effect of the resistance force to the frame structure is analyzed in lateral case. The braking force is taken in between 50 N to 1000 N. The braking force is varying each time depending on requirement. Thus, for critical case 1000 N has been taken. Mostly working braking force would be 50 N to 500 N, analysis result shows for 50 N and 1000 N braking force. Lateral forces are directly applied to the pipe which holds steering as it is directly connected to front wheel and front brake.



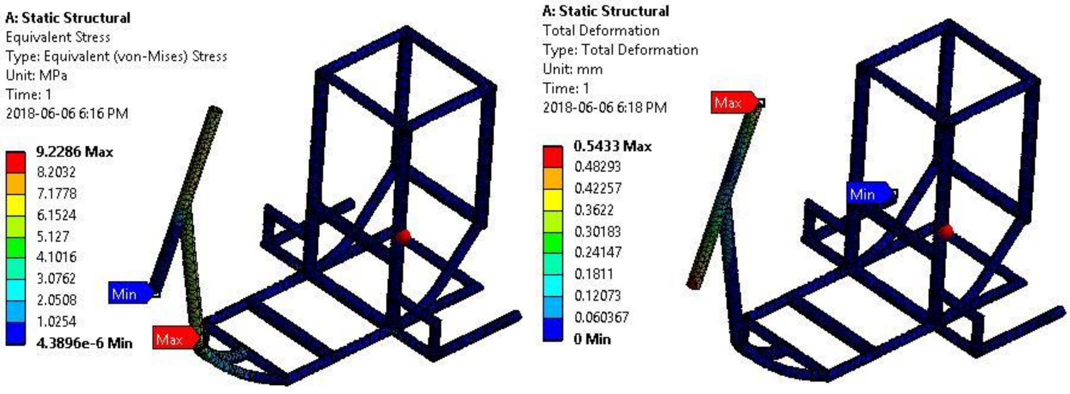
a b

Fig. 7 a - Result of Equivalent Stress; b - Total Deformation

On the operation of braking when force is minimum about 50 N, the max. stress is 9.0717 MPa and max deformation is 4.8 mm (Fig. 7). On the application of 1000N, the max. resultant equivalent stress is 183.18 MPa and max. deformation is 82.121 mm, though minimum factor of safety is 1.59 which takes design to be said safe.

6.4. Longitudinal Case

By steering operation, force acting on the frame structure on the pipe where steering is connected and hence it affects to the strength of the frame. Analysis of the longitudinal forces gives the reaction of the frame on particular forces.



a b

Fig. 8 a - Result of Equivalent Stress; b - Result of total deformation

In the case of steering operation while considering the right turn force applied to the steering handle, which acts as a remote force on the frame structure, as a resultant max stress 9.2286 MPa occurs and minimum stress is 4.3896 MPa as shown in Fig. 8, a. The maximum deformation is 0.5433 mm and min. deformation are 0 mm. Both max. and min. deformation are shown in Fig. 8, b. For the critical case of considering the 1000N force, the max. stress is 92.286 MPa and the max. deformation is 5.43 mm. The Yield strength of the material is 280 MPa hence, design is said to be safe for particular operation.

6.5. Natural Frequency

Natural frequency of the frame is obtained by fixing element nodes of place of all three wheels. For natural frequency there is no force applied. The analysis of natural frequency is done for 6 degrees of freedom.

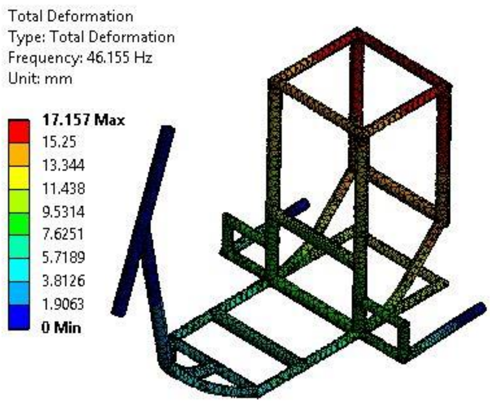


Fig. 9 Result of Natural Frequencies

Result of the analysis of natural frequency is shown in the Fig. 9. The results are gained by 6 modes for all 6 degrees of freedom. The natural frequency could not be zero however there is no zero-natural frequency in such case. Mode 1 has 46.155 Hz, Mode 2 has 61.331 Hz, Mode 3 has 101.84 Hz, Mode 4 has 135.06 Hz, Mode 5 has 135.96 Hz and Mode 6 has 13.61 Hz frequency.

Table 5

Max. deformation on each mode

Mode	Frequency [Hz]	Max. deformation
1	46.155	17.157
2	61.331	20.548
3	101.84	19.908
4	135.06	70.558
5	135.96	47.459
6	139.61	66.577

The max. deformation value for all modes is shown in Table 5. In operational condition of the vehicle, any assembly’s frequency should not match with any of these frequencies. In the case if operational frequency matches with frequency of any mode, the frame structure will deform in particular degree of freedom of that mode.

7. Calculations. Centre of Gravity

Calculation is done with max. components of the vehicle. Approximate values have been taken for the component whose exact values are unknown. Some components are combined for example wheel could be combination of wheel rim, tire and brake system for particulate. Components are shown in table 6. Calculation of C.G. has been done with “MAS1” method [7].

Table 6

Vehicle Elements with weight distribution and location

No.	Elements	Weight (kg)	X axis (mm)	Y axis (mm)	Z axis (mm)
1.	Battery	30	0	520	1350
2.	Motor R.H. side	10	285	300	1445
3.	Motor L.H. side	10	-285	300	1445
4.	Motor controller	1	0	300	1160
5.	Front L.H. Shock absorber	2	-45	400	470
6.	Front R.H. Shock absorber	2	45	400	470
7.	Rear L.H. Shock absorber	2	-150	500	1445
8.	Rear R.H. Shock absorber	2	150	500	1445
9.	Front wheel	1.5	0	245	245
10.	Steering system	3	0	600	500
11.	Rear left wheel	1.5	-225	245	1445
12.	Rear right wheel	1.5	225	245	1445
13.	Chassis	30	0	300	700

Table 7

Result of Calculated Centre of Gravity by “MAS1”

Result	
Weight, kg	96.5
Yc, mm	387.6
Zc, mm	10925

The calculated Centre of gravity of the vehicle is coordinates as x = 0, y = 387.6 and z = 1.92.5 (Table 7). This result has been calculated by “MAS1” method of center of gravity calculation. The weight and center of mass of all the component is approximated values hence, the calculated center of gravity is nearer value of the actual center of gravity.

8. Conclusions

Identified problem is a need of alternative option of gasoline two wheelers includes bikes and mopeds as these both are the most populated vehicles in the area of study Surat city. By gaining the objectives of proposed delta type electric tricycle as a green mobility vehicle cited category of two wheelers could be replace since Delta type of tricycle has more advantage in comparison of sidecar tricycle and tadpole tricycle. CAD model of frame of tricycle has been tested with FEA methodology to check whether it is suitable and stated below.

1. The result of bending test stats max. stress on body is 35.472 MPa which is said to be safer by calculated factor of safety is 8.2.
2. The result of Torsion test stats max. shear stress on the body is 106.87 MPa which is stated as safer design by calculated factor of safety is 1.5.
3. In the case of braking operation lateral force affect very less as a resultant max. stress on the body is 9.07 MPa where the material’s yield strength is 280.5 MPa.
4. In case of steering operation in longitudinal direction remote forces also doesn’t leads to failure or fracture stated by felted max. stress of 9.22 MPa.
5. Natural frequencies of the part should not be zero, by the mathematical calculation of natural frequencies in ANSYS 18.1 natural frequencies of the frame have been achieved for all six degrees of freedom are 46.155 Hz, 61.331 Hz, 101.84 Hz, 135.06 Hz, 135.96 Hz and 13.61 Hz for all six modes.

Thus, it is proven that the frame is enough strong and suitable for specified such electric tricycle and such electric tricycle could replace the gasoline powered two wheelers in the area of study Surat City.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Expectations and Attitudes of Current and Potential Passengers of Suburban Bus Transportation in the Selected Region of the Slovak Republic

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Abstract

Public transport is currently facing a number of problems determined by socio-economic development of society. In the long run, it is possible to monitor the reduction of transport performance in road public transport (especially regular) due to increase in individual and rail transport. Road public transport loses competitiveness. The management of transport companies must seek new solutions and approaches to make transport services more attractive and increase customer satisfaction, which is a prerequisite for the economically sustainable operation of transport companies ensuring the public interest. The aim of this contribution is to identify the expectations and attitudes of current and potential passengers of suburban bus transportation in the region of Zilina. This information is a prerequisite for ensuring the competitiveness of road public transport in relation to substitution solutions satisfying transport needs. Information on expectations and attitudes has been obtained through a survey. The results of the survey are an important starting point for the transport company, which ensures the transport services in the region of Zilina.
KEY WORDS: *road public transport, passengers of suburban bus transportation, transport services*

1. Introduction

Public transport is currently facing a number of problems determined by socio-economic development of society. In the long run, it is possible to monitor the reduction of transport performance in road public transport (especially regular) due to increase in individual and rail transport (Tables 1 and 2).

Table 1

Trends in the number of the public transport passengers in the Slovak Republic (in thousands of persons)

	1995	2000	2005	2010	2014	2015	2016
Public road transport	722 510	604 249	449 456	312 717	262 262	252 175	259 194
Regular	716 737	594 306	437 447	298 559	253 214	239 662	234 574

Source: Statistical Office of the Slovak Republic, Ministry of Transport and Construction of the Slovak Republic

Table 2

Trends in the number of registered personal vehicles in the Slovak Republic

	1995	2000	2005	2010	2014	2015	2016
Personal vehicles	1 015 794	1 274 244	1 303 704	1 669 065	1 949 055	2 034 574	2 121 774

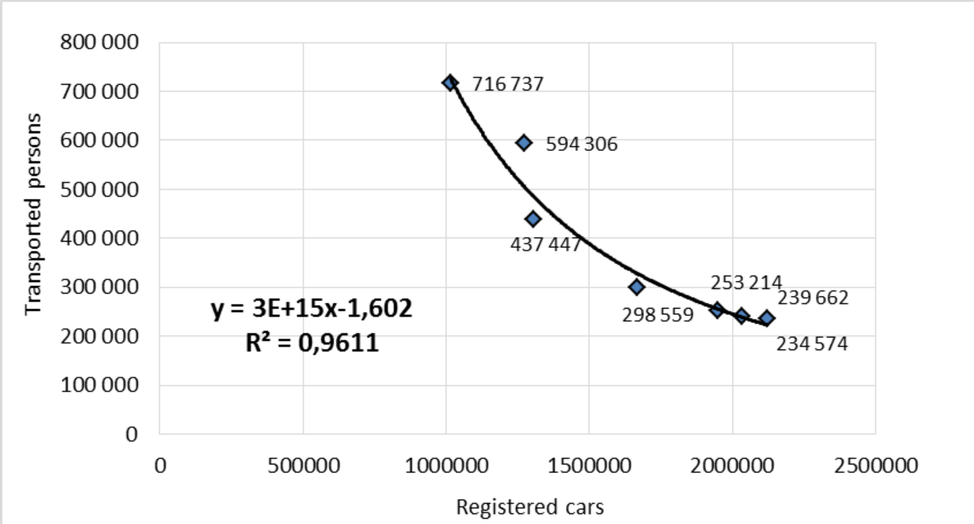
Source: Ministry of the Interior of the Slovak Republic, Presidium of the Police force

Relationship between number of registered personal vehicles and number of the public transport passengers is analyzed using Pearson correlation coefficient, which is a measure of the linear correlation between two variables. Value of Pearson correlation coefficient is -0.9443, which is close to the limit value (-1), which means that there is **strong negative linear correlation** between monitored characters.

The trend curve with the mathematical expression of relationship is shown in the following chart (Fig. 1). Through the equation, we can make a forecast of the number of persons transported by bus transport in relation to the number of registered personal vehicles in the Slovak Republic. We expect an increase in the number of personal vehicles in the Slovak Republic and, therefore, the strengthening of the position of individual transport.

In general, we can see efforts to increase the economic viability and efficiency of the public transport in the Slovak Republic. The road public transport loses its competitiveness, and therefore the management of the transport companies must seek new solutions and approaches to make transport services more attractive and increase customer satisfaction, which is a prerequisite for the economically viable operation of public transport companies.

The scope of execution of transport service is perceived by customers and their expectations. They define the customer satisfaction level. It is necessary to differentiate between the transport company's view of quality of provided service and customer's perception of quality of the provided service as well as other organizational aspects since this is the second aspect determining customer satisfaction.



Source: Authors' results

Fig. 1 Trend curve

For a potential passenger in the suburban transport segment, there are several possibilities available to meet his/her transport needs. The decision regarding selection of type of transport is based on aspects (criteria) being considered as relevant in aspiration to get the highest possible value. The offer gets more successful with higher value and satisfaction provided by the service to a passenger. From the available types of transport (transport services), the passenger chooses the one of which he/she is certain to provide the highest value.

2. Literature Review

Customer satisfaction can be defined as a difference between customer expectations and their perception of a service as provided by a transport company. Customer satisfaction is a really difficult indicator to be measured. Customer dissatisfaction can be measured only by his/her utterance and expressions [7]. Customer satisfaction is a key factor for the successful long-term survival of any company in the market and equally it can be seen as a competitive advantage. Therefore, it is necessary for the company to regularly monitor customer satisfaction. The importance of customer satisfaction is generally known and accepted fact needed for the long term success of the company in the current market environment. Park et al. to hold an opinion, that carriers which provide services meeting customer expectations enjoy a higher level of passenger satisfaction and value perception [8]. Service quality and passenger satisfaction is increasingly recognized as a critical determinant of business performance and as a strategic tool for gaining competitive advantage [5-6]. Sometimes can be the satisfaction with quality from the passenger point of view very subjective. This is sometimes very hard to measure, but the passenger opinion matters. Other criterions that can be measure very strictly are objective related to the transport service performance. The mix of these criterions can be useful for feedback for transport company. This can be also important for transport company in order to enhance the quality in public transport service [3].

Measuring customer satisfaction is a key element for modern businesses as it can significantly contribute to a continuing effort of service quality improvement [9]. Friman examined whether quality improvements have effects on satisfaction with public transport services and frequency of perceived negative critical incidents [2]. Respondents evaluated transportation services by checking a nine-point scale. The most important finding of the study is that the satisfaction people experience when using public transport services is influenced by quality improvements only to a limited extent. Beirão & Sarsfield-Cabral propose a qualitative study of public transport users and user of individual transportin order to obtain a deeper understanding of travellers' attitudes towards transport and to explore perceptions of public transport users [1]. 24 in-depth interviews were addressed to regular and occasional users of public transport and user of individual transport. This qualitative study highlighted some key factors influencing mode choice. In fact, the key findings indicate that in order to increase public transport usage, the service should be designed in a way that accommodates the levels of service required by customers and by doing so attract potential users. Jensen conducted 30 in-depth interviews and identified six mobility types based on behaviour and attitudes: the passionate car drivers, the daily life car drivers, the leisure time car drivers, the cyclists/public transport users of heart, the cyclists/public transport users of convenience and the cyclists/public transport users of necessity [4]. The results of study points out that one strategy alone is not sufficient to change the transport behaviour of the population in general. Also, she stated that the expansion and improvement of the public transport system is not going to make car users in general change from driving a car to using public transport.

3. Results of Research

In order to increase the satisfaction of public transport customers, stabilize transport performance, to acquire new

customers, it was necessary to carry out a comprehensive survey of the expectations and attitudes of current and potential passengers of suburban bus transportation in the region of Žilina. The executed survey was used to examine the key aspects of customer satisfaction with services provided by SAD Žilina transport company together with search for new solutions to increase attractivity of transport services to eliminate decrease and, at best, provide increase of transport performance.

The target group included inhabitants of the Žilina Self-governing Region (districts of Žilina, Martin, Čadca, Kysucké Nové Mesto, Bytča, Turčianske Teplice) covered by transport services provided by SAD Žilina. The target group was specifically divided into 2 strategic, mutually exclusive groups, with a separate questionnaire for each group.

1. Current customers of SAD Žilina (regular users of public bus transport).
2. Potential customers of SAD Žilina (users of individual transport or other types of public transport respectively).

When determining the size of a sample, we took into account the size of the basic statistical data set (number of inhabitants of the region: 424,067 inhabitants as of 2016, according to the Statistical Office of the Slovak Republic) at the selected confidence interval of 5% and confidence level of 95%, expressing the level of certainty regarding responses. The selected sample size of the executed survey is 3,205 of complete and correctly filled questionnaires, i.e. at the 95% confidence level, the confidence interval was at 1.72%. Upon the aforesaid we can state say that results of the survey are of an extremely high evidential value, since the reference value of the sampling set was 8.34 times higher.

Evaluation of the data and interpretation of results of the survey took place at the following levels:

1. Overall (cumulative) evaluation of response rates recorded in questionnaires for current as well as potential bus transport users.
2. Independent evaluation of response rates recorded in questionnaires filled by current bus transport users.
3. Comparative evaluation of response rates recorded by regular and occasional bus transport users.
4. Independent evaluation of response rates recorded in questionnaires filled by potential bus transport users.
5. Independent evaluation of response rates by regular bus transport users.
6. Comparison of answers of respondents with permanent address in towns and villages included in the railway and bus transport to selected questions (questionnaires of both versions).
7. Mathematical and statistical assessment of dependences between selected factors (quantitative and qualitative characteristics gained by answers of respondents).

Due to the scope of survey and depth of processing of acquired data, it is not possible to present all findings within this contribution. The most important findings and results of the survey are as follows:

- The long-term decline in public transport performance is mainly due to the expansion of individual private car transport.
- The majority of regular and occasional (irregular) customers of the company SAD Žilina is respondent with this profile: a woman aged 27-64, employed, with secondary education.
- The minority of regular and occasional (irregular) customers of the company SAD Žilina is respondent with this profile: a man, retired, unemployed or self-employed person aged 65 and over.
- Women accounted for up to 64.5 % of all respondents using bus services.
- The largest group of respondents were those with secondary education (37.4 %).
- The largest group of respondents were those living in a 4-member household (36.7 %).
- Of the total 353 households not using a personal vehicle, up to 308 households use public bus transport.
- The main reason why respondents use bus transport is the fact that they don´t have a private car (48.6 %).
- The least significant reason for using bus services is the unavailability of parking close to the work or high parking prices.
- Respondents want a higher supply of connections, the accuracy of their departure and better follow-up (59.9 %) – a key criterion for improving bus services.
- Gender does not play an important role in regularity of the use of public transport.
- As the level of education of respondents increases, the regularity of the use of bus transport decreases.
- If the net monthly income of respondents increases, the intensity of the use of bus transport decreases.
- If household has more than 4 members, the intensity of the use of bus transport changes from regular to occasional.
- Households that don´t have a car are mostly regular bus users.
- Regular or occasional bus use is largely determined by the absence of a personal vehicle or motorbike.
- Regular as well as occasional bus users see space for services improvement especially in a higher supply of connections, the accuracy of their departure and better follow-up.
- The average number of cars per household is 1.56.
- The most important reasons why people don´t travel by bus are: long transport time, the need for transfers, unconnected connections and inadequate timetables (53.9%). These are also the decisive criterions for persuading users of individual transport to use the bus.
- 9.9% of respondents said that there is no reason to persuade them to travel by bus.

4. Conclusions

The goal of the survey was to understand benefits to passengers (potential passengers) from using the transport services provided by SAD Žilina. In case the transport company would like to influence passenger decision-making regarding the selection of transport in the suburban transport segment to meet his/her needs, it is necessary to find and understand determinants contributing to creation of value of the transport service. If the parameters of values perceived by the customer are known, we can provide a better offer by applying the marketing mix tools including such values.

The survey and processing of results yielded a large volume of valuable data, direct feedback of customers including verification of the existing assumptions. Attracting new customers is extremely difficult and limited. The results of the survey also prove it. From the point of demographic characteristics, the age is a significant variable having impact to intensity of use of the suburban bus transport. On the other hand, sex has no significance whatsoever. Increasing level of education and net monthly income of respondents is reflected in decrease of regularity of using the suburban bus transport.

If the providers of public transport would like to eliminate the long-term drop of performance, they have to come up with an offer respecting the passenger requirements. That is possible by provision of marketing-oriented management based on regular monitoring of ever changing customer behavior and knowing his/her requirements. Thinking of people, their preferences and life style also play a significant role, all of them being aspects very difficult to influence.

Acknowledgement

This research was financially supported by the Slovak Research and Development Agency – Grant No. APVV-15-0505: Integrated model of management support for building and managing the brand value in the specific conditions of the Slovak Republic.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Impact Damage Analysis of Aircraft Composite Structures at Low Velocity

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Abstract

The aerospace industry is constantly pushing towards new technologies for faster and efficient flights. The new age of aerospace brought about a need for lighter yet stronger airplanes to be built, and thus entered into the scene, the adoption of composite-based constructions. The structures so built, were stronger than classical metallic airplanes but performed just as well or even better than the conventionally constructed aircrafts. The relatively new material presented a big challenge to all the personnel in the aerospace industry. Guaranteeing the safety of such a structure needed a long - term investigation into the mechanical and chemical properties. In this thesis, a study of the effects of low velocity impact damages on Aircraft Composite Structures, will be carried out using Finite Element Modelling to understand the behavior of the material. Two test models were tested upon to replicate the effects of load criteria, while an aircraft is subjected to high energy/low velocity impact. The test sections are 1 metre by 1 metre for the for the fuselage panel with stringer reinforcements and 1metre by 2 meters for the flat plate with cut-out sections. They were designed using the Dassault Systemes SOLIDWORKS software. This was done to replicate the results in real - life working conditions. The use of the composite application module in ANSYS, Inc. 18.1 software has been heavily used in the research. The skin thickness was kept the same to match the real model of Airbus A350 XWB.

KEY WORDS: *Composites, EASA CS – 25, Impact analysis, Fuselage, Low Velocity*

1. Introduction

From the early days of flight, the aerospace industry has seen growths in terms of speed, weight carrying capacity, and structural integrity. The usage of cloth, paper, etc., in the earlier days of aircraft design to the usage of metal, and the eventual usage of metallic alloys in the construction of aircraft structure was brought about due to industry's need for improved high performance structural materials. And true to its nature, the Aerospace Industry has continued-on with its research for such materials and thereby, have settled on the fact that composite materials tend to exhibit exceptional strength-to-weight(density) ratios and noteworthy physical properties [1].

In essence, composite materials are designed from two or more constituent materials which exhibit different physical and chemical properties. The combined effect of the materials together differs quite variedly when compared to the properties of the individual component. The increased demand for the usage of composite materials is driven by the fact that it leads to a considerable decrease in aircraft structural weight [2]. A decrease in structural weight decreases the fuel consumption of the aircraft; thereby, reducing the direct operating cost by increasing efficiency of the aircraft.

The extensive use of composite material has also resulted in new challenges. The impact damage is a new area in composite material that needed researching and careful accounting for the impact-related damages. There are two types of impact damages: High Velocity Impact Damage and Low Velocity Impact Damages. High Velocity Impact Damages include mid-air bird strike, bullets or any other forms of high velocity projectiles. The previously used, metal-fashioned aircraft have a comprehensive and detailed service history and the workforce: manufacturers, regulators, and operators, around the globe are quite capable enough to handle situations involving damages to such aircraft. The current generation aircraft are making a move towards composites in their construction and that brings about new challenges as the effective directory for solving problems is being updated with each new day the composites are in service [3].

Low Velocity Impact Damages are caused by bodies/objects that move at a considerably slower velocity when compared to High Velocity objects. It includes ground service equipment (commonly known as GSE – typically 3,000 to 10,000 kg) such as ground vehicles, passenger stair truck, jet/aero bridge, belt/cargo loaders amongst other vehicles. The incurred damages fall under a category called Potential Operational Threats & Damages. This has been identified by the NASA Aviation Safety Reporting System (ASRS) and has been properly documented. The database has been heavily contributed-to by aviation personnel such as pilots, as well as controllers, ramp-workers, technicians, flight attendants, and others. The industry study put the risk factor value at 56 per cent of the damages that an aircraft might

incur during its operational life. Therefore, an aircraft stands at a much higher risk percentage - damage, due to uncontrolled and improperly trained handling of airside equipment [4].

Table 1

Incident summary for Ground Vehicles by Vehicle Type [5]

Vehicle causing damage	**Number**	**Per cent**
Cargo/container loader	8	24.2
Stairs (mobile)	8	24.2
Catering truck	4	12.1
Aerobridge	3	91
Passenger lifter	3	9.1
Belt loader	3	9.1
Tug	2	61
Baggage trolley	1	1.3
Fuel truck	1	1.3
Total	33	100

The above illustrated Table 1 shows the airside vehicle that were reported to have caused damages to an aircraft at a certain airport. The events highlight the need for efficient control and care needed while working around a parked aircraft, as any damage to the aircraft could mean the scenario of aircraft-on-ground, which could mean cost bleeding. Metallic aircraft are repaired in such cases by the usage of patch repairs. The damaged section is cut-out and then a newer plated is riveted into its place [5]. Depending on the location, the patch work could be placed inside or outside.

2. Designing and Investigating of Aircraft Composite Structures

The initial approach was to design a fuselage section, modelled to dimensions of the Airbus A350 Extra-wide Body aircraft (XWB). The dimensions for the aircraft were taken from the official Airbus webpage. The fuselage section, for this research, was essentially made out of three parts: skin panel, frames, stringers. The frames and skin stringers act as the reinforcement for the skin panel. A different plate was designed to simulate the effect of damages in the absence of a reinforcing members such as frames and stringers. The test section has two cut-out, dimensioned to match the window specifications of commercial airliners [6]. This was done to study the effects of stress propagation during composite impact damage, near critical areas such as windows and doors.

The model was designed in two parts: First the entire fuselage section was built, but due to lack of suitable resources to calculate the effect of the entire section, small cut-out section was taken out to further the research work [7]. The parts have been illustrated below in the following Figs. 1 and 2.

The above illustrated Table 2 shows the number of elements that are used for reinforcing in the composite structure of the aircraft fuselage that was depicted in the Fig. 2.

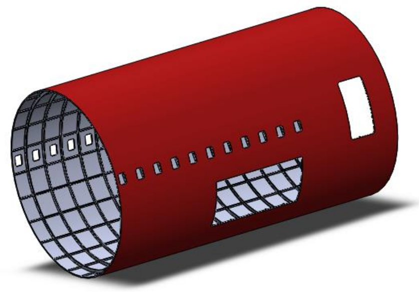

Fig. 1 The Airbus A350 XWB fuselage section

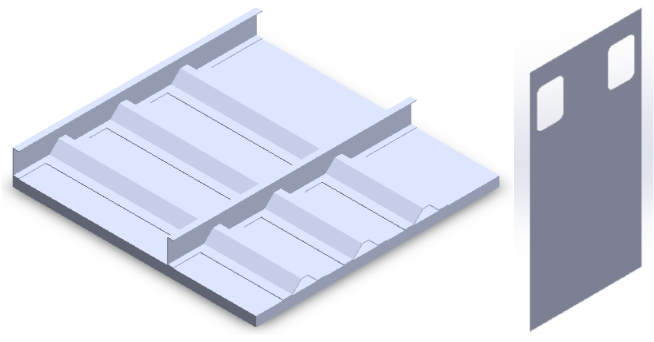

Fig. 2 Fuselage section showing all three elements (skin panels, frame, stringers) and Flat Plate test section with window cut-out

Table 2

Test Panel Stiffeners

	Test Panel Model
Number of Frames	2
Number of Stringers	3

Geometry

The frame cross-section is made of C profile. The dimensions of the frames are: Height = 100 mm, thickness = 4 mm, and the flange width = 25 mm. The pitch between two frames = 635 mm.

The omega-profile stringers have the following dimensions: Height range = 25 -35 mm, thickness = 4 mm, head width = 25 mm and a total foot width between 100 mm – 130 mm. The pitch between two stringers is 250 mm. The skin section has a thickness of 4 mm. (In accordance with EASA CS – 25).

3. Materials and Material Application for the Test sections

As the study is based on the behavior of the structures, that are made out of composites materials, when subjected to a low velocity impact damage, the material chosen for testing includes: Epoxy Carbon Woven (230 GPa) Prepreg, Honeycomb, and Resin Epoxy material. These were taken from the ANSYS 18.1 Material library [8]. The material properties are illustrated in the Tables 3-5, respectively.

Table 3

Mechanical Properties of Epoxy Carbon Woven (230 GPa) Prepreg

Properties	Value	Units
Density	1.42E-09	tonnes/mm^3
Young’s Modulus X Direction	61340	MPa
Young’s Modulus Y Direction	61340	MPa
Young’s Modulus Z Direction	6900	MPa
Poisson’s Ratio XY	0.04	
Poisson’s Ratio YZ	0.3	
Poisson’s Ratio XZ	0.3	
Shear Modulus XY	19500	MPa
Shear Modulus YZ	2700	MPa
Shear Modulus XZ	2700	MPa
Tensile Stress Limit X Direction	805	MPa
Tensile Stress Limit Y Direction	805	MPa
Tensile Stress Limit Z Direction	50	MPa
Compressive X Direction	-509	MPa
Compressive Y Direction	-509	MPa
Compressive Z Direction	-170	MPa
Shear XY	125	MPa
Shear YZ	65	MPa
Shear XZ	65	MPa

Table 4

Mechanical Properties of Honeycomb Material

Property	Value	Unit
Density	8E-11	tonnes/mm^3
Young’s Modulus X Direction	1	MPa
Young’s Modulus Y Direction	1	MPa
Young’s Modulus Z Direction	255	MPa
Poisson Ratio XY	0.49	
Poisson Ratio YZ	0.001	
Poisson Ratio XZ	0.001	
Shear Modulus XY	1E-06	MPa
Shear Modulus YZ	37	MPa
Shear Modulus XZ	70	MPa
Tensile X Direction	0	MPa
Tensile Y Direction	0	MPa
Tensile Z Direction	5.31	MPa
Compressive X Direction	0	MPa
Compressive Y Direction	0	MPa
Compressive Z Direction	-5.31	MPa
Shear XY	0	MPa
Shear YZ	1.21	MPa
Shear XZ	2.24	MPa

Table 5

Mechanical Properties of Resin Epoxy

Property	Value	Units
Density	1.16E-09	tonnes/mm^3
Young's Modulus	3780	MPa
Poisson's Ratio	0.35	
Bulk Modulus	4.2E+09	Pa
Shear Modulus	1400	MPa
Tensile Yield Strength	54.6	MPa

4. Boundary Condition of the CAD models for Finite Element Analysis

The analysis of the behavior of the parts and the materials was carried out in the ANSYS Inc. Workbench 18.1 software suite. The models were subjected to two types of tests – 1. Static Structural Test, 2. Transient Structural Test. The velocity of the impact is very low and therefore, it is difficult to simulate that using the new ANSYS Composite Pre/Post suite. Therefore, on further reading, it was learnt that such low velocity test can be carried out by converting the value of the velocity of the impacting object to a load case and can be studied under static structural and transient structural analysis. The calculation to figure out the magnitude of the force showed that impact loads are in the range of 2500 to 3500 N, for such low velocity impacts.

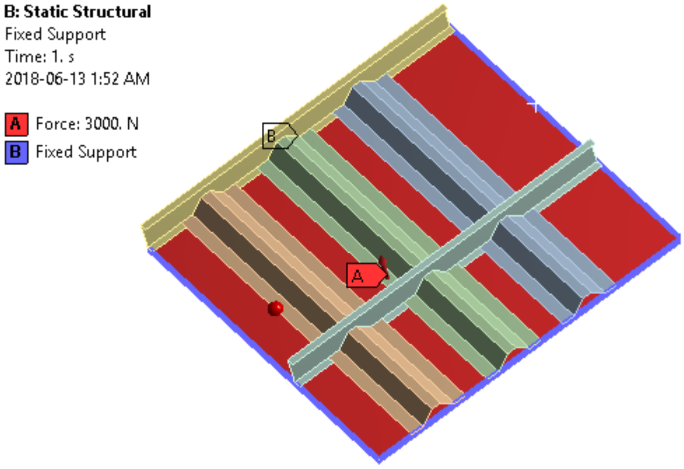

Fig. 3 Boundary Condition: Fixed Support on all four edges, Force = 3000 N

Similar Boundary conditions were applied for the Flat Plate cut-out test section. The supports consisted of fixed supports and the magnitude of the force applied was 3000N (Fig. 3). For the transient analysis, the load was applied using a ramp input to study the effect of the increasing load. The test was carried out for a time period of 1 second and broken into 0.01-time steps.

5. Finite Element Mesh for the Test Sections

Meshing is the most important part of a Finite Element Analysis as the density and appropriateness of the mesh can be difference between accurate and meaningful results and results that do not serve any purpose. The CAD models were meshed using different methods to give an optimum mesh density that would give satisfactory results as well as be easy on the computing systems. The mesh size was kept between a range of 20 mm to 25 mm for purpose of calculations.

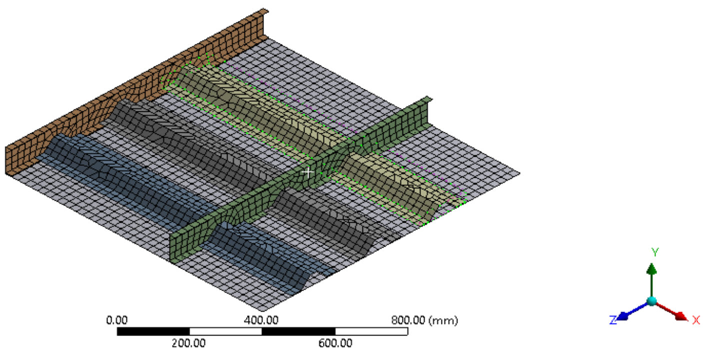

Fig. 4 Mesh for the Fuselage section

The meshed elements were carefully examined to see for any discrepancies in the mesh (Fig. 4). It is important to carry out this step as faulty meshes can result in untrue values or even failure of the analysis.

6. Results and Findings

6.1. Fuselage-section Static Structural Test

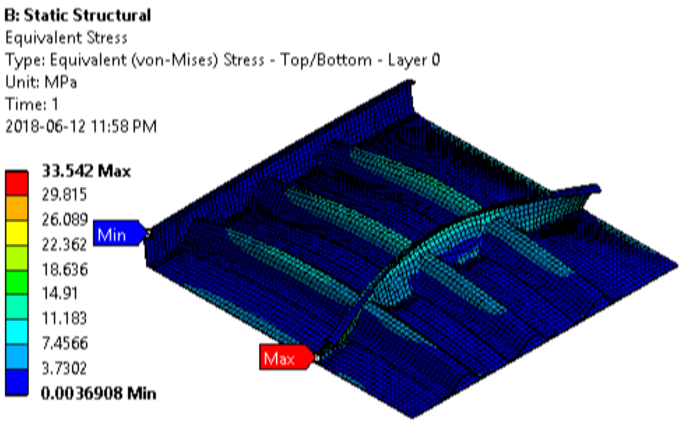

Fig. 5 Stress value – Fuselage Section

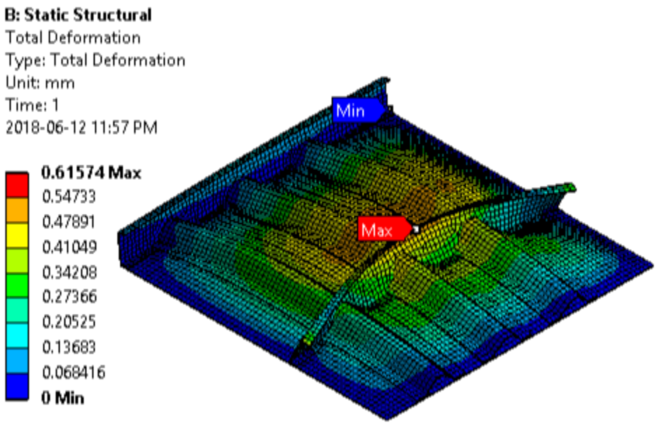

Fig. 6 Deformation value – Fuselage Section

The above shown results for the stress and deformation of the fuselage section, in Figs. 5 and 6, show a maximum value ranging between 7 – 14 MPa, although, near the fixed support, we can observe a higher value of nearly 33.54 MPa. The highest value of deformation is 0.62 mm, which was observed in the middle of the test section. On closer examination of the image, it can be seen that the frame bends due to such a load and therefore, when the failure criteria mode is switched-on, in composite analysis, we find certain new developments.

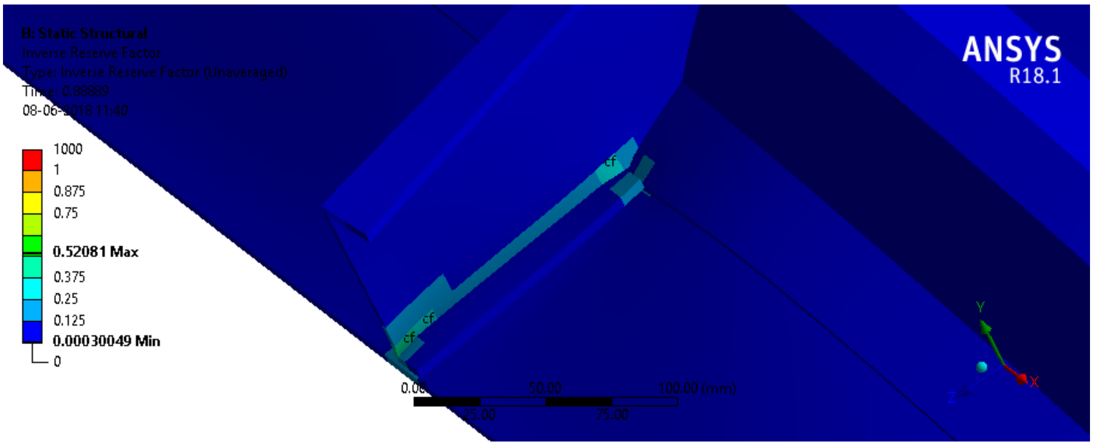

Fig. 7 Core failure due to static load

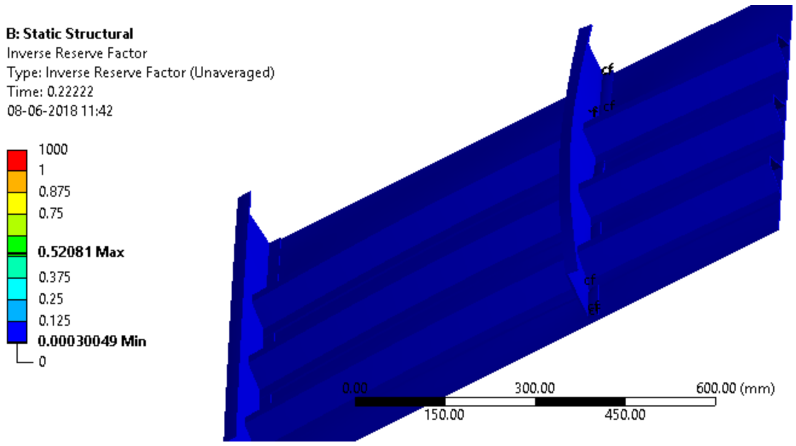

Fig. 8 Core failure along the Frame-skin interface

The above illustrated Figs. 7 and 8 show the core failure occurs near the frame-skin interface. The core failure could mean delamination or tear. ANSYS ACP module requires the user to switch on the failure criteria modes to depict the failure criteria's effects [9]. The failure criteria modes are:

1. Maximum Stress Theory;
2. Maximum Strain Theory;
3. Tsai – Hill Theory;
4. Tsai – Wu Theory;
5. Puck Theory;
6. Hashin failure criteria;
7. Core Failure;
8. Face Crimpling effect.

6.2. Flat Plate with Cut-out section - Static Structural Test

The flat plate section was subjected to two types of tests. The first one being the static structural test to measure its structural integrity due to static load (no consideration for the inertia of the load).

The above illustrated Figs. 9 and 10 show the values of stresses and deformations, respectively. A maximum value of 55.541 MPa was observed near the fixed support section of the flat plate section. A maximum deformation of 15.86mm was observed at the very center of the test section. Switching on the Failure Criteria tools will further allow to check for damages in the layer or core.

As expected, cut-out sections without reinforcing elements will have adverse effects around them. The above illustrated Fig. 11 depicts core failure around the window section of the test plate, due to the applied static load. Results such as this very useful for structural engineers to anticipate failure in critical regions.

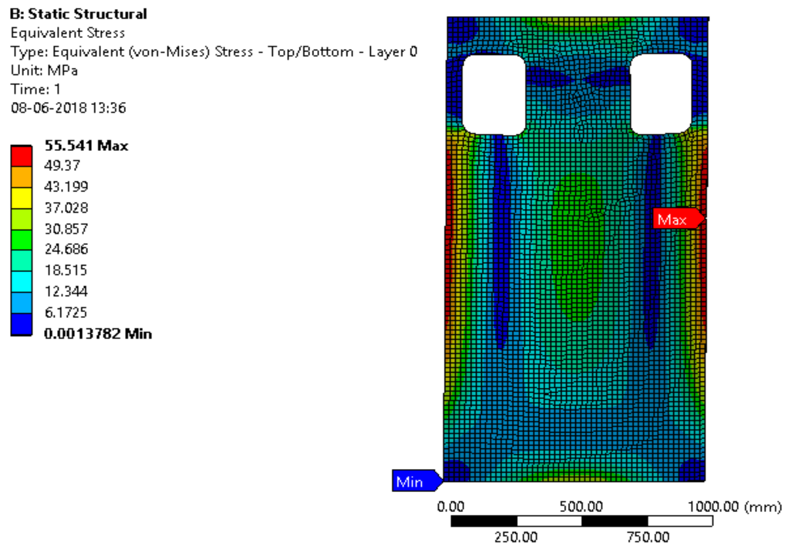

Fig. 9 Stress value for Flat Plate section

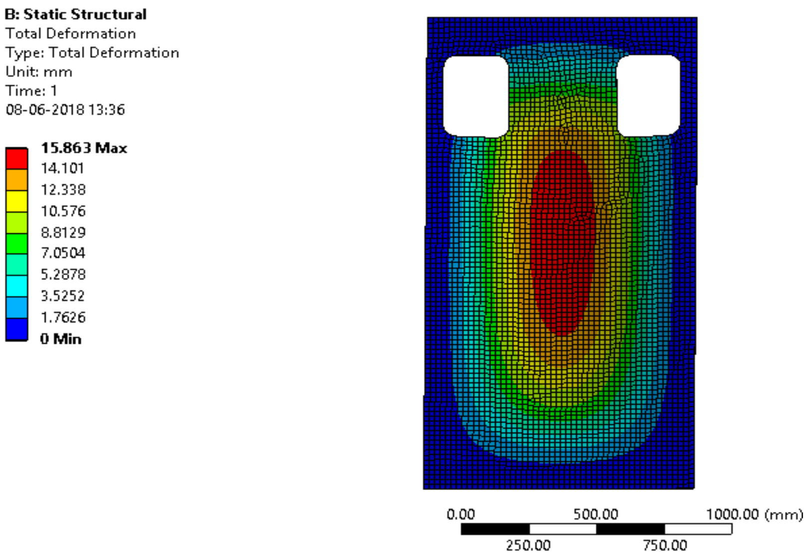

Fig. 10 Deformation value for Flat Plate section

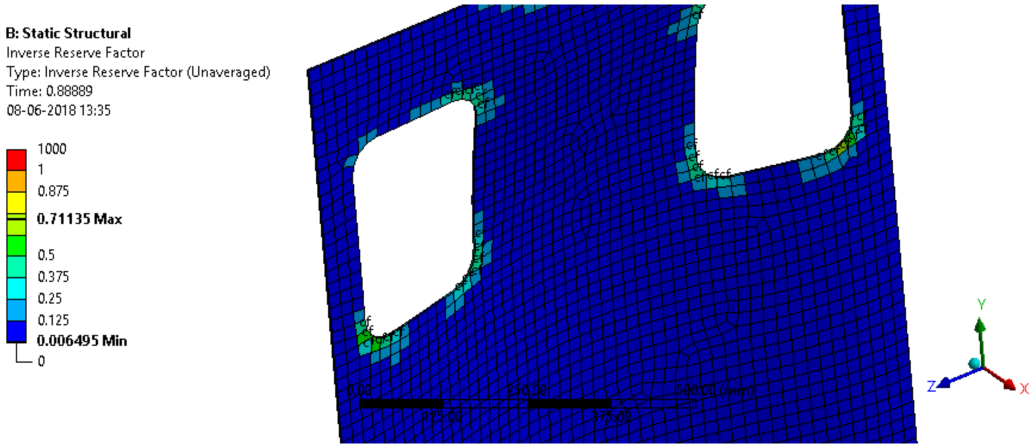

Fig. 11 Core Failure around Cut-out section

6.3. Flat Plate with Cut-out section – Transient Structural Test

As we are dealing with aircraft structural analysis, it would be wise to consult documents that are followed or prescribed by the aviation governing bodies such as EASA or FAA. For this study, the EASA CS -25 (Legislation for Large Airplanes) was followed. The regulation requires for a structure to be able to with stand critical loads, under transient conditions. For this, a transient structural analysis test was thought to be the most appropriate test. The load would be a function of time and therefore, the effects of the inertia can also be included into the study. The results of the transient structural tests are as follows (Fig. 12-14):

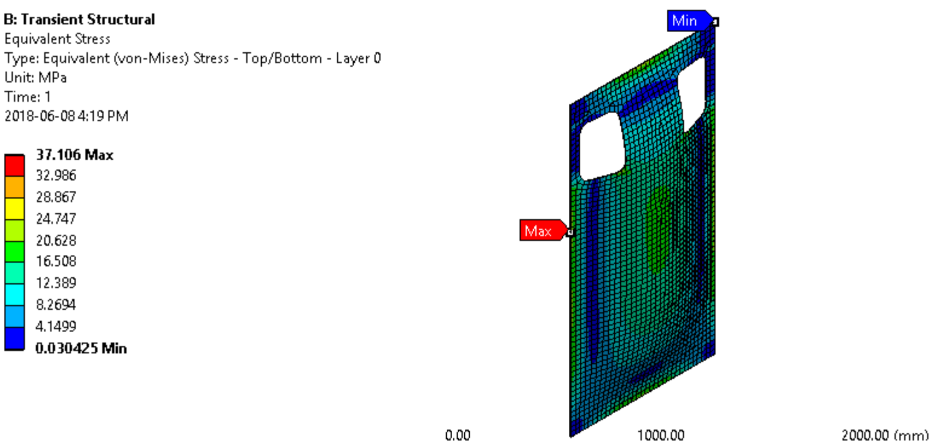

Fig. 12 Stress value due to transient load application

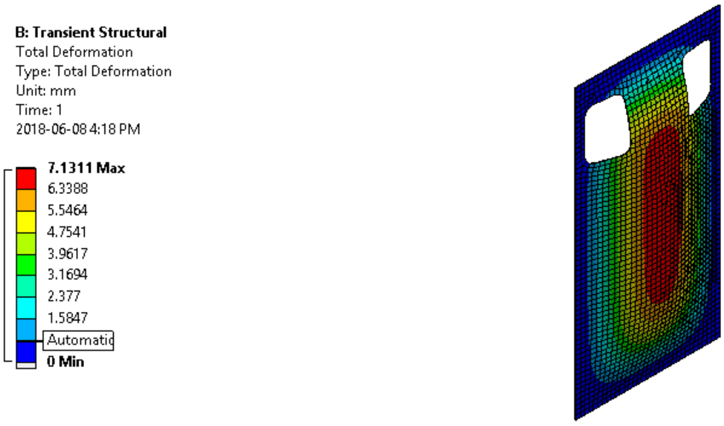

Fig. 13 Deformation value due to transient load application

Following similar procedures as carried out in the previous two tests, for composite failure analysis, we look for the effects of the load applied.

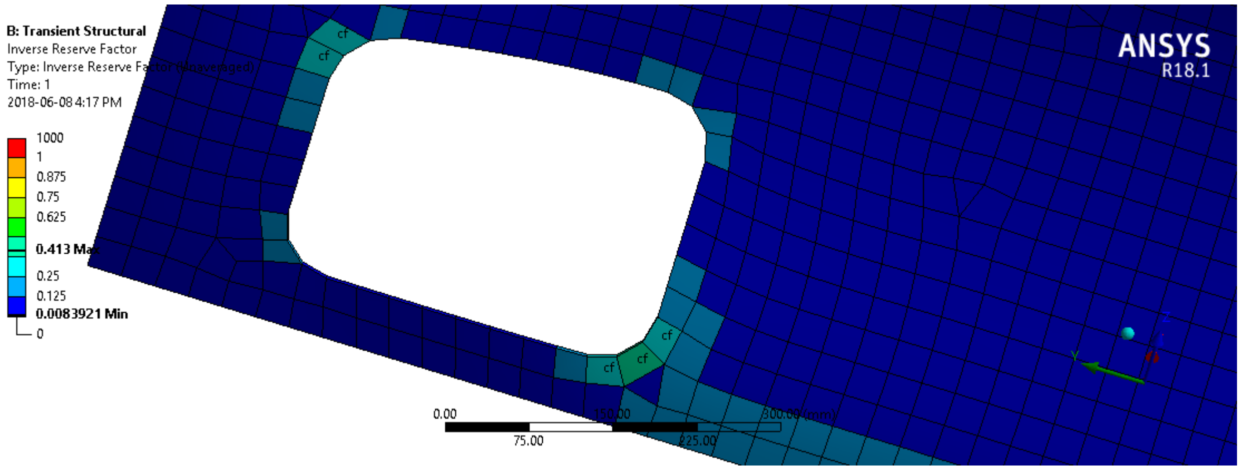

Fig. 14 Development of Core failure due to transient load application

Similar to the test results for static structural test for flat plate cut-out section, the highest value of stresses developed near the fixed supports. The value so obtained was 37.11 MPa. For the deformation, a value of 7.13 mm was observed. On analyzing the failure criteria for composite structure, it can be see that core failure does start developing due to the transient load that is being applied.

The EASA regulation requires for deformation involved to be fully accounted for. In this case, such a study is needed to see if the structure can withstand deformation and continue its normal operations.

7. Conclusions and Discussions

Aerospace industry's push for stronger yet lighter materials mean that the testing methodology will need to be revamped considerably. New materials mean structural engineers will need to understand the behavior and be able to suitably apply them, according to their usage. The objective of this research was to study the effects of loads due to low velocity impacting on critical aircraft fuselage sections.

Previous papers had shown that finite element impact damage analysis have been carried out on structures that resembled a flat composite card. Very few tests have been carried out on aircraft structures and components by individuals. All such tests have been carried out by manufacturers and aircraft legislation agencies. The aim of this research was to carry out similar tests at University level.

Formulation of the tests required careful reading of the appropriate documents. Due to resources that are available in limited cases, some tests might need to be developed further. An explicit dynamics test can be conducted for carrying out impact damage analysis at higher velocities. The usage of software such as ABAQUS SIMULIA CAE and Python scripting can also be used to further simulate the effects of a real-world scenario. In this research, the supports chosen were fixed support but using ABAQUS and Python scripting, the user can further develop the model to include the elastic effects of the surrounding fuselage section or also simulate the effects of having shear ties to connect skin panel to frames and stringers.

The maximum values for stresses ranges between 12 to 60 MPa, depending on the test section geometry and the analysis type. For the deformation value, the range is between 0.5 to 15 mm. These simulated values are important for

aircraft designers for the prediction of failure modes. The EASA CS – 25 load regulations states that the structure must be able to support limit loads without detrimental permanent deformation. At any load up to limit loads, the deformation may not interfere with safe operations. The structure must be able to support ultimate loads without failure for at least 3 seconds. This is applicable for static structural load. The above tests showed that when there is no reinforcing for the test section, it does fail before the allowable 3 seconds time limit. It only goes to show that critical areas such as window section, door sections, or other openings need metallic reinforcement to prevent stresses from promulgating and causing catastrophic structural failure.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

The Phenomenological Model of a Global Maritime Labour Market

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Abstract

The maritime labour market is of a particularly international nature, characterized by globalization and mobility. The maritime sector in general could be defined as global, mobile and growing. Seaborne trade well correlates to global economic growth and sea trade cycles generally follow cycles of the world GDP. The article discovers the maritime labour market as a complex set of interconnected phenomena and presents the phenomenological model of global maritime labour market, as a field of seafarers' supply and demand, influenced by economical, demographical, geopolitical, technological and other factors.
KEY WORDS: *Maritime labour market, global, demand, supply, seafarers*

1. Introduction

The maritime sector in general could be defined as global, mobile and growing [1]. With over 80% of global trade by volume and more than 70% of its value being carried on board ships and handled by seaports worldwide [2], the importance of maritime transport for trade and development cannot be overemphasized.

The world seaborne trade, growing in line with developments in the world economy, reached 10.3 billion tons in 2016, or expanded by 2.6% per year. However, the historical average recorded over the past four decades was of 3% per year (Fig. 1).

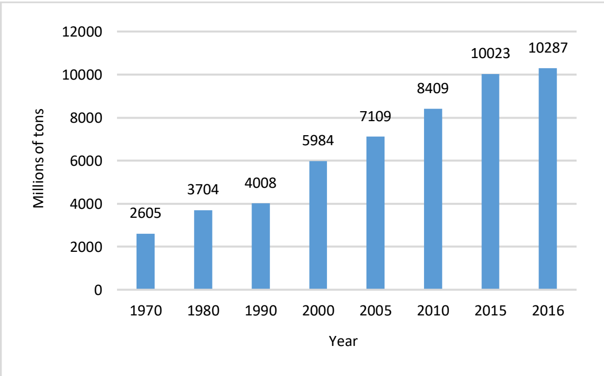

Fig. 1 International seaborne trade, millions of tons loaded per selected years [2]

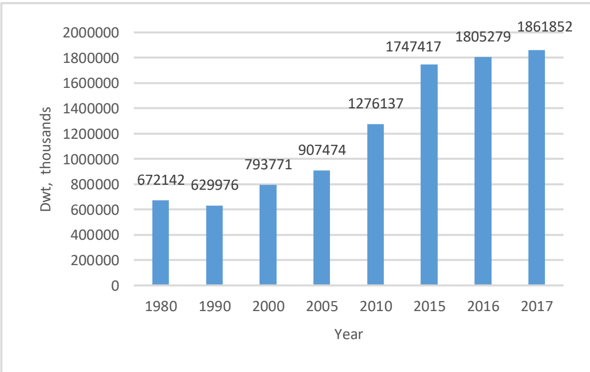

Fig. 2 World merchant fleet tonnage, dead weight tons in thousands per selected years [3]

In total, the world commercial fleet on 1 January 2017 consisted of 93,161 vessels, with a combined tonnage of 1.86 billion dwt (Fig. 2). The global supply of seafarers in 2015 estimated at 1,647,500 seafarers, of which 774,000 are officers and 873,500 are ratings [4].

However, the shipping sector sometimes appears to be invisible to policymakers and the public generally [1].

The shipping industry is also presented as highly cyclical in nature and characterised by extended periods of bust and boom [5].

New technology developments in shipping are coming. The digital revolution could transform merchant shipping in the coming decades. Such smart shipping comprises *inter alia* autonomous and connected ships with better performance and lower costs via deployment of various sensors and data analytics [1].

At all times the labour market has been a matter of demand and supply. In many countries the supply of seafarers to serve the national fleet is only a small proportion of the supply provided to the world as a whole, in the meantime in others, the nationally owned fleet is served by a mix of seafarers of several nationalities. Seafaring is a truly global, multinational and multi-cultural occupation [6]. Over 90% of the seafarers from the advanced economies work on board their home fleets, while 80% of seafarers from the developing economies and over 60 per cent of the seafarers from transitional economies work on board the fleets of advanced economies. World shipping industry has offered opportunities for seafarers from developing countries and, increasingly, from transitional economies to develop careers outside their home country [7]. From 5,430 Lithuanian seafarers about 1,800 are working on board ships, flying Lithuanian flag, another part actively participates in the international maritime labour market.

The aim of the article is to prepare phenomenological model of global maritime labour market, as a field of seafarers' demand and supply, influenced by economical, demographical, geopolitical, technological and other factors, based on global trends analysis.

2. The Link Between World Economic Development and Seafarers' Demand

Clarksons Research argues [8], that seaborne trade well correlates to global economic growth and sea trade cycles generally follow the cycles of the world GDP (Fig. 3). Changing (globally growing, *auth*.) demographics and concomitant demand patterns are a key factor in the demand for shipping [9]. According to the UN, world population is set to increase to around 10.1 billion by 2100 (Fig. 4.) [3].

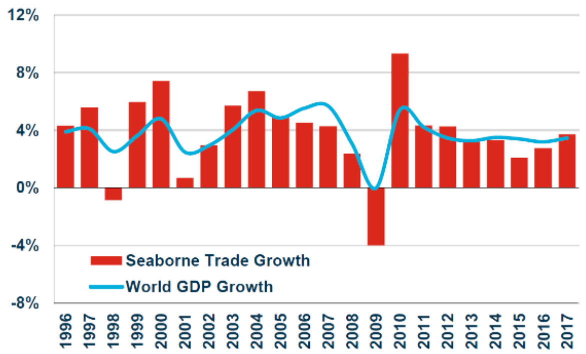

Fig. 3 Sea trade growth correlation to world GDP growth [8]

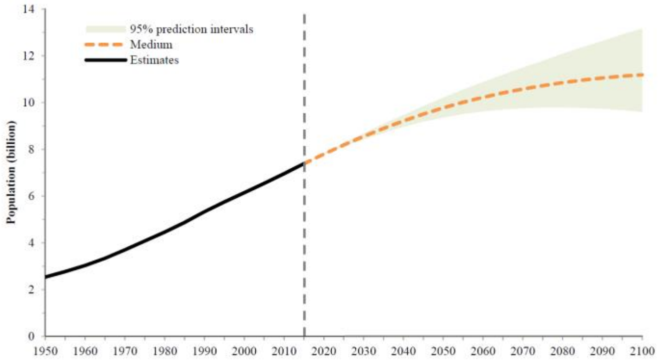

Fig. 4 Population of the world: estimates, 1950-2015, and medium-variant projection with 95 per cent prediction intervals, 2015-2100 [10]

It is worth noting that during a relatively short period of human existence, the 45-year period from 1970 to 2015, population of the world has increased from 3.7 billion in 1970 to 7.38 billion in 2015 [3], i.e. almost twice. However, during the same 45-year period international seaborne trade has increased from 2,605 to 10,023 million of tons [2], i.e. increased by 3.8 times. We can see that international seaborne trade as the result of human activity grows even much faster, than human population does.

By BIMCO [11], the future global demand for seafarers depends on a number of factors:

– the future growth of world trade, and hence the growth in the world fleet;
– the future growth of ship productivity, which will be determined by the technology embodied in new ships;
– the changing age of the fleet, which will alter the crew levels required for safe manning;
– changes in the required levels of manning to comply with national and international conventions;
– changes in the flag composition of the world fleet, because this affects overall manning totals;
– changes in the proportions of non-national crews used by ship-owners and ship management companies, as this affects the "typical manning levels".

Later some additional factors were highlighted, such as changes in the average ratio of the seafarers, required to fill each position on-board (Man-berth ratio, MBR), taking into account leave allowance, training needs and etc.; seafarers wastage and turnover rates and etc. [4].

3. Resent Changes in Global Maritime Labour Market

UNCTAD data confirms a continued trend of industry consolidation, where different countries specialize in different maritime subsectors. It also confirms the growing participation of developing countries in many maritime sectors [2]. The top five ship-owners in terms of cargo carrying capacity (dwt) are Greece, Japan, China, Germany and Singapore; together, these five countries have a market share of 49.5% of dwt. Only one country from Latin America – Brazil – is among the top 35 ship owning countries; none is from Africa. The five largest flag registries are Panama, Liberia, the Marshall Islands, Hong Kong (China) and Singapore; together they have a market share of 57.8%. Three countries – the Republic of Korea, China and Japan – constructed 91.8% of world gross tonnage in 2016; among these, the Republic of Korea had the largest share, with 38.1%. Four countries – India, Bangladesh, Pakistan and China – together accounted for 94.9 % of ship scrapping.

BIMCO data confirms a continued growing of the global supply of seafarers, which increased from 1,187 thousand in 2005 to 1,647.5 thousand in 2015 [4]. Top five seafarers' supply countries reported by companies were China, Philippines, Russian Federation, Ukraine and India. The comparison of estimates of the supply of seafarers by economic and regional grouping over the period of 2005-2015 is presented in Table 1.

It is notable, that the share of officers in total number of seafarers has increased from 39.3% in 2005 to 47% in 2015, which indicates a rising seafarer's qualification, corresponding to the advancing technical level of the fleet.

The most significant increase in the number of seafarers occurred in the Far East group, whose share of officers increased from 28 to 39% of the total number of officers, while the share of rating seafarers increased from 31 to 55%. China has a main increase in maritime labour supply, although the Chinese-owned fleet currently uses most of the additional workforce.

Table 1

Comparison of estimates of the supply of seafarers by economic and regional grouping 2005-2015

Region	2005				2010				2015			
	Officers	%	Ratings	%	Officers	%	Ratings	%	Officers	%	Ratings	%
OECD	113,000	28	174,000	24	184,000	29	143,000	19	176,000	23	118,000	14
Eastern Europe	95,000	20	115,000	16	127,000	20	109,000	15	135,000	17	125,000	14
Africa and Latin America	38,000	8	110,000	15	50,000	8	112,000	15	65,000	8	82,000	9
Far East	133,000	28	226,000	31	184,000	29	275,000	37	300,000	39	477,500	55
Indian Sub-Continent	68,000	15	96,000	13	80,000	13	108,000	14	98,000	13	71,000	8
Total	467,000	100	721,000	100	625,000	100	747,000	100	774,000	100	873,500	100

4. The Phenomenological Model of a Global Maritime Labour Market

From the above discussion, it becomes clear, that maritime labour market represents a complex set of interconnected phenomena. The phenomenological model of global maritime labour market that reflects seafarers demand and supply dependence and influence on key factors is described below (Fig. 5).

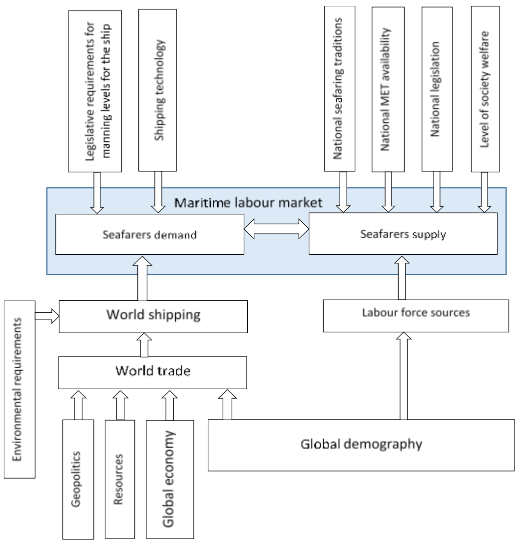

Fig. 5 The phenomenological model of global maritime labour market

Global demography and global economy are mutually interconnected related phenomena, which in general determine the global trade growth. The allocation of resources, production and consumption, to some degree influenced by geo-political decisions, have a significant impact on the routes and volumes of different cargo movements.

The essential purpose of the world merchant shipping is to cover needs of the world trade. The global cargo types and volumes, transportation routes and the search for the efficient transportation methods determine the variety of types and tonnage of existing and newly being built ships – main shipping means. Growing environmental requirements in turn affect the design of the ships, the type and technology of their energy equipment, the type of fuel used and, of course, the final shipping cost.

Seafarers demand depends on number and type of the ships. The number of seafarers on-board and their qualification must be sufficient to ensure that ships are operated safely and efficiently under all conditions. Manning levels for ships are regulated by legislation requirements of International Maritime Organization, Classification societies and others. The developing of shipping technologies, mechanization, automation and recent computerization affect the manning levels for the ship. Few people today remember about such a usual and common in the past profession as a boiler stoker (in ranges from ordinary to chief stoker on board) or just a few years ago quite reputable specialty of marine radio officer.

Shipping globality may be discovered out when the shipbuilder, ship’s port of registration, ship’s flag, ship’s

owner and ship's operator may have different addresses without a single clear national affiliation. Differently from ships, seafarers, even working in international crew on board ships of other country, remain seafarers of their country, with a greater degree of genuine link to nationality.

The participation of the country in seafarers' supply gets through the number of the seamen from that country and their qualifications. The activity of participation depends on the national seafaring traditions (that can change), on the availability and capacity of the national maritime education and training (MET), on a motivating (or demotivating) factors such as the level of country's social welfare and national legislation in the field of seafarers taxation, and finally, of course it depends on the country's demographic potency.

5. Global Trends, Influencing Future Maritime Labour Market

There is never a single and well-defined future [12]. Nevertheless, it is worth to overviewing the main trends that can affect the global maritime labour market in the future. Depending on world merchant fleet growth and composition, global marine officers' demand in 2020 could increase by 11% and in 2025 by 20%, in comparison with 790.5 thousand officers' demand in 2015 [4].

Demography. With the highest probability it could be argued, that changing demographics will remain a key factor in the demand for shipping. UNCTAD forecast of the world population by regions in 1950, 2017, 2030, 2050 and 2100 [10] is presented in Table 2.

Table 2

Total population by region, 1950, 2017, 2030, 2050, 2100 (medium variant), in millions

Region	1950	2017	2030	2050	2100
World	2,536	7,550	8,551	9,771	11,184
Africa	228	1,256	1,703	2,527	4,467
Asia	1,404	4,504	4,946	5,256	4,780
Europe	549	742	739	715	653
Latin America and the Caribbean	168	645	718	779	712
Northern America	172	361	395	434	499
Oceania	12	40	47	57	71

The size of the world population will rise over the next few decades and will stand between 8.4 and 8.7 billion in 2050, and between 9.6 and 13.3 billion in 2100, with 96% population increase coming from the developing countries. Beyond 2050, Africa will be the main contributor to global population growth. Europe is the only region with a smaller population in 2050 than 2017 [10]. India will overtake China with the largest population and the largest labour force in the world. "Aging" countries face the possibility of decline in economic growth. Increased migration will spread to emerging powers [13].

Economy. UNCTAD forecasts an increase in world seaborne trade volumes between 2017 and 2022. Projected growth estimates are based on the income elasticity of seaborne trade, including by cargo segment derived by using regression analysis over 2000–2016. Combining the estimated elasticities with the latest International Monetary Fund GDP growth projections for 2017–2022, world seaborne trade volumes expected to expand across all segments [2]. Global GDP could grow three times within 20 years. In 2030, the largest economies, by a long way, will be China, USA and India. The countries with the largest growth in per capita GDP will be China, Vietnam, India and Indonesia. Purchasing power in developing Asia will rise 8 times between 2010 and 2030. Seaborne trade could more than double [13].

Resources. Energy demand expected to be 40% higher in 2030. China oil consumption could triple, overtaking the USA to become the largest oil consumer. The USA will remain the biggest natural gas consumer, while China will see the largest growth in natural gas consumption. China and India will be the giants in the world's coal consumption. China will remain the biggest steel consumer in 2030 [13].

Shipping technology. Container ships have been increasing almost exponentially in size. The maximum container ship size is envisaged to be of around 26,000 TEU by 2030. Such "megaships" are typically deployed between major ports with smaller, feeder ships in turn servicing those ports [9]. The digital revolution using various sensors and data analytics would transform merchant shipping in the coming decades. There are hopes that by 2035 autonomous unmanned ocean-going vessels will be a common sight on the ocean [14].

Environmental requirements. This issue is extremely important and costly. The rapidly changing environmental challenges force industry to look for modern fuel and technology choices, new regulatory policies, seeking to comply with regulations.

Geopolitical decisions and trade agreements or restrictions (e.g. Brexit, trade and investment agreements or trade embargoes) will also influence future maritime cargo flows.

6. Conclusions

The phenomenological model of a global maritime labour market, as a field of seafarers' demand and supply, influenced by economical, demographical, geopolitical, technological and other factors is presented in the article. Global demography and global economy in general determine the global trade. The allocation of resources, production and consumption, have a significant impact on the routes and volumes of different cargo movements, influenced to some degree by geo-political decisions. The global cargo types and volumes, transportation routes and the search for the efficient transportation methods determine the variety of types and tonnage of existing and newly being built ships – main shipping means.

Seafarers demand depends on the number and type of operated ships, where the number and qualification of seafarers on-board must be sufficient to ensure that ships are operated safely and efficiently under all conditions. The participation of country in seafarers supply depends on the national seafaring traditions (that can change), on the availability and capacity of the national maritime education and training (MET), on a motivating (or demotivating) factors such as level of country's social welfare and national legislation in the field of seafarers taxation, and finally, of course, it depends on the country's demographic potency.

The global supply of seafarers increased from 1,187 thousand in 2005 to 1,647.5 thousand in 2015. It is notable, that the share of officers in total number of seafarers has increased from 39.3% in 2005 to 47% in 2015, which indicates the growing seafarers' qualifications, corresponding to the advancing technical level of the fleet. The most significant increase in the number of seafarers occurred in the Far East group, whose share of officers increased from 28 to 39% of the total number of officers, while the share of rating seafarers increased from 31 to 55%. China has a main increase in maritime labour supply, although the Chinese-owned fleet currently uses most of the additional workforce.

Changing demographics, the size and allocation of the world population will remain a key factor in the demand for shipping in the future. The maritime labour market, responsive to world trade needs, will be influenced by global trends in economy, the use of resources, by developing shipping technology, changing environmental challenges, geopolitical decisions and other issues. Depending on the world merchant fleet growth and composition, marine officers' global demand in 2020 could increase by 11% and in 2025 by 20%, in comparison with 790.5 thousand demand in 2015.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Transmission Error Analysis of the Gearbox

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Abstract

The transmission error analysis is described in this paper. Two gear boxes were used for creating the closed loop for measurement. The basic quantities were measured as they are angles, torque and shaft speed. The closed loop allows to analysed transmission error at different shaft speed and torque. The traction mode measurement at torque range from -1155 to 4235 Nm and -150 rpm shaft speed is investigated in this article. The aim was evaluation of the transmission error and its trend depend on torque.
KEY WORDS: *transmission error, Matlab script, shaft speed, torque, gearbox, measurement*

1. Introduction

Transmission vibrations affect the device or its users thus the gearbox development is accelerated and must be very sophisticated to reduce them. The vibration problem arises in contact with each tooth of the gearbox. It is related to geometry and the quality of the tooth surface and it can influence the overall noise of the device.

For that reason, the transmission error (TE) evaluation is described in this paper. This determines the smoothness of a gearbox running. By using this method, we can compare the quality of the gearbox in different operating modes. The transmission error reveals the accuracy of the transmission design and wear teeth surfaces. The goal of the development transmission is to achieve the lowest value of the transmission error – peak to peak. Then the vibrations transmitted by the different powertrain are also reduced. Vibration and noise analysis of the gearbox were described in this article and are based on [1, 2] and the data processing is explained in [3-5].

The goal was to verify the transmission error. And its value must be smallest for the nominal torque. Therefore, measurement and data processing are described in the individual chapters. A measuring loop consisting of two gearboxes was assembled for measurement. There were placed sensor for getting signals. Measurements were carried out at different torque settings and the rotation angle of the output and input shafts was monitored. The transmission error was evaluated from the data and results is described in this paper. This article builds on a previous study [6] of the transmission error with the braking mode set. In this case, the transmission error was analysed with the traction mode set.

2. Measurement

Fig. 1 shows a measurement loop used for testing and monitoring data. The measuring loop is assembled from two transmissions. Their output and input shafts are connected to create a closed loop. On the left in the figure, there is the gearbox to be analysed and the additional gearbox is on the right. A cardan shaft is placed between the output shafts and it is used for torque generating by move the gearbox. For this purpose, a piston rod is connected to the additional gearbox. When the force is generated by piston, the gearbox is rotated around the input shaft. In this way, the required torque in a closed loop is set. An electric motor with adjustable speed is connected to the input shaft. By combining the direction of rotation and the driving torque, the real operation conditions can be tested. That corresponds to braking and traction in the different directions of the output shafts rotation. If the gearbox is rotated upwards, a positive drive torque is generated. Otherwise, the piston rod is compressed and generates negative force and negative driving torque. If the torque and speed signs are the same, it is a traction. If they are the opposite, it is a braking. In the previous study [6], a braking analysis was performed. In this article, traction will be described so that the torque and shaft rotation signs will be the same.

ERN 460 encoders for measuring output and input shaft rotation are placed in the test loop. Their designation is E1 and E2. The encoder includes two output signals and they are offset with respect to each other. Each signal generates 3600 pulses per revolution. The required torque and revolutions of -150 rpm were set before testing. During the testing, data for post-processing was monitored in the torque range of -1155, -1925, -2695, -3465 and -4235 Nm. The

measurement system was controlled electronically to maintain the set shaft speed and torque values during testing.

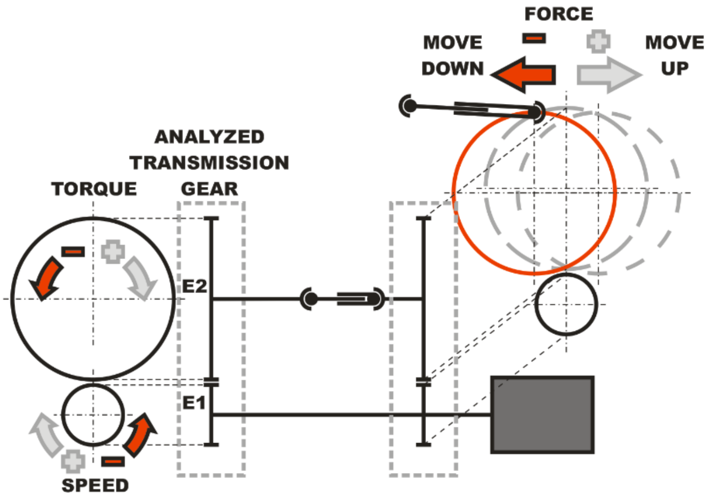

Fig. 1 Measuring loop scheme

3. Basic Description of the Transmission Error

The literature [3, 4] describes the transmission error. The transmission smooth running is determined by transmission error. If teeth stiffness is infinite and tooth shape are ideally produced, the transmission error value is equal to zero. In normal operation, shafts and gearbox cover are loaded, teeth shape is not perfectly made and each tooth are defined by their real stiffness. Therefore, vibration arises in the course of gearbox running and a transmission error (TE) is evaluated by equation:

$$TE = \left(\varphi_2 - \frac{z_2}{z_1} \varphi_1 \right) r_2 \quad , \tag{1}$$

where φ_1 is the gear pinion rotation angle, φ_2 - the gear rotation angle, z_1 - the pinion teeth number, z_2 the driven gear teeth number, and r_2 is the gear pith circle radius. The monitoring data were processed using this equation.

4. Results of the Measurement

The measured data includes time and the encoder position. This position is in the form of pulses. In order to use Eq. (1), it was important to recalculate the data of the measurement to the shaft rotation angle. A Matlab script was created for processing. In the first stage, the angle was converted. Subsequently, it was necessary to calculate the transmission error at the same position of the shafts rotation. Therefore, the output shaft signal had to be resampled according to the position of the input shaft. Then the evaluation of the transmission error was created for the combination of all teeth contacts. This means that 21 teeth of the pinion and 110 teeth of the output gear were gradually in contact. The results of the transmission error are displayed in Figs. 2-6 at the driving torque of -1155, -1925, -2695, -3465 and-4235 Nm.

For clarity, the segments are represented in graphs corresponding to a combination of 21 pinion tooth and 21 gear teeth. This means that one rotation of the input shaft is shown in the graph. The vertical axis is represented by the value of the transmission error in units of μm. On thorough analysis of the graphs, it can be ascertained that the transmission errors representing individual teeth contacts vary slightly. This is primarily due to the surface quality. Based on this transmission error analysis method we can detect just the errors caused by tooth surface machining in all the combinations of the teeth contact. But it is not the goal of this paper.

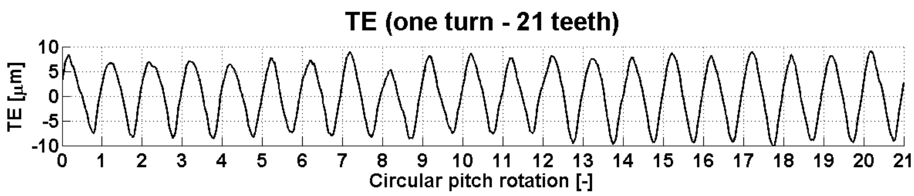

Fig. 2 Measurement result of TE at a torque of -1155 Nm (one turn of pinion)

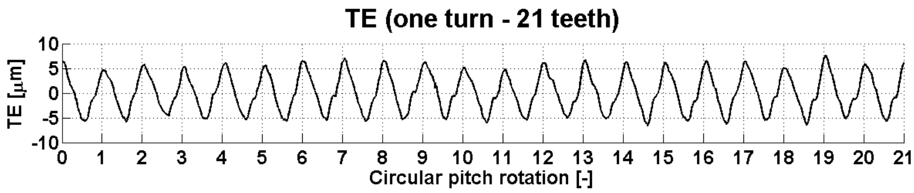

Fig. 3 Measurement result of TE at a torque of -1925 Nm (one turn of pinion)

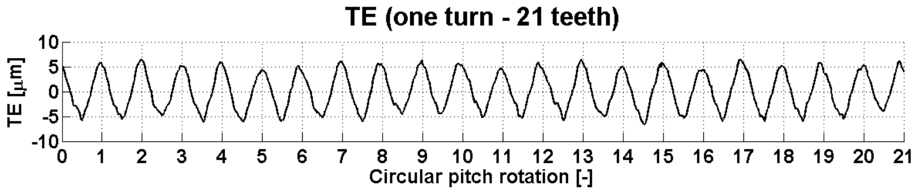

Fig. 4 Measurement result of TE at a torque of -2695 Nm (one turn of pinion)

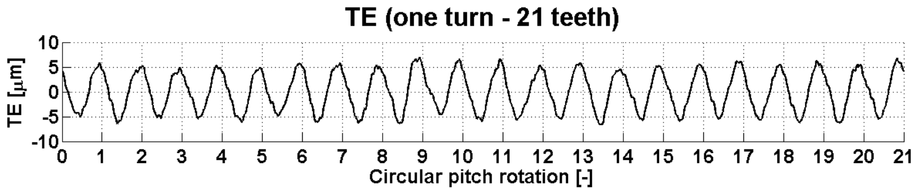

Fig. 5 Measurement result of TE at a torque of -3465 Nm (one turn of pinion)

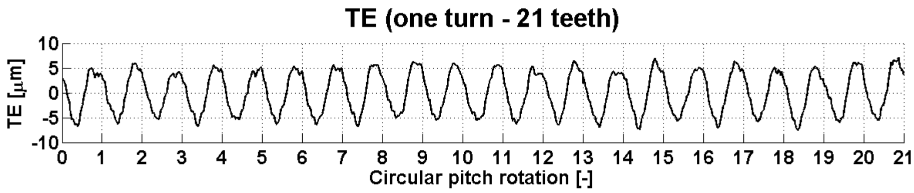

Fig. 6 Measurement result of TE at a torque of -4235 Nm (one turn of pinion)

The results of the transmission error depend on the value of the drive torque as shown in the graphs. Therefore, the created script was supplemented by a statistical method that assesses all combinations of teeth contacts. A median was used to evaluate the total transmission error. The results are shown in Fig. 7. On the horizontal axis, there is the position of one tooth. On the vertical axis, the transmission error in units of μm is displayed. The aim of this analysis was to confirm or disprove the downward trend of the TE depend on the nominal torque of the tested gearbox. This is 2700 Nm of torque and for this moment the tested gearbox has been designed so that the transmission error is small. The results show that this trend can be confirmed, therefore, it is the lowest value around the nominal torque of 2700 Nm. The next step will be to perform analyses in the opposite rotation direction for braking and traction. Consequently, the research will focus on analysing the shape of the transmission error curve corresponding to the surface quality of the teeth.

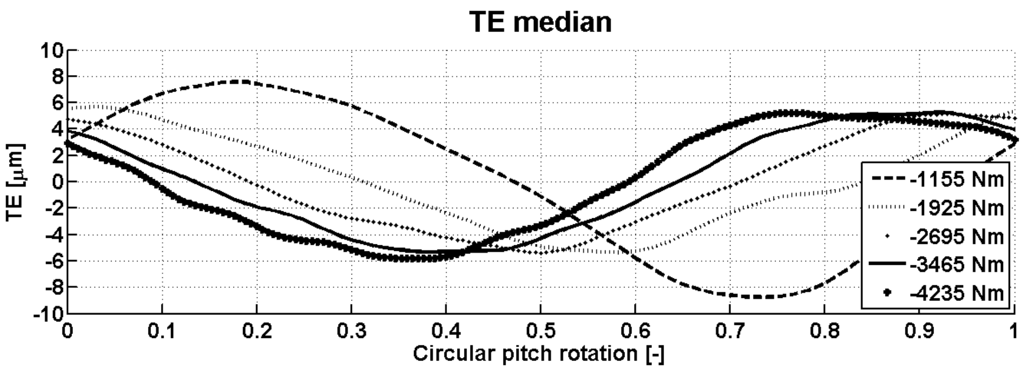

Fig. 7 Transmission error median for different torques

5. Conclusions

The current topic is the reduction of noise and vibration, so it is necessary to focus on particular machines in

more detail. This is done by various measuring devices and evaluation methods. Using one of the methods has been applied just in this article.

This article dealt with the TE analysis for powerful transmissions. In the first stage a measuring loop consisting of two gearboxes was assembled. This loop was closed. In addition, sensors were placed in the measuring loop to monitor the signals. They were the position of the input and output shaft rotation. From these data by the mathematical operations, the data was ready to use Eq. (1). The results show the transmission error for each combination of teeth contacts. In these data, we can analyze the quality of machined surfaces that influences on the overall vibration of individual combinations of teeth. But it was not the goal of this paper. The main aim was to confirm the transmission error downward trend to the nominal torque of the tested gearbox. In order to do this, the statistical method of the transmission error from the combination of all teeth contacts has to be evaluated. The results show that the transmission error to the nominal torque of the tested gearbox is small. This was the goal. A further follow-up will perform analyzes for the opposite directions of braking and traction and the evaluation of the shape of the TE curve for each tooth contact combination.

Acknowledgement

This work is an output of the internal BUT research project Reg. No. FSI-S-17-4104

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Signal Versus Noise Concept in Aviation Safety Data Processing

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Abstract

The paper focuses on the issues concerning enhancement of the safety data management through understanding of the internal data structure and system behaviour. To build a strong system foundation based on safety knowledge, and to find a system on how to gather such knowledge are the key issues in modern safety engineering. Systematic data collection is not a new concept, however, the focus was always on quantity, while data quality was often misunderstood or hard to understand and be dealt with. A research topic was therefore focused on quality and content of the available data, covering the state of the incoming data, their wider classification, analytics and utilization through instruments creating safety intelligence. Having a large amount of data, means having an ability for potential system behavioural pattern identification. This is however strongly influenced by data structure and applied analytical methods. Identifying behavioural pattern in other words means articulating a certain signal generated through system, carrying information regarding system state, functioning and potential deviations. Due to a fact that such system manifests as a stochastic one, it is highly influenced by certain level of internal or external noise. The goal of the research is to examine system abilities for behavioural deviations detection and elimination of the negative, unnecessary and inadequate structures in data gathering process.
KEY WORDS: *safety data, data structure, quality, signal processing*

1. Introduction

Aviation, as an extremely productive generator of operational and safety related data on daily basis, reached a phase, where its sustainability could be argued from the safety engineering standpoint. Increased operations, extreme exploitation of the infrastructure, resources and manpower created a great need for extensive data gathering and processing. This is a case in any field or subsystem of the whole aviation industry. Logically, aviation safety is not an exception. Even though the results in safety management are satisfactory [1-3], the questions arise, what should be done in order to improve wider data gathering and evaluation and what could be possible benefits.

Intensive daily operations of the airlines, airports, navigation service providers or other entities in aviation industry require proper understanding of the processes and their backgrounds. Performance of the involved entities is widely dependent on the ability to understand, identify and react on the particular failures, accident root causes, contributing factors, system errors etc. In comparison to the previous approaches, modern safety bases its concept on proper system engineering, data analysis and data-driven safety knowledge. Current trends direct the researches in this area on predictive models [4]. There are currently many initiates and studies in the area of causal modelling for various industry branches [5, 6]

It could be stated that the main problem of the modern safety engineering approaches is safety knowledge gathering process and relatively weak mechanisms intended for these purposes. To be clear, there is a wide range of data collection system, however in aviation safety area, they are primarily oriented on the data quantity and are dependent on the given preconditions and data structure. It is not always an easy task to deal with such amount of uncertain data, currently used mostly for the basic statistics and their representation. This is a case in many aviation organisations having implemented a safety management system. Safety management is defined as a manager's process, stating individual responsibilities for safety within whole organization [7].

To have a large amount of everyday operational data, means having a strong potential for system behaviour identification, understanding and management. Therefore, a certain steps in data structure enhancement are strongly required. Recognised behavioural patterns are in their core a certain signal emitted through a given system. Signal is a carrier of the information concerning current system state, functionalities, deviations or failures. Such systems is purely stochastic one and it is strongly influenced by both internal and external noise.

Noise in this case should not be understood exclusively as external effect on the given system, but as internal uncertainties and data structure insufficiencies. The paper tries to define on how this noise occur, what is a level of its

impact on the given system, how could it be artificially influenced and what should be a final result of the signal improvement. It is also important to define whether such noise is always well understood as negative influence, or whether it has some significant role or value.

Due to their sensitivity, safety data have their limitation, e.g. availability, form or flexibility. Previous research results, as well as European approach will be furtherly described within the paper in order to show current trends in noise reduction. It is important to highlight that defining available safety data through an expected signal, influenced by uncertain or unnecessary data, in this case defined as system noise is a way on how to evaluate an acceptable signal to noise ratio, imagined as indicator of system health state.

2. Current Approach to the Safety Data Noise Prevention

In order to actively work on data noise reduction it is a paramount priority to define it. The whole process is based on the available data from the active aviation industry entity. Taking into account safety data from the Prague airport a certain conclusion could be derived.

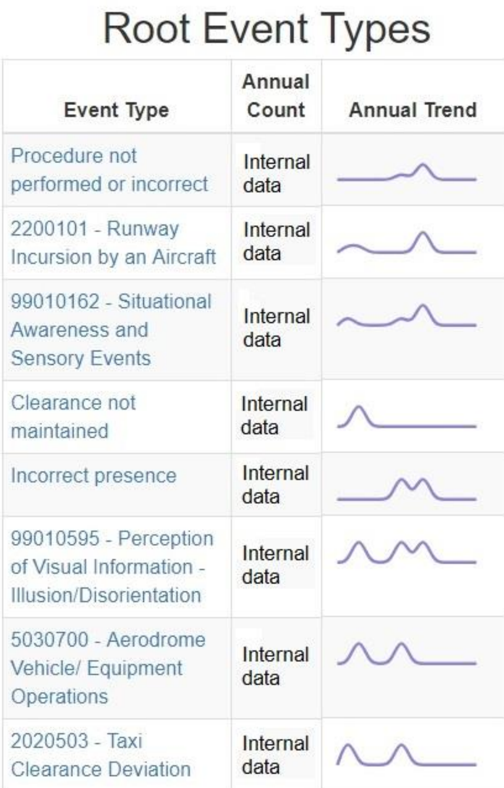
Due to an actual structure and available content of the data no standard analytical and statistical methods could be applied. Data do not obtain basic definitions of internal relationships, clear objectification, dependencies, common classification, or other characteristics necessary for performance evaluation.

This is a common state within a major part of the industry entities. Such state stimulates the European Aviation Safety Agency to make progressive steps in data quality problem solving. One of the first steps was to start with the high-level classification of the incoming data [8]. EASA and European Commission created a new obligatory schema for safety events and relevant attributes classification. These are presented within regulations 376/2014 [9] and 2015/1018 [10].

European countries agreed on a common platform for safety reporting, known as ECCAIRS, whose primary goal is to collect relevant safety data from the national and individual reporting systems. Having a common system for data collection within the Europe shows a practical steps in data collection standardisation. The goal here is clear and it supports the idea, that within a wider area (for instance Europe) a large number of interested parties should collaborate, actively share information and use experiences from the others. This way, barriers such as safety data inconsistency or structural differences are now eliminated or at least mitigated.

ECCAIRS system is actively used and brings several improvements in terms of data structure and quality. Safety reports all around the Europe are continuously collected and classified according to the given vocabularies enabling standardised and commonly used method for the identification of the certain safety issue. Member states are obligated to report safety events through this system.

Similarly as in the case of the European level, particular organisations have their own systems used for safety reporting and data management. Prague airport, as the party participating in the research provided its current safety data. The following Figure (Fig. 1) shows a representation of the data statistics gathered from the available safety data.



Root Event Types

Event Type	Annual Count	Annual Trend
Procedure not performed or incorrect	Internal data	
2200101 - Runway Incursion by an Aircraft	Internal data	
99010162 - Situational Awareness and Sensory Events	Internal data	
Clearance not maintained	Internal data	
Incorrect presence	Internal data	
99010595 - Perception of Visual Information - Illusion/Disorientation	Internal data	
5030700 - Aerodrome Vehicle/ Equipment Operations	Internal data	
2020503 - Taxi Clearance Deviation	Internal data	

Fig. 1 Prague airport safety data statistics display

This shows an approach in safety data classification and evaluation through the indicator-based platform. It evaluates the current performance using the reactive indicators [11, 12] and showing actual occurrence of the given safety issue.

Presented approaches shows us how does involved organizations on the local or regional level try to solve issues, which from the practical stand point create a systemic noise within data structure and utilization. The standard way applied on the European level is static and it is based on the given legislation. Countries are guided through common legal base to follow certain rules and reach a required level of performance in this area. On the other hand, European administration provided common system to support more structured and mutually understandable data collection system.

A little bit different situation is in case of particular organizations. Their approach is individually made and it is dependent only on the internal system design. Only a following of the higher-level European guidelines and more detailed data analysis brings a noticeable improvement in system noise reduction.

3. Data Availability and Processing

Based on the cooperation with the several aviation entities a performed research was focused on improvement of data collection and structuring. Successful reaching of a required level of conceptual modelling correctness was expected through ontological modelling of currently used taxonomies and safety itself. Ontological approach enabled precise definition of the particular elements and mutual relationships.

Development of the safety domain ontology model enabled its utilization and practical implementation. The result of such implementation was development of the supporting software, designed with respect to the ontological principles and creating that way an adequate platform for better data structuring. Current system was utilized for transformation of the available safety related data gathered by the interested and involved entities

Used data are the safety data of the Prague airport. Due to internal policy and data protection, only statistical and diagram representation will be applied.

To explain noise reduction tied to safety data structuring, we can use an event restructuring software module developed during the research. The reconstruction in depicted on the following picture (Fig. 2).

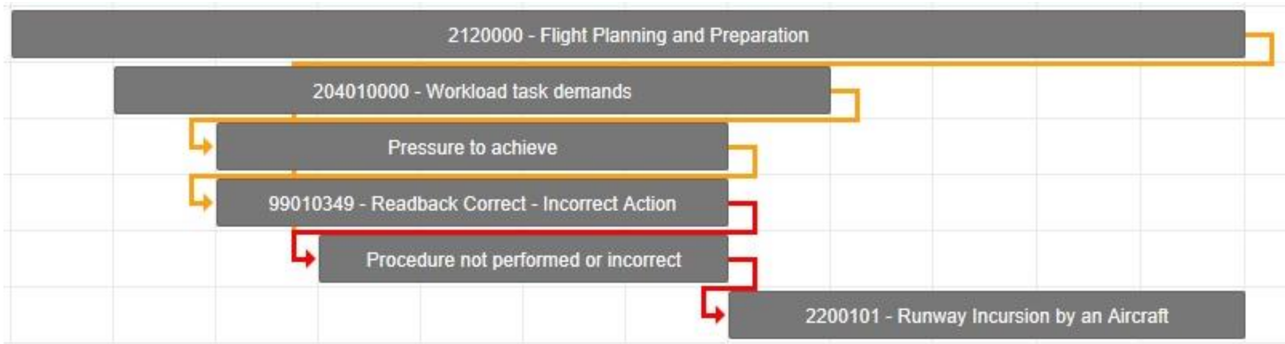


Fig. 2 Safety data structuring – event reconstruction

What kind of signal is now created from the theoretical point of view? All relevant data available or collected through the standardised reporting system pass through the classification phase. This phase is essential due to a fact that each element in behavioural pattern now receive a strong and clear identification. This identification include a taxonomy term utilization and establishment of the relation with the distinguishable element of the event chain.

All relevant and distinguishable elements are supposed to be classified in order to catch all relevant fact related to the given safety issue. Not only identification of the particular event chain elements is important. The software enables creation of the internal relation among identified chain elements. It is possible to distinguish whether two or more elements are just contributing factors to the certain safety event or whether they represent a main cause of it.

By establishing the complete picture of the individual safety events it could be claimed that description is structured in a machine-readable way. Technically, it means that data are structured in a more systematic way, enabling an elimination of the unimportant and low-quality elements of the structured data. Classical data collection that is now in place includes all kind of information received through the given system.

Following data reconstruction phase is a first practical filtration or data enhancement process. Eliminating the extended and unneeded structures stabilises the whole data structure, by excluding the elements that brings bias and uncertainties into the system behavioural patterns.

Due to a fact, that daily airport operations consists of a large number of processes it is a good environment for extensive procedure deviations or errors. Due to established classification process it is now possible to follow occurrence of the various elements common for the specific problem. Software enables catchment of the so called behavioural patterns. It means that repetition of the particular scenarios are now noticed and systematically followed. All created relations in the reconstruction phase are now integrated into one larger picture, showing all interconnections with the main element in focus.

For instance, airport safety issue classified as “Incorrect use of equipment” is reconstructed and integrated data are presented on the following figure (Fig. 3). Reduction of the noise in this case practically means complete classification and relation establishment among all included entities or elements.

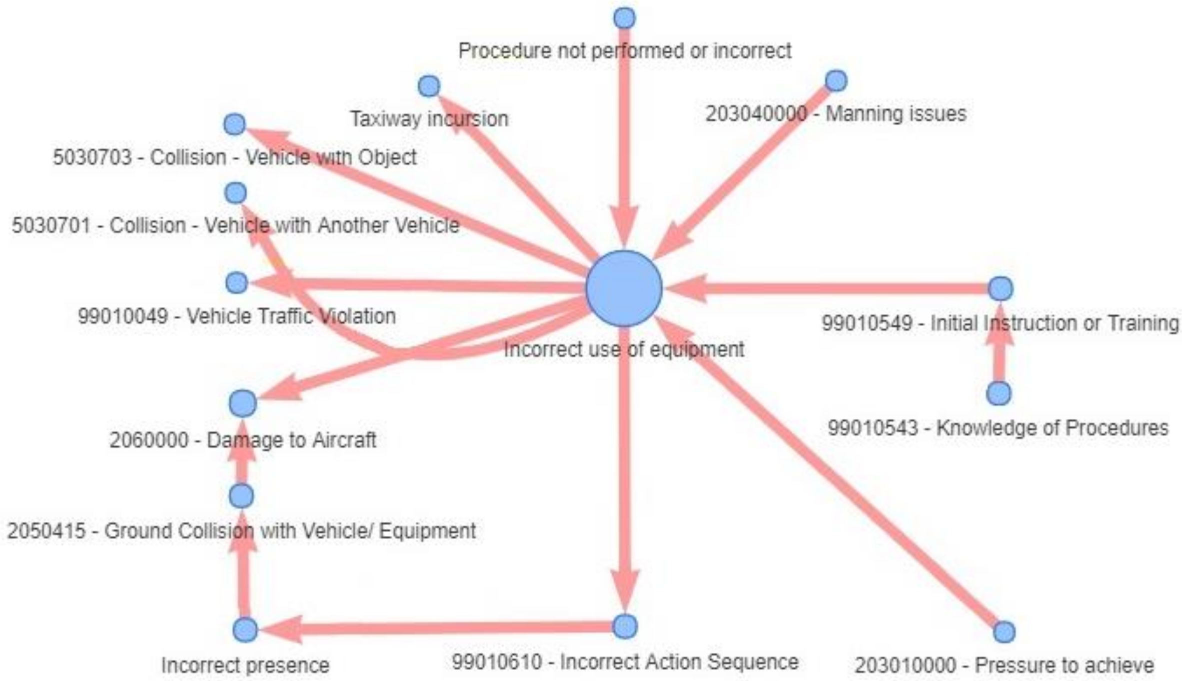


Fig. 3 Systematic safety knowledge representation

An assumption is of course that not all contributing factors chain patterns frequently repeat. Proving an existence of a structure of contributing factors, responsible for some events is surely a clear contribution for more proactive safety management.

Technically speaking, it does not matter whether contributing factors chain as such confirms itself by constant appearance in a same manner. Internal relations and causal links between individual contributing factors determines whether pattern as such has strong and clear structure or whether is it just a random string of independent factors. There are good examples on how universities (University in Delft) through projects approached an issue of causal modelling. It for instance introduce that input requirements for consequence model form the output specifications for the causal models [13].

EUROCONTROL (European Organisation for the Safety of Air Navigation) for instance approaches the issue in an innovative manner [14]. It tries to define a barriers on several levels that should prevent safety event realisation. These barriers are actually safety event prevention measures applied on a set of defined contributing factors in order to block their appearance and eventual effects that these factors could have.

To establish a relevant and efficient barrier structure, causality of involved contributing factors must be understood and reasonably evaluated in order to enable creation of valid contributing factors structure. Currently, for more proactive use of contributing factors organizations need to relay on creativity and analytical skills of safety inspectors or managers.

Efforts spent on developing more systematic approaches to the issues are significant, but possible solutions are still on a system development level.

4. Discussion

The whole research was oriented on the establishment of the proper data structuring approach that will eliminate additional and unnecessary data integration into the safety knowledge base. The filtering process should be set in a way to be able to prevent extensive clogging of the database and data analysis mechanisms.

Having the research results, some basic principles could be highlighted and evaluated. Because primarily airport data were used, analysis should be focused on airport management system. The system passes from the wide data gathering to the smart data filtering. The sources of data are functional and well established. Attention should now be drawn on the information structuring and safety knowledge creation and storing.

Performed event reconstruction activities brought well-structured database with internal relations records. All additional information, evaluated as irrelevant were excluded from the records. Such irrelevant information are recognised as a system noise, not beneficial in any reasonable way.

Elimination of the extended data is exhausting process, which will be a focus of the future work in this area. Automatic recognition and following elimination is a feature that will enhance an overall safety data analysis

performance and efficiency of the safety management system as a whole.

5. Conclusions

Evolution of the safety management systems is based on proactivity. A transit from classic event chain investigation to more proactive system theory principals for understanding what was the system configuration that did not manage to prevent irregularities or failure of particular system elements is a core of the offered approach.

Detecting weak spots and potential for event realisation (from the available data) creates a starting position for effective event prevention. The main idea is that available data could and should be analysed and represented through causal models of relevant contributing factors.

There are different opinions on how contributing factors should be treated. Naming them without further analysis most probably will not provide valuable information, relevant for effective safety management.

Assumption is that such contributing factors due to their clearly visible role in event realisation should be examined in relation to the other present factors. Character of the relations between individual contributing factors is understood as a main criteria for their behaviour within created chain. Proposed solutions try to draw attention on causal relations between individual factors assuming that these relations are not random but created according to character of the individual factors. Having a complete picture of the system behaviour enables creation of the clear system signal representing a behavioural pattern cleaned from the unneeded and internally induced noise.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Comparison of CO_2 Emission of Urban Public Transport per Passenger between Dresden and Bremen

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Abstract

Urban public transportation is by governments seen as one of the main ways to reduce the congestion and air pollution in cities. The tram is returning in the streets of cities in the USA and governments are investing to expand the public transport and make it more environmental friendly. One of the main indicators of how clean a city is, is the amount of CO_2 emitted. Two German cities are being compared in this article, which are similar in terms of population. The amount of CO_2 emitted per passenger kilometre is the main factor of this article. In order to establish probable causes of a higher of lower emission, the cities are compared on several factors such as their bus fleets, network and population density. The results show that the cities, however a difference in fleet composition, are strikingly similar in the amount of CO_2 emitted per passenger kilometre. Average vehicle occupancy does not seem to be the cause for the slightly higher emission of Bremen, since this is similar. Advised is to research the power source of Dresden's electric vehicles, the CO_2 emission in other cities and the exact division of the passenger kilometres per bus and tram.
KEY WORDS: *urban public transport, CO_2 emission, sustainable transport*

1. Introduction

The transportation world has seen many changes and developments in order to reduce the amount of Greenhouse Gasses (GHG) emitted. People are actively stimulated to use public transport instead of their private cars, in order to reduce congestion, but also the amount of GHG emitted. In the freight industry this is also stimulated, with governments trying to achieve modal shifts from trucks to more environmental friendly modes as barge and train.

In urban public transport is this development also on going. Companies are purchasing new vehicles, switch over to environmental friendly energy sources and try to improve the driving style of the drivers. However, public transportation is always dependent on its surroundings. In cities they are dependent of all the DEPEST-factors[1]:

- Demographical: Population, population density and demographic structure;
- Economical: Economic activity in the cities, welfare and the location of this;
- Political: Commitment of the local government to invest and subsidise public transportation;
- Ecological: Climate of the city and sustainability goals of the city;
- Social: Status of travelling by public transportation, cultural role and role in the current society for welfare;
- Technological: Development is dependent on the technological possibilities.

A comparison between the modalities itself has already been taken out by Condon and Dow, where they compared the different modalities on their emissions and costs [4]. They stated: "What is the optimal relationship between land use and transit, and what transit mode would best support this optimum state. On this there is no agreement - neither here in the Vancouver region nor in the rest of North America." [4]

The aim of this article is to achieve a comparison of the urban public transportation between two similar sized and developed cities. It is focussing on the emission of CO_2 of the transport systems. Additionally, it will proceed on with the possible reasons behind a certain amount emitted in this cities as demographics, network structure and power sources, in order to contribute to a future answer to the question how a transport system can be set up as sustainable as possible for a city around 500,000 - 600,000 inhabitants.

2. CO_2 Emission of Public Transport Modes

The streetcar is one of the least emitting modalities per passenger mile with typical occupancy [4]. The main reason given by the authors is that trams are able to renew their energy by generating braking energy, which again can be used for equipment on board or returned in the overhead power lines.

The difference between trams and trolleybuses, both modalities without direct emission, is that trams "are inherently more energy efficient than buses because they generally have higher passenger capacities and lose less energy to frictional resistance than rubber wheeled vehicles."[4] This however does not directly mean that the tram is

[1] The DEPEST-analysis is originally found as PEST-analysis by (Aguilar, 1967)

the best for every city.

Trams are responsible for at least 0.45 g CO_2 per passenger mile, and 23.4 g at most. This is dependent on the source of the energy (hydro vs coal). Regular buses of this research are responsible for 188 g. [4]

Another important part of the article is the power source behind the used energy by the electric vehicles in the city. However, in Condon and Dow's studies in 2009, they revealed that the main difference is to find in the higher efficiency of the electric motor in comparison with the internal combustion engine. Electricity coming from a coal power plant with 206 g CO_2 per kWh is not even so much more emitting than gaining energy from diesel, which has 262 g CO_2 per kWh.

For diesel buses, "despite the diesel bus's relatively good environmental credentials, the public often perceive diesel buses as polluting."[6] Urban public transport is also much more efficient and less polluting than journeys by car. The most polluting urban public transport mode, a diesel bus with 188,9 g CO_2 per passenger mile is still twice as less polluting than the Ford Explorer with 370,9 g per passenger mile [4].

3. Methods

The research has been taken out between two cities in the European Economic Area of a similar size with a similar development, since these cities are located within the same country. In the cities is the urban public transport organised by one company, which is another main factor to obtain data. Excluded of this research is inner-city usage of regional public transport. For Dresden is data of the company *Dresdener Verkehrs Betriebe* [5] obtained. In the case of Bremen, the data is obtained from *Bremener Straßenbahn Aktiengesellschaft* [3].

The data is found via desk research mainly, since both companies have published this data online. This data is analysed on the useful data and data which is useful for additional calculations. In order to get a more complete view of the CO_2 emission, power sources and modal split, questions are asked to the companies, in order to establish similarity in data and find additional data. Next to Dresden and Bremen are Vilnius, Antwerp, The Hague and Bradford asked for data.

The obtained data is coming from the companies itself, added with data about the following facts:

- Inhabitants of a city;
- City area (km^2), if not provided by company data;
- Demographic structure of the city.

In order to find the amount of grams CO_2 emitted per passenger kilometre in Dresden, the following formula is applied:

$$CO2\ per\ pkm\left(g\right)=\frac{CO2t}{Pkm}\,, \tag{1}$$

where Bremen already calculated the amount of CO_2 per *pkm* in their "*Umwelterklärung"* of 2016.

For seeking possible reasons behind the amount of CO_2 emitted, several facts are being researched. These factors are:

Population density:

$$Population=\frac{cp}{km2}\,, \tag{2}$$

where is *cp* – city population; μ – Vehicle occupancy (%):

$$\mu\,Vehicle\ occupancy\left(\%\right)=\frac{Skm}{Pkm}*100\,, \tag{3}$$

where *Skm* – total seat kilometres per year (capacity); *Pkm* – total passenger kilometres per year; μ – Trip length per passenger:

$$\mu\ ptl=\frac{Pkm}{P}\,. \tag{4}$$

Network density:

$$Network\ density=\frac{km\ of\ \ public\ transport\ lines}{km2}\,. \tag{5}$$

Stop density:

$$Stop\ density = \frac{Total\ \ public\ transport\ stops}{km2}\ . \tag{6}$$

µ Inhabitants per stop:

$$Inhabi\,tan\,ts\ \ per\ stop = \frac{Inhabi\,tan\,ts}{Total\ \ public\ transport\ stops}\ . \tag{7}$$

µ Seats per vehicle:

$$\mu\ Seats\ \ per\ vehicle = \frac{Skm}{Vkm}\ . \tag{8}$$

Tram/Bus-ratio:

$$Tram\ Bus\ ratio = \frac{Total\ of\ \ trams\ in\ city}{Total\ of\ \ buses\ in\ city}\ . \tag{9}$$

Bremen's Energy used per pkm:

$$Energy\ used\ \ per\ \ pkm\ in\ kWh = \frac{Total\ energy\ used\ in\ kWh\ per\ \ year}{Pkm}\ . \tag{10}$$

Used abbrevations in formulas: *CO2t* – Total amount of grams CO_2 emitted during the year 2016; *pkm* – passenger kilometre; *Pkm* – Total amount of *pkm* during 2016; *Skm* – Total amount of Seat kilometres in 2016; *Vkm* – Total amount of Vehicle kilometres in 2016; μ – Average; *ptl* – Passenger trip length; *cp* – City population; *P* – Total amount of passengers in 2016.

Additionally to the facts, also the fleet of buses is reviewed. The main facts researched is the engine type in the bus.

4. Results

Dresden's DVB and Bremen's BSAG both published documents with data upon the usage of energy. DVB has consolidated all their data over 2016 within the same document. Bremen has their data spreaded over their website within multiple documents. Most of the data is coming from the "*Umwelterklärung 2016*".

The first findings in Table 1 show the total amount of CO_2 emitted by both companies in total and per passenger kilometre.

Table 1

CO_2 emitted in total and per passenger kilometre

Findings	**Dresden**[2]	**Bremen**[3]
CO_2 total (metric t)	32245	28034
CO_2 / *pkm* (g)	43.02	45.7

Dresden and Bremen have quite similar amounts of CO_2 emitted per passenger kilometre. This seems interesting, since Dresden makes more use of trams, whereas Bremen the bus is the dominant mode.
Dresden has counted their direct and indirect emissions (Table 2):

Table 2

Dresden's division of direct and indirect CO_2-emission

Direct CO_2 of daily operations per year (in metric t)	14,431, of which: *Bus*: 9,641 *Bus external power*: 4,700
Indirect CO_2 of daily operations per year (in metric t)	18,114, of which: *Tram*: 17,897 *E-Bus*: 14 *Switch point heating*: 203

[2] Numbers, Data and Facts in overview (DVB, 2017)
[3] Environment declaration (BSAG, 2017)

Even though Dresden makes use of the tram, the indirect CO_2-emission as shown in table 2 in 2016 is still quite high. This is most probably caused by using CO_2 emitting power resources. Using these types of power resources leads to higher emissions. In Table 3 are other probable factors are shown [4].

Table 3

Data of both cities after calculations

City's urban public transport characteristics	**Dresden**	**Bremen**
Energy used / pkm (kWh)	Tram: 0.096 Bus: 0.25	Combined: 0.219
Population density	1433	1737
µ Vehicle Occupancy (%)	18.45	18.74
µ Trip length (µptl)	4.8	5.4
Network density (nd) (km/km^2)	1.22	1.86
Stop density (sd) ($Stop/km^2$)	1.68	1.54
µ Inhabitants / stop	854	1131
µ Seat / Vehicle	150.34	132.54
Ratio trams/buses	1.31	0.52

Bremen is a more dense city in terms of the population and line network. Dresden has more stops and the average trip length is lower. This means that the number of passengers is higher overall in order to compensate it in passenger kilometres. The average capacity of Dresden's vehicles is higher, but have a similar occupancy as Bremen. In these factors are no real outstanding factors visible, rather than the higher tram-to-bus ratio of Dresden. In Tables 4 and 5 are data of the engine types shown (Figs. 1 and 2).

Table 4

Dresden's fleet categories

Engine type of buses	*Percentage*
Euro-III without DPF	5%
Euro-III with DPF	15%
Euro-IV	5%
Euro-V	45%
Euro-VI or Hybrid	30%

DPF – Diesel Particle Filter

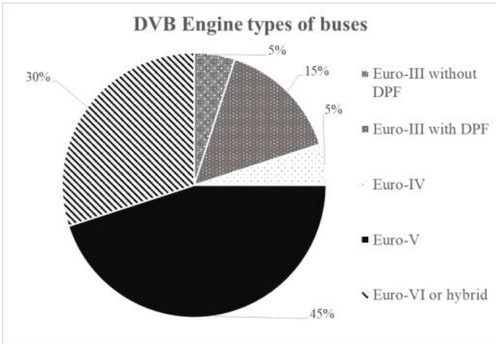

Fig. 1 DVB's Engine types

Table 5

Bremen's fleet engine types

Engine type of buses	*Percentage*
EEV	99.1%
Euro-V	0.8%

Data: Bremen[4]

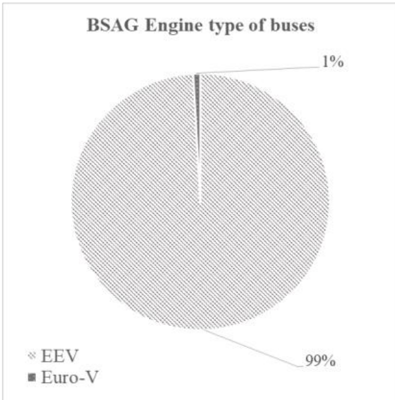

Fig. 2 Pie chart BSAG's Engine types of buses

Clearly visible is that Bremen's BSAG has a fleet with many of their buses in the EEV-category. This category is between Euro-V and Euro-VI and this can be a cause that Bremen is even closer to Dresden in terms of their emission, next to the power resources of Dresden's trams.

The missing data is the exact power source of the trams and e-buses. Also a split between trams and buses in terms of passenger kilometres would have been useful in order to establish a more complete benchmark. A third and possibly fourth city would probably have given a better comparison due to the possibility for a collaboration research. In this case there are just 2 cities. A recommendation for a following research is trying to find more cities next to these two cities in the same category.

[4] Bus fleet (BSAG, 2018)

Down below in Fig. 3 is the hypothetical collaboration of factors shown.

In Fig. 3 the hypothetical factor collaboration chart is worked out, based on the current results of Dresden and Bremen. The fleet structure, power sources and the size of the network seem to play a part. The fleet is dependent of power sources, and the amount of energy used is in that way important as well. The density of the network seems to decide the total number of passenger kilometres, in addition to the total amount of passengers.

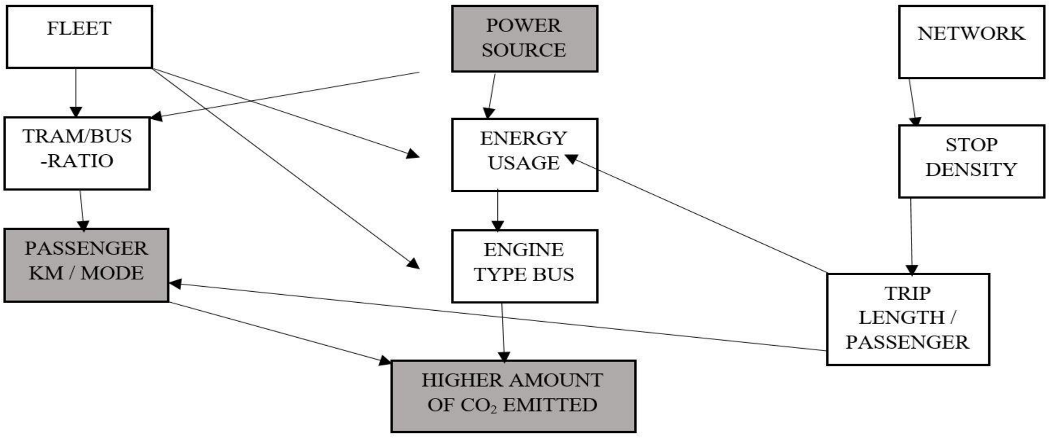

Fig. 3 Hypothetical collaboration chart

The engine types of buses are also very important in this way, since these engines are emitting less GHGs due to efficiency and filters. Further research into this with other cities is required.

5. Conclusions

The amount of CO_2 emitted per passengers between the German cities Dresden and Bremen is strikingly similar, with a difference of only 1,68 gram per passenger kilometre.

The tram/bus-ratio in Dresden is 2,5 times higher than in Bremen. However this does not cause a much lower amount of CO_2 emitted per passenger kilometre, while is said by Condom and Dow (2009) that the tram is responsible for lower CO_2 emission.

The vehicle occupancy is as well strikingly similar, with a difference of 0.29 percent point. In comparison with Condon and Dow (2009), this seems like a typical occupancy of urban public transport.

The average trip length in Bremen is longer. This is probably caused by the lower stop density and the higher amount of passengers per stop. The network density of lines however is higher in Bremen. This is advised to take in account in future research.

Bremen has a lower amount of seats per vehicle than Dresden. This is caused by the lower tram/bus ratio in the city, since the buses of this city have typically no more than 153 seats, and mostly lower.

Bremen has cleaner buses in use than Dresden, with 100% of the buses at least meeting the Euro-V category. In Dresden is this amount 75%, with even Euro-III buses without DPF still driving within the city. An advice is to research this in a future research upon this topic.

Dresden has an high amount of indirect CO_2 emitted. This seems to be a probable cause of the nearly similar amount of CO_2 emitted per passenger kilometre as Bremen. However, the power source needs to be discovered in order to reveal this.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Model Proposal Regarding the Integrated Passenger Transport Assessment: a Case Study

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Abstract

The article is focused on the designing the specific model regarding the comparative assessment of integrated passenger transport and bus passenger transport mode from the perspective of potential clients. This case study was carried out in different cities in different countries where bus passenger transport as well as integrated passenger transport modes are in real traffic operation. In the introduction, the basic theory related to integrated passenger transport is summarized. Subsequent part of the article describes substantial data concerning the undergone case study. The most important part covers the model design itself varying in possible options in terms of transport modes.
KEY WORDS: *model, integrated passenger transport, bus passenger transport, assessment*

1. Introduction

The expression integrated passenger transport (hereinafter IPT) includes individual passenger transport modes into a comprehensive transportation element utilizing the unified tariff and check-in system, and joined transportation conditions with an integrated telematics, communication and management technologies considerably contributing to passenger transportation service quality improvement [1-4].

The most important advantage of IPT [5] is represented by an offer of more comfortable transportation opportunities for passengers. IPT consists of innovative check-in systems and technologies [6], integrated infrastructure, unified transport services as well as operative, planning and management methods utilized for cargo and passengers' transportation [7].

Considering integrated transport, the term "intermodality" may not be put aside. This term is considered the customers' use of several transport kinds during single transportation journey. For "intermodality" of customers, it is necessary to integrate transport paths, information subsystem and also customers' services unification within transfer nodes as well as coordination regarding timetables and tariff conditions. Integrated traveling for passengers requires appropriate transport area consumption and advanced urban planning. Advanced intermodality [8, 9] in passenger transport represents the major factor within the development of an effective IPT.

Integration may be described as a merging, combining, forming a single unit from individual parts or components. It can occur at several degrees and can comprise a lot of activities and features. Any unified definition of integrated passenger transport has not been determined so far and it may be comprehended by distinct researchers and experts in different ways [4, 5].

Experts have defined several alternative specifications of IPT for various territories and transport areas. One of those definitions is, as follows: "determined rules for efficient integrated transport for passengers as well as utilization of several transport modes within such an integration using single ticket for their traveling [4, 10].

The most popular definition is, as follows: the functional system that is operated by several carriers utilizing various transport modes and interacting more effectively and intensively within transportation system (transport network, tariff system, check-in system, information system and promotion-advertisement, timetables and transportation conditions, etc.). This results in comprehensive improvement of transportation conditions and transport service quality [2, 11, 12].

In general, passenger transport concerns an ensuring the attractive transport service chains related to "door to door" transport system by an inclusion of [1]:

- different transport modes and various means of transport;
- individual and public transportation, cycling and related transport systems, such as P&R, B&R and K&R;
- transport policy regarding spatial planning and funds used to construct high quality transport infrastructure intended for private and public operators.

An integration of passenger transport can occur at distinct degrees [11-13]:

- **Transport infrastructure integration** comprises of combination of specific elements forming the coherence

of a transport system territory. It concerns all the elements, such as: bus, trolley and tram stop location, stations and transfer nodes (transport terminals + stairs, elevators, pathways, underpasses and crossroads) for convenient and fast passengers transfer within individual transport modes.

- **Organizational integration** covers all kinds of transport modes operating within urban, suburban or regional transport. It comprises of functional integration of transport modes (individual modes timetables coordination involving their synchronization and alignment in order to minimize travel time losses associated to need to change transport mode) and vehicles across the transport network ensuring the continuity of a passenger travel as fast and comfortable as possible.
- **Tariff integration**, similarly to the organizational integration, covers all kinds of transport modes operating within urban, suburban or regional transport, involving individual journeys arrangement across various transport modes in order to provide the best economic circumstances for passengers' travel when shifting public transport vehicles (regardless of the carrier) throughout the given transport network.
- **Information system integration** also consists of all transport network components operating within urban, suburban or regional transport. Its main objective is to ensure no-stress passengers' journey across various integrated transport systems. This system signifies that information for passengers is provided across entire journey no matter what transport operator or transport mode is chosen. There are specified several sources of information regarding passenger transport: information at passengers´ service points, information broadcasted to cellphones, Internet and information at stops and stations. Dynamic real-time-information represents more sophisticated service for passengers allowing the greater travel flexibility for passengers to easier respond to vehicle delays and IPT network failure.
- **Spatial integration** consists in development of the regional transport territory. Appropriate and efficient territory consumption and transport network development should be ensured by the coordination of spatial planning with transport planning.

Recently, research studies aiming to integrate several passenger transport modes within urban and regional transport territory into the IPT were carried out in the EU countries. Such research studies related to IPT implementation were especially related to urban passenger transport. Subsequently, this issue has been supplemented to cover all transport modes and degrees, for both passengers and cargo (freight), and consider the material flow as a whole, which means transportation, reloading and warehousing of cargo, and the flow of information running through various corporate degrees that may enhance a decision-making process. IPT implementation initiated discussions of brand new questions as well as new techniques within top management encouraging the rise of emerging research studies and issues, like traffic jams monitoring in real-time, traffic safety control or navigation system with real-time traffic [14-20].

2. Data and Methods

The questionnaire traffic survey [21] with defined factors among various city areas was conducted with respect to passengers' perspective in regard to relevant IPT. First of all, public transportation journey was selected. In this context, a brief specification of two alternative journeys, i.e. a separate transport system (bus) and an IPT system (synchronization of timetables applying urban trolley, suburban bus and regional train), was carried out. Such two passenger transport systems were operated within mixed traffic. The distinction consists in the vehicles' drive and their transport capacity.

During second stage of the traffic survey, respondents were requested to identify one of these transport systems for different transportation scenarios regarding travel time consumption. These scenarios were specified depending on several values of un-productive travel time, travel time itself and journey charge (ticket price) separately for bus transport and IPT system [22, 23].

The third stage of the traffic survey was focused on respondents' socio-economic personal characteristics; to find out following features: respondents' gender and age, their education, occupation and income, vehicle owner. Assessed factors and their particular numbers are summarized in Table 1. The value of all combinations was eliminated to 2.

Samples were provided by passengers of a potential IPT system for each city area. Data collection itself was conducted in August 2017. During conducting traffic surveys, especially face-to-face questionnaire was implemented. For 2 from 6 city areas, the extra-charge value was limited to 1€ per return travel considering current traffic circumstances.

Table 1

Assessed factors and their particular values

Transport system	Factor	Number of combinations	Value
Bus / IPT	Un-productive time of travel	2	3/7 min
	Time of travel	2	7/10 min
	Journey charge	2	extra-charge of 1.5 € per return journey

Following model designed was applied. The bus transport alternative is denoted as V_1, and IPT system alternative is referred to as V_2. The basic expression of the model design is, as follows (see Eq. 1):

$$\left.\begin{aligned} V_1 &= \beta_1 UT + \beta_2 TT + \beta_3 JC \\ V_2 &= \beta_1 UT + \beta_2 TT + \beta_3 JC + Sc \end{aligned}\right\}, \tag{1}$$

here UT – un-productive travel time; TT – travel time; JC – journey charge; β_1, β_2, β_3 – coefficients; SC – specific constant.

Referring to Table 2, as for journey charge, coding (-1/1) was applied instead of (0/1) in order to get rid of misunderstanding in regard to SC, i.e. code -1 is related to a case when an extra-charge is paid and code +1 addresses a case when a travel ticket price is the same like for rest of passenger transport systems. Regarding other characteristics, coefficients representing the marginal utility of individual factors are common for both of alternatives. Assessment of specific constants values were taken into consideration as well. SC value estimation for IPT represents a specific research issue, given the fact it should take into account the purpose of all unmonitored factors affecting the final determination. As already mentioned, rest of factors consists of respondents' personal features (gender, age, income, education, occupation, vehicle owner) [24, 25].

According to routes determined within IPT system in six EU transport city areas, following three real urban traffic degrees are assessed:

1. the downtown: Linz (Austria), Trnava (Slovak Republic);
2. the major object of interest: Zlín (Czech Republic), Kielce (Poland);
3. the passengers' transfer node: Szeged (Hungary), Lublin (Czech Republic).

The downtown

IPT system within Linz is linked to central rail station and the biggest transfer node in the downtown – travel distance of 9.6 km. IPT system in the city of Trnava interconnects central rail station with the most important travel node within tourism – travel distance of 6.2 km.

The major object of interest

IPT system in the city of Zlín is operated in the central city square and surrounding area – travel distance of this transportation section is of 7.7 km. In Kielce, IPT system is headed from the central square area to the main administrative zone where it interconnects southern with northern part of this territory – travel distance of 8.1 km.

The passengers' transfer node

IPT routes and connections in Szeged are of distance of 6.4 km and join the downtown shopping mall with passenger transport transfer node. IPT system in Lublin connects the city rail station with the central part of urban built-up area – travel distance of 8.3 km.

3. Results

Obtained results of the designed model implementation are ordered in Table 2.

Table 2

Results obtained within a designed model

Factor	A		B		C	
	Linz	**Trnava**	**Zlín**	**Kielce**	**Szeged**	**Lublin**
Un-productive time	-0.0563 -1.74	-0.1168 -2.69	-0.2664 -9.54	-0.3131 -6.71	-0.2237 -5.14	-0.1967 -4.77
Travel time	-0.2416 -7.92	-0.0857 2.06	-0.3552 -19.73	-0.2004 -5.97	-0.1769 -5.88	-0.1869 -5.17
Journey charge	1.4927 8.66	0.4332 3.29	0.5261 2.46	0.7193 3.84	0.5689 2.28	0.9953 6.27
IPT	0.5439 3.73	-0.0204 -0.0965	0.9118 5.439	1.2365 6.9983	0.1782 1.2613	-0.259 -1.86
Number of respondents	120	97	135	78	84	106

Explanatory notes:
A – the downtown
B – the major object of interest
C – the passengers' transfer node

During the examination, the journey charge coefficients had the positive sign. Based on the SC sign, rather greater importance for IPT may be seen in both city areas for real urban traffic degree "the major object of interest". For one of two of these degrees, SC of IPT system is statistically important – "0" hypothesis of "0" index; 10% of degree of importance- both sides. As for next real urban transport degrees, greater importance is assigned either for IPT or for bus transport system.

Values estimation with specifying the IPT utility including socio-economic features of passengers shows following results. In five city areas, the variable male implies a relatively higher preference for IPT system; and unlike this statement, the variable female implies rather lower preference in case of IPT system. In two city areas of the major

object of interest for current urban transport degree, this state may occur with a statistically importance – “0” hypothesis of “0” index, of degree of importance - both sides.

In the aspect of impact on preferences of variables, i.e. age, salary, job, education, and vehicle owner, compliance among city areas, was not observed, which means that the impact of variables are diverse for all the city areas. In one of two city areas for real urban traffic degree “the downtown”, greater degree of education implies statistically important rather greater preference in case of IPT system.

Designed system has confirmed that particular factors as time and price are not so statistically important, except a travel time in the city of Lublin, i.e. marginal utility of time of travel for both transport system alternatives appears to be the same. However, in regard to the city area of Lublin, the utility of time of travel within IPT system was obtained to be lower compared to bus transportation system.

4. Conclusions

Based on the undergone surveys within all six city areas, the concept of passengers’ point of view on IPT was highlighted. Respondents included potential passengers of IPT within particular transport routes in six various city areas. Obtained outcomes have representative values of subjective of passengers’ perspective having some information on IPT and no information of this advanced transportation system. Sufficient information basis represents and important aspect in the matter of building the preference according to the behavioral model determination. This represents the major issue regarding future potential research studies on similar topics.

The outcomes confirmed that IPT is not necessarily considered the valued in case that time of travel and ticket prices values for journeys within IPT are equal compared to bus transport. Common feature of obtained results for all the real urban transport degrees is rather greater importance for IPT in terms of its operation in the area of major object of interest. Common sign in terms of effects on preferences of passengers’ socio-economic features was not observed.

Model design applied in this research study has confirmed that it may be a handy technique in terms of achieving the overview about emerging innovations within customers’ preference leading from increase and improvement of the IPT system in comparison with bus transportation system importance. It may be also useful in terms of value calculation of the increase regarding the occurrence of the IPT system necessary to obtain the greater importance.

At second hand, it expresses customers’ intention to pay more for innovative advanced transportation system since they may allow for variations in preference assessment following distinct journey charge conditions.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Methodology for Selection the Optimal Route and Transport for Carriage of Containers

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Abstract

In this research is elaborated a methodology for selecting the optimal route and type of transport between two points. The theory of decision has been applied to determine optimal solution. The classical criterion of Hurwitz's, Savage's and Laplace's are used and compared. The assessment was made on the basis of operating cost of transportation for railway and automotive transport. The methodology is experimented for the routes in the railway and road network of Bulgaria. For railway transport was investigated two alternative routes, for automotive transport was investigated three alternatives routes. It was found that the technology of carriage of containers with rail transport is the best variants of transportation in case of increment the fees for use of the road network.
KEY WORDS: *container transport; theory of decision; optimization; route*

1. Introduction

For users of freight transport services an important task in the organization of cargo transportation is the goods to be delivered at minimal transport costs and performance of the deadline for delivery. By land transport, containers can be transported by rail and road. In railway transport for transportation the container are composed container block-trains. For the road transport the containers are transported by trucks called road trains.

Different methods are used to choose the optimal route for transportation. In [1] is elaborated a model for routing by criterion the lowest cost. The authors present the road network as a graph and take into account the uncertainty of the information. In [2] is applied statistical analysis to develop routes for freight trains. The capacity of railway line is investigated in [3], which is important when choosing a route in a railway network.

The method of Analytic Hierarchy Process (AHP) has been applied for best routes prioritization and selection [4-7]. In [4] the authors have been elaborated a decision support system. An combined approach by using Graph theory, AHP method and Cost Benefits analysis have been applied for route selection of a road train in [6, 7]. The criteria for evaluation have been selected so as to take account of the characteristics of the road, the throughput of the road and convenience in travel.

In [8] is studied the efficiency of intermodal transport using PROMETHEE method. The both railway and road transport are investigated. In the study have been investigated the criteria defined in [9].

The theory of Decision have been used to determine the best alternative taking into account of the states of investigated system by applied the decision criteria under uncertainty such as: maximin (Wald's); maximax (optimist); minimax, Savage's criterion; Laplace's criterion, Hurwitz's criterion and other. These criteria have been used to solve different problems in the management of transport companies [10], in agriculture [11], in human resources training [12], the needs of farmers [13], for decision making in construction design and management [14], of the aeronautics supply chain [15], of currier service, [16]. In [17] is studied the Hurwicz's criterion for decision under imprecise risk. In [18, 19] the authors present combination of the Hurwicz's criterion with the Laplace's criterion to investigated the choice of an investment project.

The aim of this research is to elaborate a methodology based on theory of decision for the selection of optimal route and type of transport for carriage of containers taking into account of uncertainty of the process.

2. Methodology

The methodology for selection the optimal route and transport for carriage of containers includes the following steps:

- Step 1: Compilation of the payment matrix. The alternatives and the states of the studied system are determined. The payoff matrix is composed of the cost of transport. They include the operating costs and infrastructure charges that are determined by [8].
- Step 2: Choice of decision criteria to assess the alternatives. In the study is applied the following criteria of Theory of decision in the state of uncertainly, [20]:
    - Laplace's Criterion;
    - Savage's criterion;
    - Hurwicz's criterion.

The use of classical criteria allows minimizing losses.

- Step 3: Comparison of the results of the selected criteria. Choice of optimal alternative.

In the payoff matrix the number of rows is equal to number of alternatives, and the number of columns is equal to the number of events (states, strategies). The set of decision alternatives is a_i, $i = 1,\ldots, m$; the set of events is b_j, $j = 1,\ldots, n$; the set of elements of payoff matrix is $c(a_i, b_j)$ obtained by choosing alternative a_i in state b_j. Table 1 presents the payoff matrix.

Table 1

Payoff matrix

States / Alternatives	b_1	b_2	…	b_n
a_1	$c(a_1, b_1)$	$c(a_1, b_2)$	…	$c(a_1, b_n)$
a_2	$c(a_2, b_1)$	$c(a_2, b_2)$	…	$c(a_2, b_n)$
…	…	…		…
a_m	$c(a_m, b_1)$	$c(a_m, b_2)$	…	$c(a_m, b_n)$

The Laplace's criterion is based on the principle that all events b_j are likely equally. When the elements of payoff matrix are costs, the criterion of choosing an optimal alternative is the minimum cost, i.e.:

$$\min_{a_i} \left\{ \frac{1}{n} \sum_{j=1}^{n} c\left(a_i, b_j\right) \right\}. \tag{1}$$

The Savage's criterion presents the regrets of the decision maker of the possibility to obtain non-optimal results.In this criterion first is construed the regret matrix with the following elements:

$$r\left(a_i, b_j\right) = \left\{ c\left(a_i, b_j\right) - \min_{a_k} c\left(a_k, b_j\right) \right\}, \text{ when } c(a_i, b_j) \text{ expressing costs,} \tag{2}$$

here k is the minimal value of column j.

The newly-formed matrix represents a loss and therefore only for it the minimax criterion can be applied. To apply the minimax criterion, the maximum costs by rows for each strategy of the new matrix are determined. Optimal is the strategy for which the maximum cost is the smallest.

The Hurwicz's criterion allows for different decision approaches with the introduction of an additional parameter – coefficient of optimism α. The value of α can be set between zero and one, for taking any decision. Generally $\alpha = 0{,}5$, which could be taken as representing a balanced approach. While $\alpha = 1$ represents a totally optimistic person/company, $\alpha = 0$ represents a totally pessimistic person/company.

The optimum state of the management system corresponds to this action for which:

$$\min_{a_i} \left\{ \alpha \min_{b_j} c\left(a_i, b_j\right) + (1-\alpha) \max_{b_j} c\left(a_i, b_j\right) \right\}, \text{ when } c(a_i, b_j) \text{ expressing costs.} \tag{3}$$

3. Results and Discussion

The methodology was experimented for direction of Sofia – Varna. This direction has been investigated also in [8] to assess the efficiency of carriage of container block trains by railway transport and road train by road transport.

The alternatives of transportation are:

- Railway transport.
  Alternative 1 (a_1) - Freight train (FT1): Iliyantsi - Gorna Oryahovitsa – Varna;
  Alternative 2 (a_2) - Freight train (FT2): Iliyantsi - Karlovo - Karnobat – Varna.
- Road transport. In the paper is investigated the carriage with road trains.
  Alternative 3 (a_3) - Route R1: Road train (RT1) Sofia - Veliko Tarnovo – Varna;
  Alternative 4 (a_4) - Route R2: Road train (RT2) Sofia - Plovdiv - Burgas – Varna;
  Alternative 5 (a_5) - Route R3: Road train (RT3) Sofia - Plovdiv - Karnobat - Shumen – Varna.

The events are chosen according the number of wagons in a train:

- b_1 – the number of wagon in the container block train is 20.
- b_2 – the number of wagon in the container block train is 15.
- b_3 – the number of wagon in the container block train is 10.

In the study was experimented the carriage of 40-foot containers with gross mass 20t.

The payoff matrix includes the operating costs for transportation and infrastructure charges. For rail transport, the infrastructure charges depend on the length of route and the gross mass. For road transport are determined vignette charges, which can be determined for different periods. To determine the values of the operating costs and infrastructure

charge have been used the methodology in [8].

The research has been conducted in two variants according the vignette taxes by road transport:

- Variant 1: weekly vignette.
- Variant 2: an increase of vignette fees by 8% - introduce an electronic tolling system for vehicles with the maximum permissible weight over 3.5 tonnes.

Table 2 presents the payoff matrices for two studied variants. The elements of payoff matrices are the sum of operating costs and infrastructure charges. In order to make comparisons between rail and road transport, the costs are calculated for one train.

Table 2

Payoff matrix for Variant 1 and Variant 2

Alternative	Length, km	Variant 1			Variant 2		
		Event: Train composition –number of wagons			Event: Train composition –number of wagons		
		b_1	b_2	b_3	b_1	b_2	b_3
		20	15	10	20	15	10
		Costs, BGN/day for road train					
a_1: FT1	543	431	459	457	431	459	457
a_2: FT2	514	413	447	437	413	447	437
a_3: RT1	447	413	413	413	447	447	447
a_4: RT2	524	488	488	488	521	521	521
a_5: RT3	551	412	412	412	446	446	446

Tables 3 and 4 show the values of Laplace's criterion and Hurwicz's criterion using formulas (1) and (3).

The study of Hurwicz's criterion is made for different values of parameter α. In column "min" and column "max" are shown the minimum and the maximum values by row, which coincide with the values of $\alpha = 1$ and $\alpha = 0$, respectively.

Table 5 presents the results of Savage's criterion for both variants. Initially, the new matrix is formed by using formula (2) for which the criterion minimax is applied.

Figs. 1 and 2 show a comparison of results for investigated criteria for both variants. It can be seen that by all criteria for variant 1 the best alternative is transportation by road train using route R1 - Sofia - Veliko Tarnovo – Varna; in the case of an increase of the road transport charges or the introduction of tolls charges the best transport are railway transport and transportation with container block train by railway line Iliantsi - Karlovo - Karnobat – Varna.

Table 3

Variant 1 – Results for Laplace's criterion and Hurwicz's criterion

Alternative	Laplace's criterion	Hurwicz's criterion										
		min	max	α								
				0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9
	Costs, BGN/day for road train											
a_1: FT1	449	431	459	456	454	451	448	445	442	440	437	434
a_2: FT2	432	413	447	444	440	437	433	430	427	423	420	416
a_3: RT1	**413**	413	413	**413**	**413**	**413**	**413**	**413**	**413**	**413**	**413**	**413**
a_4: RT2	488	488	488	488	488	488	488	488	488	488	488	488
a_5: RT3	**412**	412	412	**412**	**412**	**412**	**412**	**412**	**412**	**412**	**412**	**412**

Table 4

Variant 2 – Results for Laplace's criterion and Hurwicz's criterion

Alternative	Laplace's criterion	Hurwicz's criterion										
		min	max	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9
				α								
	Costs,BGN/day for road train											
a_1: FT1	449	431	459	456	454	451	448	445	442	440	437	434
a_2: FT2	**432**	413	447	**444**	**440**	**437**	**433**	**430**	**427**	**423**	**420**	**416**
a_3: RT1	447	447	447	447	447	447	447	447	447	447	447	447
a_4: RT2	521	521	521	521	521	521	521	521	521	521	521	521
a_5: RT3	446	446	446	446	446	446	446	446	446	446	446	446

Table 5

Results for Savage's criterion

Alternative	Variant 1				Variant 2			
	Event: Train composition – number of wagons				Event: Train composition – number of wagons			
	20	15	10	Savage's criterion (minimax)	20	15	10	Savage's criterion (minimax)
	Opportunity Loss matrices				Opportunity Loss matrices			
***a*₁**: FT1	19	47	45	47	18	13	20	20
***a*₂**: FT2	1	35	25	35	0	1	0	**1**
***a*₃**: RT1	1	1	1	**1**	34	1	10	34
***a*₄**: RT2	76	76	76	76	108	75	84	108
***a*₅**: RT3	0	0	0	**0**	33	0	9	33

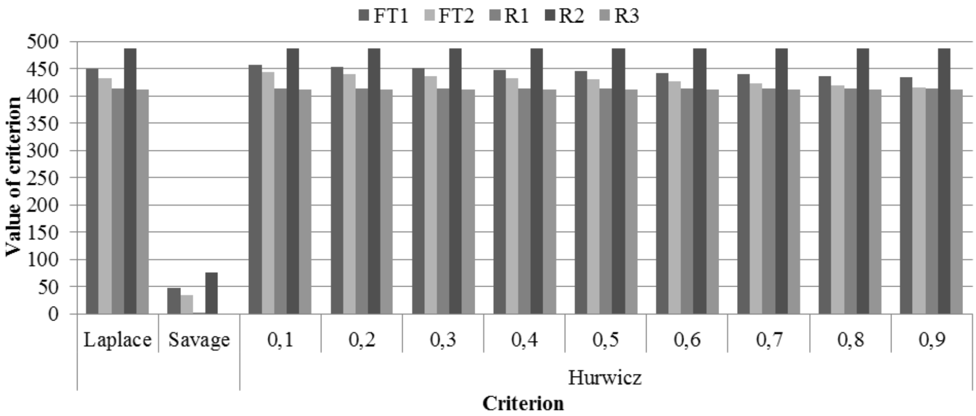

Fig. 1 Values of criteria for Variant 1

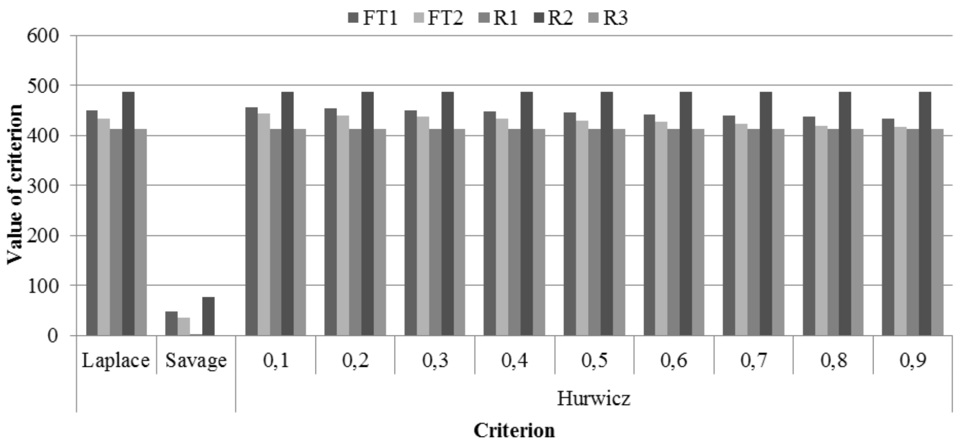

Fig. 2 Values of criteria for Variant 2

4. Conclusions

In this research have been developed a methodology for selection an optimal route and transport for carriage of containers based of Theory of decision in uncertainly.

The different criteria - Laplace, Savage and Hurwicz have been used. The results by applying the different criteria are similar.

The influence of the vignette charge on the choice of transport technology was investigated. Two variants of cost according to the vignette fee for road transport have been studied. It has been established that for the investigated route the value of vignette fee influence of the optimal technology.

The results of research are similar to those obtained by methodology elaborated in [8]. This shows the adequacy of the results.

The methodology can be used to study other routes or others type of transportation.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Operators’ (Pilots and ATCOs) Load Monitoring and Management in Highly Automated Systems

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Abstract

The main purpose of this study is to introduce the operators (pilots, ATCOs)’ load model and developing load measuring systems for operators’ load management. Nowadays, because the development of the highly automated systems, the role of operators is in a transition from active controlling to passive monitoring. Therefore, the operators’ models with their load monitoring and load management become the level of the most important tasks. By deployment of the develop load monitoring and management system, the safety of aircraft flights and air transport management will be increased, especially in an emergency or an abnormal situation.
KEY WORDS*:* *passive operator, highly automated systems, operators’ load systems, ATCOs model, integrated sensors*

1. Introduction

Further improvement in information, computer, navigation and communication technologies catalyze the development of highly automated systems, like future air traffic management (ATM) systems. Worldwide, several international and national projects have been initiated for the research, development and implementation of systems, regulations and procedures for future air traffic management such as; the Single European Sky ATM Research (SESAR) [1] in Europe, US the Next Generation Air Transportation System (NextGen) [3] in the United States, the Collaborative Actions for Renovation of Air Traffic System (CARATS) [4] in Japan, and the SIRIUS (Impulsionando o Desenvolvimento do ATM Nacional (Sirius) [2] in Brazil etc. These investigations have been introduced countless technological and system innovations in operators’ working environments. In these systems, the role of the operator (pilots, ATCOs) is changed from active control to passive monitoring by introducing the intensive automation. In case of active control, the operator deals with continuously situation awareness, decision-making and control actions; while, in case of future automated systems, the operator monitors the operating system and only in abnormal, and an emergency situation should initiate active control. The work quality of passive operators depends on their loads, namely information, task, work and mental loads. Especially, the information and mental load as physical - psycho-physiological condition play the much greater role in future systems.

The Budapest University of Technology and Economics (BME) in collaboration with HungaroControl, started to investigate the potential development of an advanced ATCO workstation. The university and its Department of Aeronautics, Naval Architecture and Railway Vehicles has an outstanding experience in the development of advanced simulation environment [5, 6], electric systems/sensors [7, 8] and mental models [9, 10].

This paper analyses the developed concept of load monitoring and measuring systems for operators and describes the development of advanced operators’ working environment. These systems are following: (i) developing the operator model (ii) operators’ load measurement system (iii) integrating sensors into operators’ working environment (iv)outside measuring equipment such as eye-tracker, heart rate monitor, electrodermal activity device (EDA), micro camera.

2. Future Operator Support Systems

2.1. Pilots’ Role in the Future of Aviation

Global air traffic has been increasing steadily for decades. A large number of aerospace companies, universities and institutes are working on advanced autonomous systems for the future of air travel. The crucial next step towards

ensuring the aircraft industry becomes efficient is the new concepts of commercial aircraft (Fig.1.). Modern flight technology now available to operators has dramatically increased aircraft efficiency and improved safety while reducing workload during flight. Unfortunately, the added benefits gained by the use of highly automation systems have also created unexpected side effects that could compromise safety. It appeared new types of operator loads: information load and mental load.

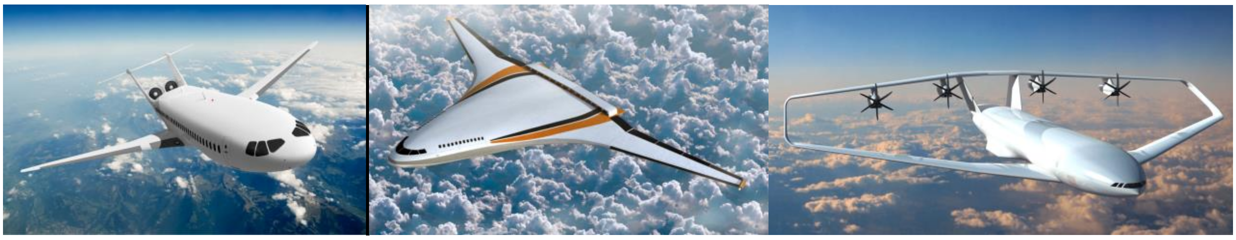


Fig. 1 The D8 airliner concept (left) [11], A Blended Wing Body Aircraft (middle) [12], and Boeing & NASA Prandtl Plane air freighter (right) [12]

Long back, about 60 years ago, there were five people in the cockpit: A captain, first officer, a flight engineer, a navigator and a radio operator. First, the Radio Operator was eliminated, then with the advent of Inertial Navigation System(INS), the Navigator became redundant. And with more automation, flight engineers began to disappear too. The next step for commercial flight is, reduced the number of pilots needed in the cockpit (Fig. 2.) to one (possibly none) and replaced by the autonomous flight systems now being developed. The aviation industry is looking at putting second officers on the ground to take over by remote control if needed. More automated systems would be needed for the single-pilot operation and without humans in the cockpit.

Fig. 2 The Centaur OPA by Aurora Flight Sciences (left), and Automated Flight System, robotic cockpit (right) [13]

2.2. Air Traffic Controllers in Future ATM

Air traffic controllers coordinate the movement of air traffic, taking responsibility for the aircraft's safety and ensuring that safe, efficient movement of the air traffic including the ground, terminal and en-route operations (Fig. 3.). Air traffic controllers typically do the following: (i) keeping radio and radar contact with aircraft, (ii) monitor and direct the movement of aircraft on the ground and in the air, (iii) control all ground traffic at airport runways and taxiways, (iv) issue landing and takeoff instructions to pilots, (v) transfer control of departing flights to other traffic control centers and accept control of arriving flights, (vi) providing information to aircraft about weather conditions, runway closures, and other critical information, (vii) handling unexpected events, emergencies, and unscheduled traffic etc.

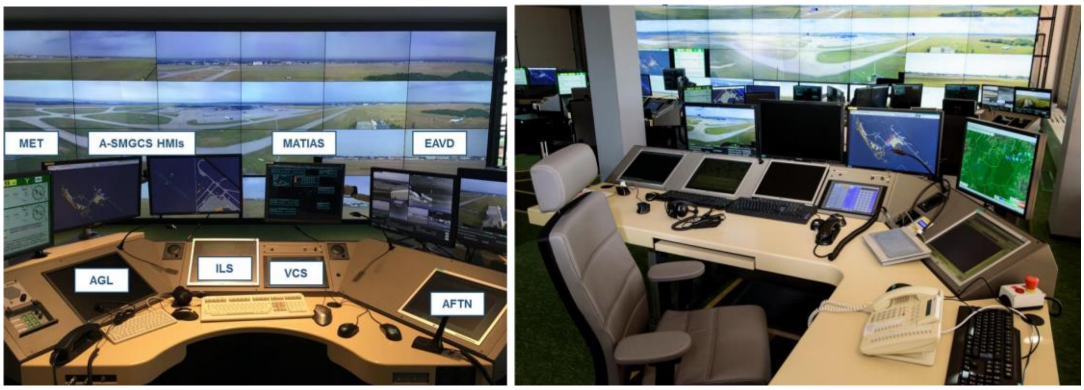


Fig. 3 ATCOs (left) and supervisors (right) working environment) [14]

The air traffic controller workstation has changed a lot since the 1910s. Today the modern workstation is quite simple, computerized and it integrates several subsystems into one working environment. In such an environment as developed at the HungaroControl (Fig. 4) the controllers' load management, especially, the mental and information load monitoring and management initiate new requirements for information processing.

Fig. 4 Very large scale demonstration (VLD) test of Budapest remote tower (rTWR) developing at HungaroControl [15]

The future works and working environment of ATCOs might be characterized by following four major aspects: (i) ATCOs will play role of passive operator in highly automated system – instead of active separation control management, (ii) ATCOs will have "greater" environment", namely they will have several displays or large screens, several windows working parallel on their computers, etc., (iii) they will be working on-line in an "off-line" environment, i.e. in remote tower environment equipped with large synthetic vision screens, etc., (iv) they will have too much information that may confuse them.

With increasing traffic complexity and stress on conflict detection and resolution, the available time for situation awareness and decision making might play the most important role in the success of the performed actions. Secondly, with the aviation industry experiencing continued growth in modern times, the responsibility of operators is changing from actively operating the systems to monitoring, managing and supervising its systems, thus making ATCOs' job more monotone. In case of an abnormal or an emergency situation, ATCOs as operators might solve the problems based on their knowledge-based behavior. Therefore, human aspects and mental condition will have an even higher role in the future ATM, compared to the present circumstances.

2.3. Future Automation in Operators' Working Environment

While technology has helped drive improvements in the aviation industry, automation has also increased significantly. For example, in the cockpit pilots receive company information via datalink and routinely use the autopilot to fly the aircraft. Automation is used to provide information to the pilot, to control the aircraft and to manage aircraft configurations and for the ATCO monitoring, detecting and decision support systems, namely surveillance, conflict detection, conflict resolution.

The concept of different levels of automation (LOAs) has been pervasive in the automation literature since its introduction by Sheridan [16]. According to Sheridan [16], there are 8 different Level of Automation (LOA), corresponding to different uses and interactions with technology, enabling the operator to choose the optimum level to be implemented based on the operational context, from the Level 1 (operator's fully manual control) to the Level 8 (fully automated control) [17]. These levels are:

1. The computer offers no assistance; the human operator must perform all the tasks;
2. The computer suggests alternative ways of performing the task;
3. The computer selects one way to perform the task and
4. Executes that suggestion if the human operator approves, or
5. Allows the human operator a limited time to veto before automatic execution, or
6. Executes the suggestion automatically then necessarily informs the human operator, or
7. Executes the suggestion automatically then informs the human operator only if asked.
8. The computer selects the method, executes the task and ignores the human operator.

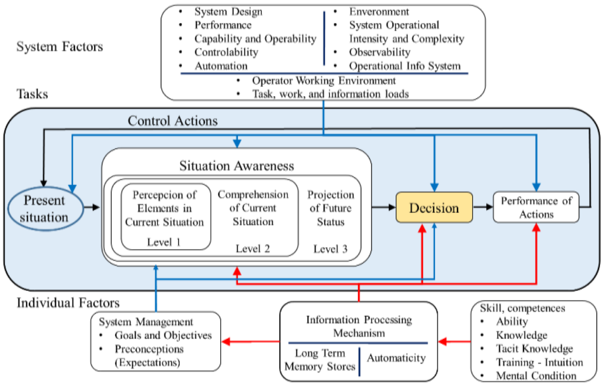
In most cases, an automated system operates perfectly well without a human operator being actively involved and empowers human operators to be more efficient and productive in their tasks. However, there are circumstances when automation does not function as intended, when an emerging situation necessitates a manual change to the automation parameters or if anything goes wrong. On the other hand, automation will not solve all the aviation industry's problems. Even with the automation improvement in aviation, some new problems may arise from different ways of operating. For example, operators' (pilots and ATCOs) actions; including situation awareness, decision making, information analyzing become to level of most important issues with the advanced automation systems, thus may generate extra problems on operators such as changes in operators' vital health signs: heart rate, skin conductivity, blood pressure, skin temperature and so on. Developed monitoring systems were integrated into the operators' working environment which is aimed at monitoring the managing of the operators' total load systems, namely work, task, information and mental load.

2.4. ATCOs Model Applicable on Pilots

The ATCOs model can be applied to pilots after minor changes and this model would be defined by two different approaches. On one hand, the situation awareness and decision making is the central element of the model. Fig. 5 (left) shows the model [18, 19] developed by adaptation of the well-known and probably the most used model created by Endsley [20, 21]. The situation awareness is made at three different levels:

- Level 1 - encompass and awareness of specific key elements of a situation;
- Level 2 - comprehension of a current situation, integration of that information in the light of operational goals;
- Level 3 - an ability to project future states of the systems.

In this model, the situation is evaluated from the present situation instead of the state of the environment as defined by Endsley. The model is improved by including the actual mental condition of operators into the individual factors because in the highly automated systems the role of the psycho-physiological condition of the operators is increasing.



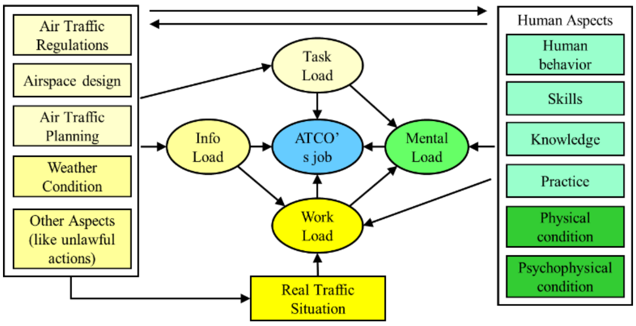


Fig. 5 Situation awareness model (left) and ATCO's work model (right)

The (i) system functions, (ii) operational characteristics and (iii) operator - system interface (working environment) compose the system factors. The model includes some new system factors as (i) system operability (including interoperability), controllability and automation; (ii) system operational intensity and (traffic) complexity, observability and operational (flight) information system; (iii) developed working environment to increase the level of situation awareness.

As it is investigated and well known, the success of situation awareness and decision making depends on human behavior (skill and performance) and operators' loads. As Rasmussen [22] thirty years ago defined, the situation awareness and decision making might be realized on three different levels. The first level, the so-called skill-based control is applied by the operators when the situation is normal and the operator can easily recognize the situations and can work 'automatically'. At the second level, the operators must recognize and identify the situation and apply the rule-based solutions to reach the expected situations. In case of abnormal flight situations, the operators must derive the solution with their knowledge and practice. This is the knowledge-based level.

The second approach applying to the description of the model is based on the operator loads. The created model (Fig.5. right.) contains the task, information, work and mental load [19]. The task load is generated by the number and hardness of tasks to be solved. It depends on airspace demands, interface demands, traffic regulation, airspace design, traffic planning and weather condition etc. In case of the highly automated systems, the changes in traffic intensity, abnormal and an emergency situation may generate several extra tasks.

- Task load is defined by the preliminary records on e.g. flight plans, traffic complexity, weather conditions;
- The information load is applied for characterizing a relatively new problem, initiated by supporting the operators with too many and partly not harmonized information from the different sources. This situation confuses operators, and putting them into difficulty to evaluate the right and required information [23];
- The task and information loads together with real traffic complete the workload of the operators. This is the most known and applied merit. For example, Endsley and Kiris [24] developed a special situation awareness global assessment technique (SAGAT) that is applied nowadays, too by NextGen and SESAR. The workload depends on real traffic conditions, traffic complexity, etc. and it can be determined from the traffic performances [25] or evaluated from the operator reactions (for example from the evaluation of the ATCOs voice - see [26];
- Finally, the actual physical and psycho-physiological condition called as mental load might be defined and measured. Mental load takes into account the human subjective behaviors including knowledge, skill, practice and psychological conditions. The mental load plays a determining role in the so-called subjective situation awareness and decision making of operators [27, 28]. It can be determined from the human basic medical parameters, like heart rate, blood pressure, electroencephalogram and skin conductance.

The developing operator load management system requires to use new methods and a wide range of microsensors integrated into the working environment, into a cockpit.

3. Future Operator Support Systems

3.1. Eye-Tracker Usage

Eye tracking has been gaining popularity around for over a hundred years. Several researchers have been carried out for developing eye tracking systems such as in reading [38, 39], human-computer interaction, psychoanalysis and over-learned task such as hand washing, tea making or even how people compose photographs with digital cameras [29].

In aeronautics, the first eye tracking measurements were realized in flight and ATC simulations. Optical measurements were used, namely, video recorded by cameras mounted into the working environment in front of the operators, and /or on the headband. The head positions were measured by wearing special items by operators. The headband as usually held eye and screen cameras. The measurements resulted in aggregated metrics like fixation duration, dwell times and moving average time windows (MAW) introduced by Anders [30]. Such simplified measurements are applied even nowadays [31]. The results give information not directly about the eye movements, only, but discover some special peculiarities of ATCOs.

The eye tracking method can be applied to three major tasks:

- Training of operators – pilots, ATCOs, (even maintenance staff) for supporting their self-learning and evaluate their working qualities [32];
- Monitoring the operators' activity and mental conditions [33, 34];
- Use of eye tracking in control [35].

The eye motion of pilots was measured in two seats fix based flight simulator of a medium size passenger aircraft as Boeing 737. There were invited pilots having the large practice, and beginners so-called less skilled pilots to the flight simulator. All pilots realized different tasks. The measured eye motions and visual attention were rather different depending on the tasks and skill of the pilots (Fig. 6).

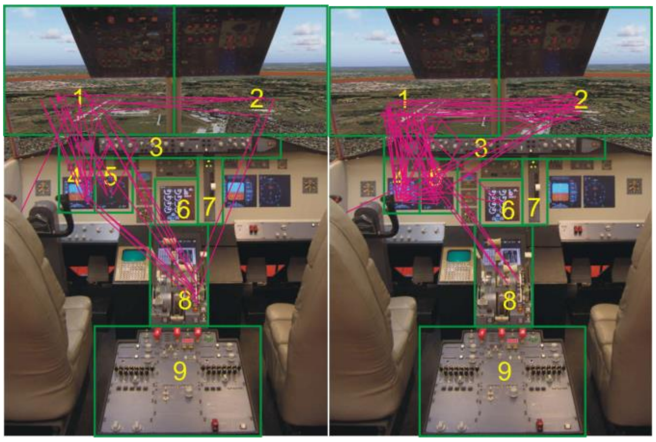


Fig. 6 Eye movements and visual attention measured in flight simulator during take-off (left) and final approach (right)

Fig. 7 Tobii eye-tracker gaze plot: Fixational eye movements of pilot during the engine failure scenario

Tobii Eye-tracker has been used to record the visual patterns of the pilots through failure scenarios, such as engine failure and equipment failure in the simulator of Piper Seneca 3 multi-engine aircraft. Fig. 7. shows the pilot' eye movement during the engine failure. Several areas of interest in the cockpit were defined to study gaze allocation during the simulated scenario by authors.

According to the result in Fig. 7. (left), after the engine failure, the pilot spent most of his time gazing at the engine instruments and finding the best place to make a precautionary landing somewhere off of the airport. Studies have led to generating an idea of using the eye tracking in decision support systems. The first developments had been focused on the accuracy of visual attention measurements and developing the supporting ideas.

3.2. Use of Integrated Micro Sensors

To measure the selected physiological parameters, to identify changes in operators' workload and in a mental state, a side-stick and a computer mouse with integrated sensors were developed (Fig. 8). These integrated devices consist of a heartbeat sensor, skin conductance sensor, temperature sensor, and strain gauges to measure grasp force applied by pilots on the handle. The microsensor technology can be used for developing the operators' working environment to increase the level of situation awareness.

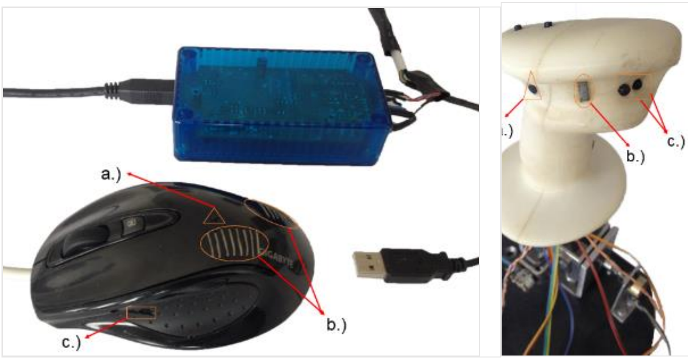


Fig. 8 Integrated microsensors into a computer mouse and a side-stick a.) skin resistance; b.) skin temperature sensors; c.) heart rate sensor

The aim of this investigation is to collect all the critical information by sensing the operators' healthy signs and storing on a computer. This method has been used in the ATC/ATM simulation laboratory at Budapest University of Technology and Economics (BME). Similarly, these microsensors are actively used in hospitals to measure heart rate and oxygen level of patient blood.

3.3. Electrodermal Activity Device (EDA)

The measurement of electrodermal activity (EDA) has a long tradition starting in the 1800's and it has been used in a wide variety of studies related to psychology. EDA is an efficient indicator of arousal reflecting the activity of the sympathetic branch of the autonomic nervous system [36]. Different characteristics of electrodermal activity are important psychophysiological indicators of the emotional state, studied extensively in adults [37] as well as infants [38]. For the purpose of the present study, skin conductance activity of an experienced pilot was measured on a flight simulator. Open source bio-monitor for electrodermal activity (Obimon), a new low-cost, small and reliable device capable of synchronized measurement was used to record EDA from the wrists and shoulders of the participant (Fig. 9.)

Fig. 9 Electrodermal activity device (EDA) usage in the flight simulator

Skin conductance is caused by the activity of sweat glands. And sweating causes a brief drop in the electrical resistance of the skin. This resistance also can be measured by means of electrodes placed on the human body surface.

3.4. Concept Validation by Use of Binocular System

To validate the concept of application of the motion tracking system, a test set up was built in the simulator laboratory of the Department (Fig. 10, left). The motion tracking cameras were placed above the test area to ensure the unobstructed view on the target. In the test area, a binocular was placed which was followed by the motion tracking system. The system followed the motion of the binocular and from the position and orientation a self-developed algorithm determined the point of gaze. An information providing system was also developed to test the applicability of augmented reality and to develop methods load and information management methods to this concept.

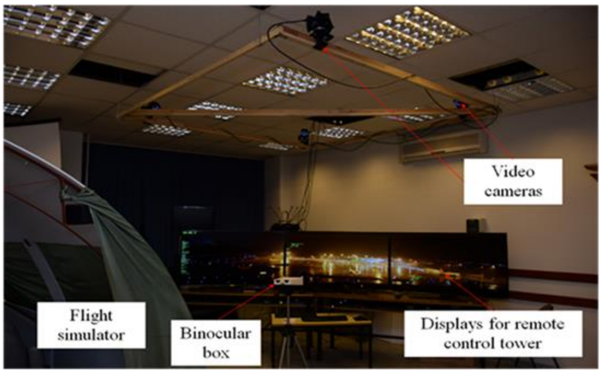


Fig. 10 Laboratory test of the binocular used in detection of the point of regards (left) and The dedicated displays with augmented reality features (right), as presented in the World ATM Congress in 2015

The tests showed that the developed test system is accurate enough to support the work of controllers in a classical tower and a more modern remote tower environment in the future. The test system based on the developed concept was presented by the HungaroControl in the world ATM Congress in 2015 (Fig. 10, right).

4. Conclusions

The Department of Aeronautics, Naval Architecture and Railway Vehicles at Budapest University of Technology and Economics has a long-term program developing skills and competence in operators working simulation, their load management and developing their working environments. The Department has two flight simulators (namely one is a fixed based middle size aircraft simulator with conventional control yoke and with side control at other seats applying for scientific investigations, while the other simulator is a two seats small aircraft simulator applying in pilot training program) and one ATC/ATM simulation laboratory.

By developing and introducing the highly automated systems in aviation, the role of operators (pilots and ATCOs) in a transition from active controlling to passive monitoring. Therefore, the operator models and their load monitoring, load management becomes to the level of the most important tasks. In this changing environment, the traditional operator model had to be redefined hence the concept of the future operator model was developed and introduced in this paper. There were developed measuring systems (i) integrating into the pilots and ATCOs working environment (ii) eye tracking system, (iii) electrodermal activity device, (iv) out-side measuring equipment. Operator load management was created by using the measurement.

The research was made on developing a working environment enhanced with integrated sensors to collects information on operators' activity, to increase situational awareness and reduce total loads on the subject, namely work, task, information and mental load. A concept of a system based on these sensors was developed in a collaboration between the Budapest University of Technology and Economics and HungaroControl. Different methods and systems were tested to develop such a system. The developed model is well usable for measuring the operator loads. By deployment of the develop load monitoring and management system, the safety of aircraft flights and air transport management will be increased, especially in an abnormal and emergency situation.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Optimization Process of the Stock Quantity Based on a Set of Criteria when Considering the Interaction among Logistics Chain Components

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Abstract

This article describes the optimization process of the stock quantity in the particular logistics enterprise when applying a specific algorithm. Current models and methods of the stock volume management are focused mainly on cost-site management and take into account a limited set of criteria. The article outlines the determination of the comprehensive set of factors affecting the stock quantity and which are affected by the stock volume throughout the logistics chain. Following the interaction of determined factors within the logistics chain, criteria which are taken into consideration in the designed algorithm for the stock degree optimization are defined within this research study.
KEY WORDS: *logistics chain, stock quantity, optimization criteria, algorithm*

1. Introduction

Stock (inventory) fulfills the important functions in the enterprise depending on the sufficient stock degree (inventory level), and besides that, it is necessary to take into consideration the fact that stock degree has an considerable impact on the financial aspect of a business. Stock comprises by 10-25 % of the total assets and its maintaining requires costs that might constitute by 10-20% of the total costs of an enterprise.

The aim of any enterprise is to minimize the stock degree, since it binds funds and incurs the costs related to their storage and maintenance. On the contrary, the particular stock volume compliance reduces a risk of the deficiency and disruption in production, which could result in a decrease in terms of the customer service level. For these reasons, it is necessary to pay attention to their effective management.

There are several models for stock management which take into consideration a number of criteria for optimization focused mainly on the cost aspect. The paper describes a comprehensive range of factors affecting stock quantity, and vice versa, factors influenced by stock volume throughout the logistics chain. Based on the determined factors, the aim of this paper is to propose the set of criteria and methodology (algorithm) of the stock degree optimization.

2. Analysis of the Relationship among Stock and other Parts of the Logistics Chain

Stock is to be considered as a part of a complex system and should examine their interaction with other components and activities within the entire logistics chain, from the supplier's point of view to meet needs of the customer [1].

Also, the intensity and character of consumption as well as choice of supplier influence the ordered stock quantity that subsequently has an impact on a stock volume in a warehouse and stock degree in a warehouse affects the continuity of production and customer service level [2].

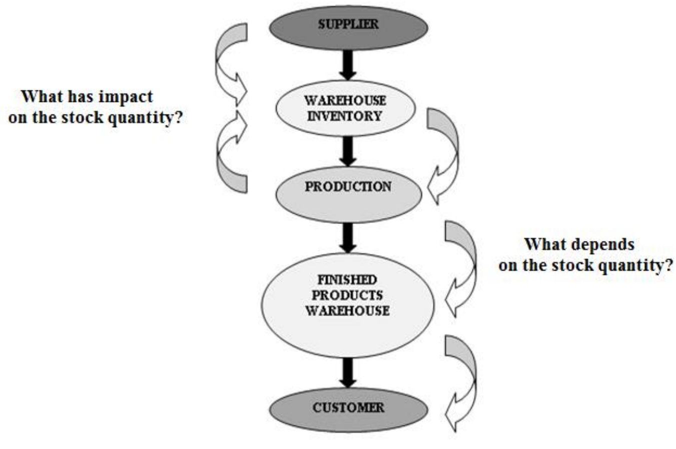

Fig. 1 Relationship of stock quantity with other parts of the logistics chain

On this principle, logistics chain can be divided into two parts. In the first part, it analyzes what has influence on the stock amount, and vice versa, in the second part of the logistics chain, it analyzes what is dependent on the stock quantity. Border between these two parts of the logistics chain is represented by the production process. The breakdown of the logistics chain is illustrated in following Fig. 1 [3].

The number of order quantities is influenced by [4]:

- intensity of stock consumption;
- character of stock consumption;
- acquisition costs;
- delivery conditions of suppliers.

The acquisition costs are relatively fixed costs changing by jumps, i.e. cost increasing occurs just after exceeding a certain limit of delivered supplies volume. Hence if only certain parts exceed the capacity of means of transport, in terms of acquisition costs for enterprise, it is appropriate to order more (to fulfill the capacity of means of transport), i.e. to increase the stock degree beyond the determined intensity and consumption. This increase regarding the stock degree may be eliminated if the supplier is able to deliver a specified quantity, regardless of the capacity of means of transport declared in acquisition costs [5].

The risk of the stock deficiency and the resulting costs also depend on the character of consumption. Thus, costs resulting from deficiency of stock represent another important group of costs. In the case of manufacturing enterprise, costs of disruption in the production may occur. In regard to a commercial enterprise, these costs are referred to as lost sales. In both cases, these costs also include penalties resulting from the disruption in the production or lost sales. These facts are the reason for higher stock degree to aim the prevention of such costs [6].

In case of the stock volume deficiency, the resulting costs may be partially reduced by reduction of a length of delivery time. The risk regarding the stock quantity deficiency may be eliminated if the supplier is characterized by a high degree in terms of the delivery time compliance, delivered goods quantity and delivered goods quality [7].

Following table (Table 1) provides a summary of factors affecting the order quantity.

Table 1

Factors affecting the order quantity

<table>
<tr><th>Production</th><th>Supplier</th><th>Risk</th><th>Costs</th></tr>
<tr><td rowspan="2">intensity of consumption</td><td rowspan="2">flexibility in the supplied quantity</td><td rowspan="2">the risk that the stock will not be used</td><td>acquisition costs</td></tr>
<tr><td>costs resulting from the unused stock</td></tr>
<tr><td rowspan="4">character of consumption</td><td>length of delivery time</td><td rowspan="4">the risk of the stock deficiency</td><td rowspan="4">costs resulting from the stock deficiency</td></tr>
<tr><td>keeping the delivery time</td></tr>
<tr><td>keeping the delivered quantity</td></tr>
<tr><td>keeping the delivered quality</td></tr>
</table>

Also, the production has an impact on the stock quantity in terms of its intensity and character as well as stock degree has effect on the production in terms of its continuity. The stock quantity also affects the storage and maintenance costs that are variable cost and are dependent on the quantity in storage stock. It means that in the context of costs reduction, the enterprise try to minimize the stock degree [8].

Excessively high stock degree can also cause the generation of costs due to unused stock, since their obsolescence, deterioration, etc. The reason to minimize the stock level is that stock binds the capital which depends on the value of stock and has a significant impact on the overall management of enterprises [9].

Customer represents a priority for each enterprise represents. The level of customer service is an important indicator of competitiveness and position of an enterprise on the market. Customer service also includes, among other aspects, the level of coverage of random demands; and that is the reason for maintaining bigger stock quantity by an enterprise [10].

Following Table 2 summarizes an impact of the stock quantity on others parts of the logistics chain.

Table 2

An impact of the stock quantity on others parts of the logistics chain

<table>
<tr><th>Customers</th><th>Production</th><th>Warehouse</th></tr>
<tr><td rowspan="4">customer service</td><td rowspan="4">continuity of production</td><td>storage and maintenance costs</td></tr>
<tr><td>costs resulting from unused stock</td></tr>
<tr><td>costs resulting from the stock deficiency</td></tr>
<tr><td>binding capital in stock</td></tr>
</table>

3. The Synergic Effect in the Logistics Chain for a Set of Criteria to Optimize the Stock Quantity

To streamline the stock degree, it is necessary to take into account three fields of impact of stock volume within the logistics chain:

- customer requirements;

- features of supplier;
- the economics of enterprise.

Following figure (Fig. 2) depicts the interaction of these factors:

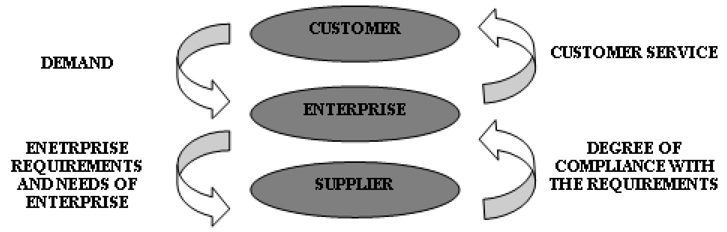

Fig. 2 The interaction of customer, enterprise and supplier in the procurement process

To optimize the stock degree, it is important to taken into account the requirements and needs of customers which is reflected in the intensity and character of stock consumption in the production (sales) process. The intensity of consumption reflects the size of a demand for products. Character of consumption is defined by a time interval of demand which can be constant, fluctuating or random [11].

The more character of consumption is random, the more the risks regarding the stock deficiency arise, or vice versa. The randomness of demand affects the continuity of production which in turn affects the customer service. The important part of the proper functionality of the enterprise is represented by the cost optimization. In the supply process, four main groups of costs occur:

- acquisition costs;
- costs resulting from the stock deficiency;
- storage (warehouse) and maintenance costs;
- costs resulting from unused stock.

To optimize acquisition costs and costs resulting from unused stock of stock deficiency, the supplier has an important role. Determining the acquisition costs depends on the unit for their calculation. Costs resulting from the stock deficiency are associated with a degree of risk of the stock shortage which is affected by a reliability of the supplier in compliance with delivery time, delivered goods quantity and delivered goods quality. In case that costs resulting from the stock deficiency are already incurred, the supplier may affect their quantity by the delivery time period duration [12].

Above stated factors affect the stock volume which directly affects the storage and maintenance costs and costs resulting from unused stock. The proposal of criteria is carried out based on a comprehensive view on the logistics chain and the interaction among its various components and their mutual synergies regarding stock. This process is illustrated in following Fig. 3 [13].

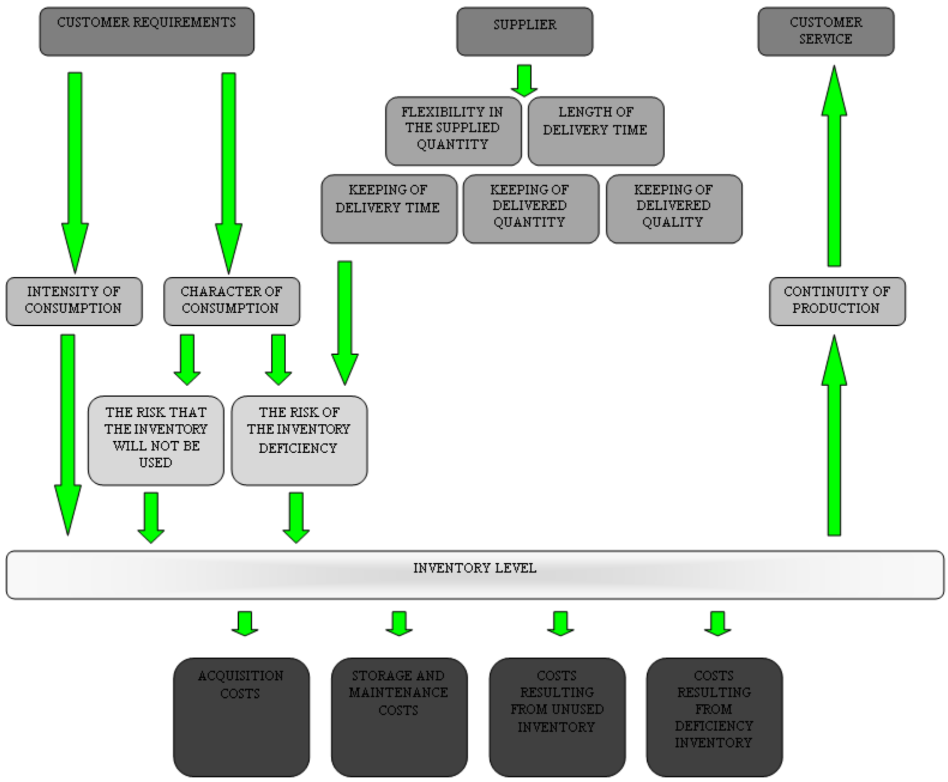

Fig. 3 The synergistic effect in logistics chain

The previous figure shows that key factors to optimize the inventory are:
- intensity of consumption,
- likelihood of a risk of the stock deficiency,
- likelihood of a risk that the stock will not be used,
- order quantity.

The intensity of consumption is determined by the customer requirements representing the first criterion of a proposed set of criteria to optimize the stock and ensure adequate customer service. Taking into account the customer's requirements provides also prevention against the risk that the stock will not be used and the resulting costs [14].

The likelihood of a risk that the stock will not be used and also a risk of the stock deficiency are influenced by the character of the consumption of inventories in production, the length of the delivery time, keeping the delivery times, delivered quantity and quality of the goods, which represent other criteria of a proposed set of criteria for optimization of the stock degree. Moreover, it is also prevention to minimize the risk of the stock deficiency and ensure the continuity of production [15].

The flexibility in the supply quantity, which has impact on the order quantity and optimized acquisition costs, represents the final criterion. The optimal stock volume with adequate binding funds and reasonable storage and maintenance costs represents the outcome of a proposed set of criteria. These criteria and their reasons for the proposal are indicated in following Table 3 [16].

Table 3

Basis, reasons and result of proposed criteria

<table>
<tr><th>Basis for the proposed criteria</th><th>Proposed criteria</th><th colspan="2">The reasons for proposed criteria</th><th>Result</th></tr>
<tr><td>intensity of consumption</td><td>customer requirements</td><td rowspan="2">customer service</td><td rowspan="2">minimization of the risk that the stock will not be used and the resulting costs</td><td rowspan="7">optimal stock degree with adequate binding funds and reasonable storage and maintenance costs</td></tr>
<tr><td rowspan="5">likelihood of risk that the stock will not be used or the risk of the stock deficiency</td><td>character of consumption</td></tr>
<tr><td>length of delivery time</td><td rowspan="4">minimization of the risk that the stock will not be used and the resulting costs</td><td rowspan="4">continuity of production</td></tr>
<tr><td>keeping the delivery times</td></tr>
<tr><td>keeping the delivered quantity</td></tr>
<tr><td>keeping the delivered quality</td></tr>
<tr><td>order quantity</td><td>flexibility in the supplied quantity</td><td colspan="2">optimized acquisition costs</td></tr>
</table>

4. Methodology for Optimization of the Stock Quantity

The proposal of methodology for optimization of the stock degree is based on the following pillars:
- consideration of all the factors which were specified by analysis,
- defining the correct configuration of factors from the perspective of the interaction among them,
- enterprise priorities.

Methodology for optimization of the stock volume is depicted applied the proposed algorithm. That is indicated in following figure (Fig. 4).

The customer represents the priority for the enterprise. Thus, determining the intensity of consumption *"I"* in regard to the customer requirements represents the first step of the proposed methodology (see Eq. 1).

$$I = O^*, \tag{1}$$

where O^* is order quantity [pcs].

Next step is to determine the likelihood of a risk of the stock deficiency *"P"* based on (Eq. 2):
- character of consumption - $P1$;
- length of delivery time - $P2$;
- keeping the delivery time - $P3$;
- keeping the delivered quantity - $P4$;
- keeping the delivered quality - $P5$.

$$P1 + P2 + P3 + P4 + P5 = P\,. \tag{2}$$

Determination of the order quantity O^{**} (see Eq. 3) based on the likelihood of a risk of the stock deficiency *"P"* represents the next phase of the procedure.

$$I + P \times I = O^*. \tag{3}$$

Determination of the optimum order quantity *O**** (see Eq. (4)) based on the flexibility of supplier which depends on his possibilities in the supply quantity or capacity of means of transport *"C"* represents the final step of the procedure.

$$O^{***}= I + P \times I + (C - I). \quad (4)$$

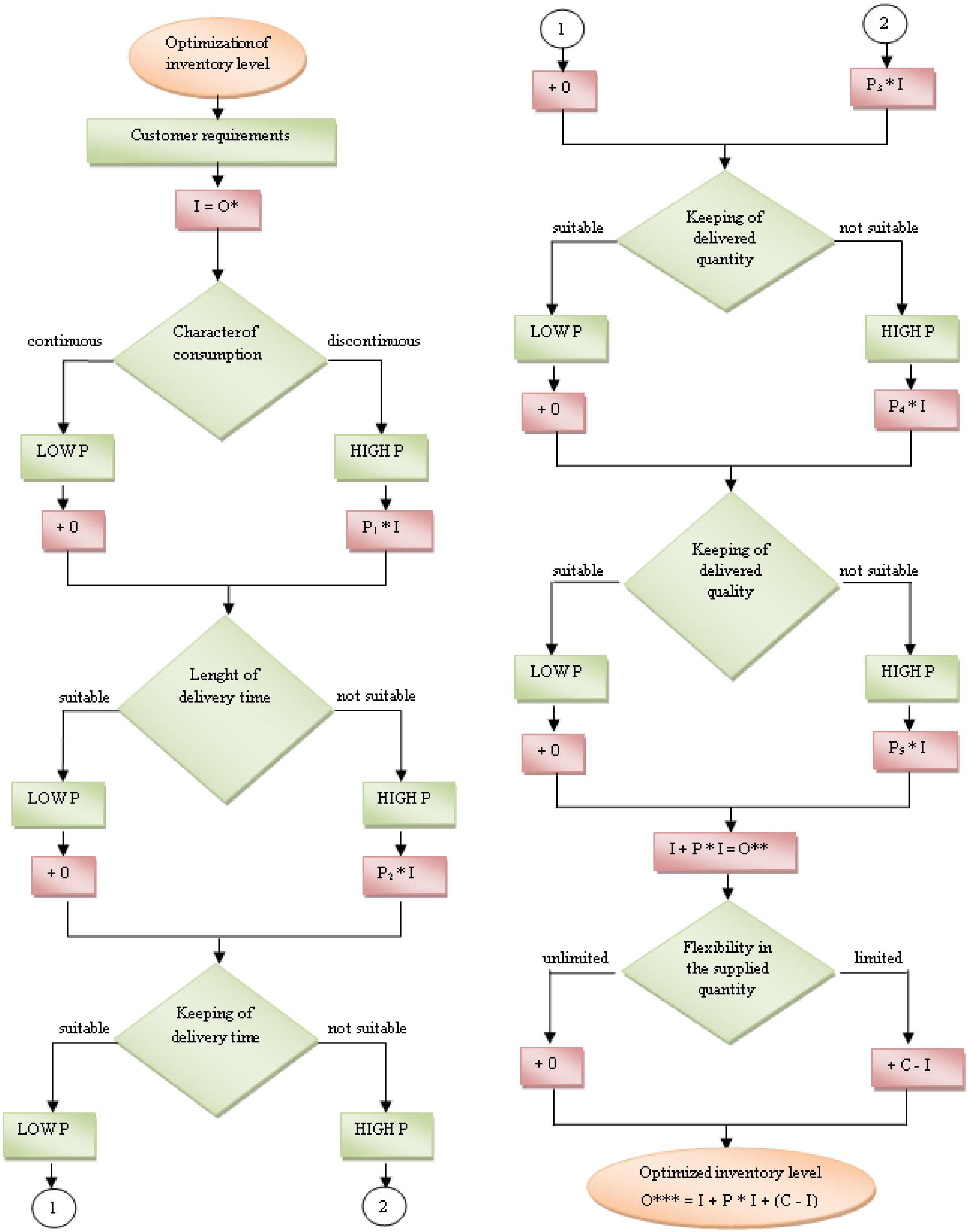

Fig. 4 Algorithm for stock degree optimizing

5. Conclusion

In order to optimize the stock quantity, it is necessary to take into account a comprehensive scope of factors

affecting it as well as those which are affected by the stock volume. These factors are reflected in a design of the stock optimization which is based on the comprehensive insight into the logistics chain and the interaction among its distinct components and their mutual synergy effects within relationship to stock.

Proposal of a set of criteria to optimize the stock degree takes into account needs of customers and an enterprise. Thus, following factors need to be taken into consideration: customer requirements, nature of consumption, length of delivery times, keeping the delivery times, delivered quantity and quality, flexibility in the supply quantity and a risk of the stock deficiency or the risk that the stock will not be used.

On the basis of interaction among determined factors within the logistics chain, criteria which are considered in the designed algorithm to optimize the stock degree are proposed. Determining the optimum stock quantity ensuring the continuity of the production process and adequate customer service, with adequate binding funds and reasonable storage and maintenance costs, represents the final outcome of this methodology. The designed methodology to optimize the stock volume is significantly different from current models regarding the stock management from the perspective of its structure and comprehensive set of criteria.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Technical Requirements for Systems for the Reception of Waste from Inland Vessels Operated on International Waterways of the European Union

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Abstract

The paper discusses the issues of waste and cargo residues management on inland waterways in the light of the applicable technical requirements on the international waterways of the European Union. The first part of the paper contains an analysis of the international and national legal requirements for the management of waste and cargo residues from inland vessels. This is followed by the concept of using seagoing vessels to receive waste and cargo residues. The solution presented here has been developed on the basis of data provided by state authorities and analysis which allowed to, *inter alia*, identify the key technical requirements for waste reception systems in inland navigation. The third part contains an analysis of selected single-hull tankers which could be used for the reception of waste and cargo residues.
The goal of the paper has been to analyse the existing technical requirements for systems for the reception of waste from inland vessels operated on international waterways of the European Union and to develop a concept for sound waste management on inland waterways based on the use of single-hull seagoing tankers.
The concept of using single-hull tankers for sound waste management is both technically and economically justified. The proposed solution allows to, for instance, extend the lifetime of a vessel and derive further economic benefits from its operation. However, it calls for proper technical preparation of the vessels in order to perform new functions.
KEY WORDS: *waste, waste management, pollution, inland waterway transport, single-hull tankers*

1. Introduction

The European inland waterway transport system is shaped primarily by the existing technical conditions of the linear and points infrastructure, as well as the economic and legal circumstances of the shipping market. The European inland waterway transport system rests on four fundamental pillars: vessel fleet, port infrastructure, waterways and infostructure (support systems for river information services). The contemporary transport services operated on the waters of the European Union involve primarily bulk cargo (farm products, coal, iron ore, consumer products, chemical products, oil products), general cargo (machinery, metals, waste), heavy and over-sized cargo (ship hulls, bridge structures, generators, wind platform components). In addition to this, inland vessels perform special functions, other than typical transport services, including mining, dredging and supply activities etc.

Modern fleet includes three groups of vessels: cargo vessels (self-propelled barges, pushed convoys, pusher vessels, passenger vessels, ferry boats, special barges), support vessels (port pushers, port tugs, supply vessels, rescue vessels, fireboats, floating cranes), technical vessels (hydrographic vessels, dredgers, ice-breakers, patrol boats, house boats, floating workshops, floating equipment). The reception of waste and cargo residues is a key activity provided for ships in inland ports. From the perspective of the arrangement of reception of waste and cargo residues in ports, it is essential to be aware of the types of pollution generated by ships, their approximate quantities and sources. Analysis of the extent, type and kind of ship facilities used in the context of the waste generated provides insights on the necessary solutions, considering the characteristics of the vessels handled by the inland port in question.

Along with the growing number of vessels handled in ports and operated on inland waterways, the volume of waste and cargo residues that need to be disposed of appropriately is bound to increase. This calls both for the development of organisation and execution procedures and approaches for the safe and effective handling of inland vessels during waste delivery operations and activities, and for the design of new concepts for sound waste management [3, 4, 6].

The goal of the paper has been to analyse the existing technical requirements for systems for the reception of waste from inland vessels operated on international waterways of the European Union and to develop a concept for sound waste management on inland waterways based on the use of single-hull seagoing tankers. To date, the vessels have been used for maritime oil product transport operations, and in view of the contemporary legal restrictions, they will have to be decommissioned in 2018. The change of purpose of the vessel, along with an update of the shipping register, allows to continue the operation of the vessel on inland waterways within shipping areas 1, 2, 3 and 4, provided that the cargo structure changes from fuel to waste, such as oily bilge water, sewage etc.

2. Legal Requirements Pertaining to the Management of Inland Ship-Generated Waste and Cargo Residues

The most important pieces of legislation governing the principles of management of ship-generated waste and

cargo residues from inland vessels include but are not limited to:

1. Directive 2006/87/EC of the European Parliament and of the Council of 12 December 2006 laying down technical requirements for inland waterway vessels and repealing Council Directive 82/714/EEC;

2. Act on inland waterways shipping of 21 December 2000 (Journal of Laws [*Dz.U.*] 2001 No. 5, item 43);

3. Regulation of the Minister of Infrastructure of 21 May 2003 concerning the accumulation, storage and disposal of waste and wastewater from inland vessels (Journal of Laws [*Dz.U.*] 2003, No. 104, item 973);

4. Regulation of the Minister of Infrastructure of 5 November 2010 on the technical requirements and mandatory equipment for inland vessels and the authorisation of operators to perform technical inspections of vessels (Journal of Laws [Dz.U.] No. 216, item 1423).

The above documents lay down, *inter alia*, detailed guidance for the accumulation, storage and disposal of waste and waste water from inland vessels. Further, they identify the ways to prevent pollution resulting from cargo transport operations [5] [8] [9] [11]. In accordance with the applicable legal rules, the minister in charge of transport, in consultation with the minister in charge of the environment, shall apply the respective provisions taking into account the current international requirements.

In accordance with the provisions of the Act on inland waterways shipping, no items or substances shall be thrown out or discharged from ships that could pose an obstacle or danger to inland waterway transport operations. Further, pollution from vessels must not endanger other waterway users or pose a threat to the aquatic environment. A shipmaster who comes across any undesired items or substances on a waterway is obliged to notify competent authorities immediately of the location and nature of the pollution [11].

In accordance with the Regulation of the Minister of Infrastructure of 21 May 2003 concerning the accumulation, storage and disposal of waste and wastewater from inland vessels, there are three groups of ship-generated waste [8]:

1. Ship-generated waste containing oil or lubricants – used oils, bilge water and other waste containing oil or lubricants, such as: used lubricants, used filters or rags, as well as their respective containers and packaging materials;

2. Cargo residues – the remnants of any cargo material in cargo holds or tanks of a vessel which remain after unloading procedures and cleaning operations, including loading/unloading excesses and spillage;

3. Waste water and domestic waste generated on board – waste water from galleys, sculleries, bathrooms or washrooms, laundry rooms, as well as faeces, organic and inorganic waste from onboard households and catering facilities.

All points of reception of ship-generated waste should be located at loading berths, in ports, harbours or other sites intended for accommodation of vessels, and the costs of reception are to be borne by the vessel agents. Waste containing oil or lubricants can be accumulated only in special built-in tanks designated for the purpose or in separate containers, while oily bilge water must be stored in machinery space bilges [1, 2]. With respect to waste containing oil and lubricants, tanks must not be overfilled, i.e. the maximum levels in machinery space bilges cannot be exceeded, which calls for appropriate planning of activities over time. Each reception operation of this type of waste requires a confirmation, which has to be recorded in an oil record book that has to be on board at all times. The oil record book is issued by the director of an inland navigation authority who issues the seaworthiness certificate. Complete reception records must be retained for 6 months from the record date. The same procedure applies to domestic sewage and waste.

After offloading, residues should be removed from all holding tanks and holds. This is not required only if subsequent transport operations involve the same cargo. On the other hand, waste water from tank cleaning operations or ballast water with cargo residues should be accumulated and disposed of according to the applicable procedure, depending on the type of pollution. Ships carrying liquid cargo must be equipped with bilge water polishing systems. These are permanent bilge arrangements in holding tanks allowing for the maximum drainage of holding tanks and pipes, with the exception of cargo residues [8].

3. A Concept of Using Seagoing Vessels to Receive Waste on Inland Waterways

The Act of 21 December 2000 on inland waterways shipping lays down the technical requirements for single-hull vessels by reference to the ADN international regulations, in conjunction with Article 41: *“Dangerous goods can be carried on board inland vessels in a manner that does not endanger the safety of navigation and precludes pollution or contamination of the environment, as required by the European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN), hereinafter referred to as the “ADN”.”* Specific provisions in this respect are laid down in the Government Statement of 12 June 2017 concerning the entry into force of amendments to the Annexed Regulations to the European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN), made in Geneva on 26 May 2000, effective from 1 January 2017. Section 1.6 of the Statement contains the following provisions applying to single-hull vessels:

- *“Single-hull tankers operated as on 1 January 2009, of less than 1000 tons displacement as on 1 January 2007, may continue until 31 December 2018 to be used for the carriage of materials authorised for carriage as on 31 December 2008.”*

- *“Supply vessels and oily water separation vessels operated as on 1 January 2009, of less than 300 tons displacement as on 1 January 2007, may continue until 31 December 2038 to be used for the carriage of materials authorised for carriage as on 31 December 2008.”*

The provisions above will necessitate the decommissioning of single-hull vessels of less than 1000 tons

displacement listed in the register of seagoing vessels on 31 December 2018. In practice, this means that vessel agents operating dangerous cargo services on the sea will be forced to retire some of their fleet despite its good technical condition, satisfying the requirements of classification societies, recognised bodies and maritime authorities. One of the ways to ensure that the single-hull tankers continue to be used is to change their intended use and shipping areas. The use of holding tank capacities to carry waste is an example of a sound and reasonable utilisation of the vessels under discussion, allowing the vessel operators to continue the operation of the vessels, without having to scrap or sell them. In order to pursue this line of action, the vessel must be de-registered with maritime authorities and registered with inland navigation authorities, which cover four shipping areas, including internal sea waters. By way of an example, single-hull vessels are represented by a group of self-propelled tankers built in the 1960s by the River Shipyard in Wrocław (*Wrocławska Stocznia Rzeczna)*. Table 1 shows the technical and performance parameters of this group of vessels.

Table 1

Technical and performance parameters of single-hull self-propelled tankers

No.	Parameter	Value
1.	Overall length – L [m]	56.74
2.	Overall width – B [m]	7.74
3.	Total draught – T [m]	1.85
4.	Freeboard – F_b[mm]	150
5.	Deadweight tonnage – DWT [t]	506
6.	Number of watertight transverse bulkheads [pcs]	5
7.	Number of holds (holding tanks) [pcs]	3
8.	Number of main propulsion engines [pcs]	2
9.	Total rated power of main sources of motive power – P_B[kW]	214
10.	Number of main propellers [pcs]	2
11.	Number of bilge pumps [pcs]	2
12.	Minimum pump capacity [l/min]: - first bilge pump - second bilge pump	 80 530

Source: own based on [10]

Every floating craft in the group under review should have the following documents and equipment in order to be admitted to operate on inland waterways:

– A concise oil pollution emergency plan (vessels of an overall length L ≥ 24 m);
– An approved and up-to-date flow diagram of oily bilge water and oil residues (sludge) handling system;
– Records of oil bunkering and oily bilge water and oil residues (sludge) reception operations – oil record book;
– A placard placed in a prominent position next to the side valve for direct overboard discharges of oily bilge water;
– A discharge system for oily bilge water;
– A discharge system for sewage;
– A placard placed next to the side valve for direct overboard discharges of sewage or in the room from which the sewage is drained overboard;
– Means for waste accumulation;
– Permanent placards in appropriate locations (vessels of an overall length L ≥ 12 m),
– Systems/equipment containing ozone-depleting substances (controlled).

Furthermore, the vessels must not have any systems or equipment containing controlled substances which have been barred from further use. For Convention vessels that are not authorised for international shipping in the European Union, fuel quality is determined on the basis of fuel supply documents from the last three years confirming that the supplied fuel meets the requirements of Regulation 18(3) of Annex VI of the MARPOL 73/78 Convention [7]. Depending on the shipping area, the parameters of floating craft (i.e. deadweight tonnage, draught and freeboard) might need to be brought in line with the required parameters presented in Table 2.

Table 2

Selected parameters for single-hull self-propelled tankers determining suitability for inland navigation

No.	Description	Shipping area 1	Shipping area 2	Shipping area 3	Shipping area 4
1.	Freeboard – F_b [mm]	380	300	150	-
2.	Draught – T [m]	1.62	1.70	1.85	-
3.	Deadweight tonnage – DWT [t]	416	447	506	-

Source: own based on [10]

In order to protect the aquatic environment, the following equipment should be provided on board the vessels under consideration: for the prevention of oil pollution (storage tanks, systems for discharge to reception facilities); for the prevention of pollution by sewage (storage tanks, systems for discharge to reception facilities; means of waste accumulation (bins); for the prevention of air pollution – use of CCNR 1, CCNR 2 and STAGE 5 compliant engines (Table 3).

Table 3

NO_x and PM exhaust gas emission standards developed by the Central Commission for Navigation on the Rhine (CCNR) applicable to EU inland waters

No.	CCNR standard	Standard in force [year]	Level NO_x [g/kWh]	Level PM [g/kWh]
1.	CCR 0	< 2002	-	-
2.	CCR 1	2002 – 2007	9.2	0.54
3.	CCR 2*	Since 2007	6.0	0.20

Source: CCR2 ≈ EU Stage IIIA, NRMM

The most recent STAGE V standard introduces the following constraints in relation to the previous thresholds for selected engine categories in terms of emission levels: CO reduction by 81% (for IWP-v/c-5); NO_x by 80 to 89.1% (for IWP-v/c-4); NO_x by 93.3 to 96.3% (for IWP-v/c-5); PM by 90 to 95% (for IWP-v/c-4); PM by 90 to 95% (for IWP-v/c-5). Table 4 presents a detailed list of equipment for the group of vessels under consideration, in order to meet the requirements of environmental protection.

Table 4

List of equipment for single-hull self-propelled tankers for the purposes of environmental protection

No.	Items of equipment	Intended purpose / Location	Number [pcs] / Transfer pump	Total capacity [m^3] / Discharge connection
To prevent oil pollution				
1.	Storage tanks	Oily bilge water/ –	1 / –	3.75 / –
		Oily residues (sludge) / –	1 / –	0.85 / –
2.	Systems for discharge to reception facilities	Oily bilge water	Own	- / Standardised
		Oily residues (sludge) / –	Own	- / Standardised
To prevent sewage pollution				
3.	Storage tanks	Oily bilge water/ –	1 / –	3.75 / –
4.	Systems for discharge to reception facilities	Sewage from storage tanks / –	- / Pump other than own	- / Standardised
To prevent pollution by waste:				
5.	Means for waste accumulation (bins)	- / Bow locker, machinery space, poop deck	4 / –	0.7 / –

Source: own based on [10]

4. Analysis of Selected Single-Hull Tankers Designated for the Reception of Waste and Cargo Residues

Considering the applicable environmental protection requirements, vessels meeting the aforesaid technical parameters and listed in the administration register of Polish inland vessels have been analysed. The change of purpose of single-hull tankers is intended to support the management system for ship-generated waste and cargo residues. The use of holding tank capacities to carry waste is an example of a sound and reasonable utilisation of the vessels. Tables 5 and 6 show the main dimensions and technical and performance parameters for five tankers based in Szczecin. Three of the floating craft under review have similar main dimensions and cargo capacities.

Table 5

Basic data for the single-hull inland vessels under review

No.	Vessel type and intended service	Base port	Place of construction	Year of constructio n	Vessel length [m]	Beam of ship [m]	Maximum permissible draught [m]	Deadwei ght capacity [t]
1.	Tanker	Szczecin	Wrocław	1968	56.76	7.75	1.85	499
2.	Tanker	Szczecin	Wrocław	1967	56.66	7.66	1.85	492
3.	Tanker	Szczecin	Wrocław	1962	56.74	7.72	1.85	506
4.	Tanker	Szczecin	Bremerhaven	1957	79.91	8.20	2.51	1223
5.	Tanker	Szczecin	Dordrecht	1984	109.10	11.36	4.02	3706

Source: own based on [10]

Table 6

Propulsion parameters of the single-hull inland vessels under review

No.	Vessel type and intended service	Propulsion type	Number of main machinery items [pcs]	Total power [kW]	Type	Propeller type	Number of propellers [pcs]
1.	Tanker	Szczecin	2	220	6NVD24	Water-screw propeller	2
2.	Tanker	Szczecin	2	242	SW680/195	Water-screw propeller	2
3.	Tanker	Szczecin	2	213	SW680/195	Water-screw propeller	2
4.	Tanker	Szczecin	1	622	-	Water-screw propeller	1
5.	Tanker	Szczecin	1	1325	6MDZC-1000-166A	Water-screw propeller	1

Source: own based on [10]

The analysis of the existing technical requirements for systems for the reception of waste from inland vessels operated on international waterways points to a possibility of tapping the potential of single-hull seagoing tankers which, due to the restrictions imposed by maritime administration provisions, will be phased out from use on seas by the end of 2018. The solution for retaining the phased-out fleet involves a change of purpose of the vessels, along with an update of the shipping register, which will allow to continue the operation of the vessels on inland waterways within shipping areas 1, 2, 3 and 4, provided that the cargo structure changes from fuel to waste, such as oily bilge water, sewage etc. No significant design changes, main propulsion parameter modifications or capacity parameter modifications are required. The cargo space can be fully utilised to receive waste from several vessels during a single journey, or even to receive waste from ports. The potential need to adapt the craft to the technical requirements in force, including the mandatory equipment for a seagoing vessel which is transferred to the register of inland vessels, could pose a challenge. In accordance with Order No. 2 of the Director of the Maritime Office in Szczecin of 4 March 2016 laying down additional requirements in respect of safe navigation for inland vessels operating on maritime waterways, vessels used for the reception of waste and cargo residues must be equipped with life-saving appliances and equipment of the type and number required for the shipping area concerned. Selected water areas covered by this obligation:

a) navigation in ports – navigation within the perimeters of ports, and on the waters stretching from the northern border of the Port of Szczecin to the parallel line crossing Brama Torowa No. 4 on the Piast Canal, Kamieński Lagoon and Dziwna Strait to buoy W2;

b) sheltered waters voyage – navigation on the Szczecin Lagoon (inland navigation area 2);

c) near-coastal voyage – voyage restricted to the territorial sea of the Republic of Poland and the part of Pomorska Bay southward from the line linking NordPerd on Rugen Island and the lighthouse Niechorze (inland navigation area 1).

5. Conclusions

The issues of waste management in inland waterway transport pose a considerable challenge today, due to the

increasing numbers of vessels operating on inland waterways and handled in ports, which leads to the generation of considerably larger amounts of waste.

A change of purpose of a vessel and its navigation area, for single-hull tankers, is both technically and economically justified. The proposed concept allows to, for instance, extend the lifetime of a vessel and derive further economic benefits from its operation. Such activities require the adaptation of ships to the existing procedures and methods of efficient, effective and safe handling of single-hull vessels with respect to the arrangement of reception of waste and cargo residues from inland vessels.

The implementation of the solution presented above should be based on technical guidance arising from international legal regulations, technical expertise of inspection bodies and requirements of classification societies.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Intelligent Transport Systems for Traffic Flow Management on Capacitive Roads

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Abstract

The main aim of the contribution is to briefly describe the various types of intelligent transport systems used on motorways and on capacitive roads in large urban areas. The reader will be familiarized with some examples of telematics applications and devices, which are increasingly being installed on capacitive roads primarily due to efforts to improve traffic fluency and safety. Telematics devices are widely used not only in most Member States of European Union, but also in other developed countries where the intelligent transport systems can communicate with each other. In addition to a brief description of these telematics devices, a graphic representation of selected telematics devices on motorways is also part of the paper.
KEY WORDS: *Intelligent transport systems, road line traffic control, RDS-TMC technology, telematics devices*

1. Introduction

It is obvious that the capacity and safety of motorways depend mainly on fluent traffic without limitations. Higher capacity road networks consisting of, for example, motorways and particular highways have newly been designed only with a grade-separated access with strict geometric parameters of their directional and height routing. In spite of these design measures, there are often traffic limitations resulting from both unexpected situations and planned or predictable situations. For both types of situations, however, congestion and other traffic limitations are very common. In extreme cases, the whole situation may result in the formation of few-kilometre tailbacks with the drivers waiting for several hours [1].

In order to mitigate the consequences of these negative traffic limitations, the concept of intelligent transport systems (ITS) was developed in most EU Member States and other developed countries. The core of these systems are telematics applications, whose correct function is based on the integration of information and telecommunication technologies with traffic engineering in order to increase the driving speed of vehicles and traffic fluidity and, above all, to improve traffic safety, which is the most widely used criterion when evaluating roads. The following chapter provides a brief description of telematics applications used on motorways. The description is also supplemented by photo documentation and diagrams.

2. Intelligent Transport Systems on Motorways

As mentioned above, telematics applications are special information technologies that enable monitoring and evaluating the current traffic situation in current time (e.g. closures, traffic accidents, or traffic fluidity) on motorways and higher capacity roads in large cities. In addition, they provide drivers with other traffic information, such as road temperature, travel time, or ice formation. Furthermore, telematics applications can evaluate individual characteristics of traffic flow, for example, its average speed, intensity and density, time spacing and distance between vehicles, etc. Other telematics systems can enable drivers to receive the necessary information about the current traffic situation in advance or, in case of an extraordinary situation, the systems can take control of the traffic [2, 3].

Fig. 1 Variable message sign – Germany [4]

The most commonly used telematics systems on higher capacity roads include, in particular, variable message signs (Fig. 1), road line traffic control, traffic information device, surveillance camera system, electronic toll, FCD technologies (Floating Car Data) or RDS-TMC, etc.
The following chapters describe in detail selected telematics applications and also include their graphical representation.

2.1. RDS-TMC

This telematics application (Radio Data System-Traffic Message Chanel) serves to display current traffic information in the navigation device's map directly in vehicles during the journey (Fig. 2).

Fig. 2 Navigation device′s map – Poland [5]

The driver is thus immediately informed about all the serious situations currently occurring on the road network and can respond to these emergencies in a timely manner by, for example, using an unmarked detour in case of a mass accident. Two most common types of devices used by drivers include [4]: devices integrated in the vehicle as part of the standard equipment of the vehicle when purchased, and mobile (portable) devices. The navigation device which is located in the vehicle receives encoded traffic information delivered by TMC (Traffic Message Channel) using the silent RDS (Radio Data System) data channel transmitted within the FM broadcast modulation of a particular radio station. The information is encoded in the international Alert-C protocol that is language-independent; therefore, any foreign driver can receive this traffic information on his navigation device that provides this service. To ensure reliable receipt of traffic information by the navigation device, it is necessary to have map data with location tables, an antenna capable of receiving FM broadcasting, and a navigation device set to receive a specific service for the selected route. While RDS-TMC service is operated in most European countries, some of the countries are covered by this broadcasting only partially or are not covered at all. In some other countries the service is still being prepared to start operations [6].

2.2. Road line Traffic Control

This telematics system consists of portals with variable message signs above or beside roads. Pictograms of the signs are based on the relevant regulations and represent mainly a combination of prohibitory, mandatory or warning signs. The recommended distance between the portal frames is between 1 and 1.5 km. Thus, the road line traffic control system (Fig. 3) automatically reduces the speed or changes the organization of traffic in lanes so that the stream of vehicles always moves as fluently and safely as possible.

Fig. 3 Road line traffic control system – Germany [4]

Therefore, this telematics application increases traffic fluidity and thus decreases the likelihood of forming tailbacks and their range [3]. For this reason, the portals are mainly constructed in places where frequent tailbacks and higher traffic intensities occur (e.g. access roads to large cities, surroundings of tunnels, etc.).

2.3. Variable Message Signs

This telematics device is used to control traffic directly on the road via an appropriate pictogram/symbol of a traffic sign. Sometimes the variable message signs are located together with a traffic information device (Fig. 4), which enables the drivers to be informed of the current traffic situation on the route ahead or in the vicinity.

Fig. 4 Variable message sign in road line traffic control – Italy [4]

In addition, the use of mobile variable message signs is becoming increasingly common on motorways in places of road repairs and reconstructions. Moreover, the undisputable advantage of traffic information devices over other telematics systems is that the first published information concerning emergencies that happened on a specific road section is the one automatically supplied by these devices [3, 6].

2.4. Floating Car Data (FCD)

The FCD method is used on roads to determine the speed of traffic flow. It is based on the collection of information from the mobile phones of individual drivers about their vehicle location, current speed and direction. The data obtained in this way represent one of the most important input sources for intelligent transport systems (telematics applications); each mobile phone can be described as a detector of traffic flow characteristics. These characteristics are used for calculations of, for example, travel times, or for informing drivers of the traffic situation ahead. Thus, the entire FCD system saves road infrastructure managers′ investments in the installation of telematics devices along roads, such as induction loops in the roadway, infra-red detectors, etc. Fig. 5 schematically illustrates the process of publishing information of the current traffic situation through the mutual compatibility of FCD technology with telematics applications (intelligent transport systems) [2, 7].

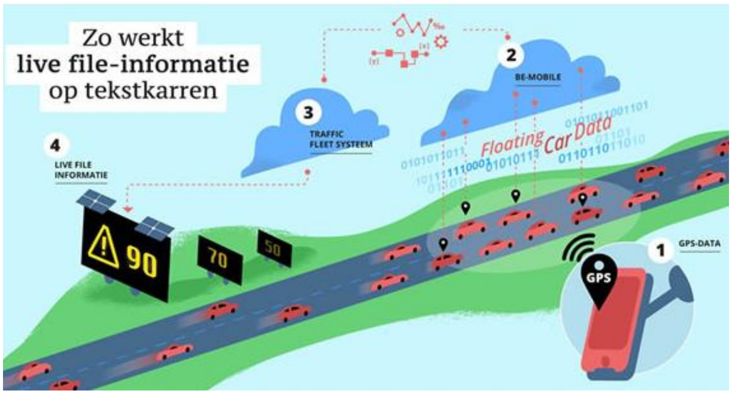

Fig. 5 Floating Car Data – scheme [8]

The FCD method uses cellular network data (such as CDMA, GSM, GPRS), and its advantage is that the only necessary device for its proper operation is a mobile phone, which serves as an anonymous source of information. The location of the mobile phone is determined either by triangulation method (Fig. 6) or the data stored by the network operator. When evaluating the detected data, it is also necessary to consider their quality. For this reason, the FCD uses complex algorithms and monitors many phones to eliminate, for example, the simultaneous ride of a train and vehicles travelling on a parallel road, which would, to some extent, distort the speed of the whole traffic flow [3, 8].

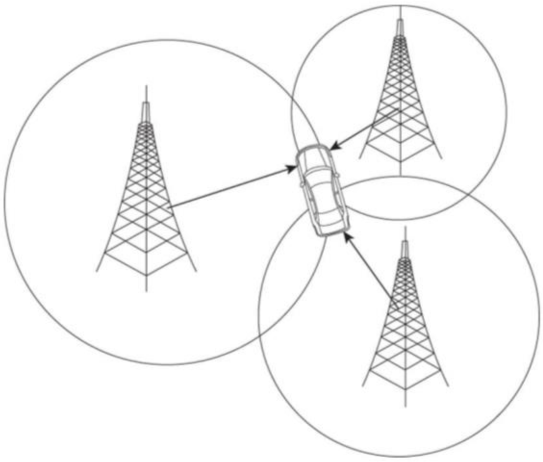

Fig. 6 Location of a mobile phone in a vehicle using triangulation [9]

3. Conclusions

The main objective of the paper was to describe the different types of intelligent transport systems on motorways and higher capacity roads in large cities, which are increasingly being installed in order to improve traffic fluidity and safety. Investing in intelligent transport systems along roads is much more efficient than the actual construction of new communications; this trend is particularly evident in those cities and countries that have already constructed their higher capacity roads system without the possibility of its further development [10]. The only way to improve fluidity and increase traffic safety on these existing communications are telematics applications and devices that are common, as mentioned in the introduction, not only in most Member States of the European Union but also in other developed countries in the world.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Exploitation of Transport Means in the Aspect of Carrying out Transport Tasks in Public Transport

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Abstract

Exploitation of means of transport is an important decision issue for enterprises that perform transport tasks in public transport. The number of transport tasks in public transport and their character as well as the requirements of the public transport manager means that transport companies must maintain an appropriate number of transport means with specific technical and operational parameters. Due to the fact that means of transport lose their useful properties during operation, the number of transport means maintained in the enterprise is usually increased by the so-called reserve. The article presents selected aspects related to the organization of public transport and the operation of means of transport necessary to carry out transport tasks. The problems of transport in public transport and booking of transport means are presented. In addition, the basic parameters of the assessment of transport services in public transport and the assessment of the reliability of transport means were characterized. The final part of the article presents the results of research related to the issues discussed, conducted in a communication company.
KEY WORDS: *public transport, reserve of means of transport, technical readiness of transport means*

1. Introduction

Despite the rapid development of the automotive industry, public transport still plays a key role in serving the population. The demand for transport services, including public transport, depends to a large extent on the functional and spatial structure of the city. In the case of the metropolis, there are currently significant changes in the urbanization process. The ongoing migration of residents from the city center to the suburban area, with a continuous increase in the number of jobs increases the number of commuters to work in the metropolis, and on the other hand the limitations in keeping punctuality are variable and usually result from reasons dependent on atmospheric conditions and random events, for example, road congestion along the route, transport failures as well as renovation and modernization works carried out in the city [1, 6, 9]. Two model solutions can be distinguished in the field of organization and management of public transport: communication without public regulation (deregulated communication),regulated communication.

The term "deregulation" means the management of a decentralized system. The role of government institutions and local self-government in the field of organization and management of public transport is limited only to the development of the road system, ensuring good traffic conditions and controlling and enforcing the necessary safety requirements. In the conditions of deregulated public transport, there is unlimited access to the provision of transport services for all companies with appropriate rolling stock.

Public communication in its organization and management is constantly changing. This is caused by changes occurring both in the external environment and the requirements of communication users [19]. Such a situation leads to reforming the structure of public mass transport in individual cities and limiting expenditures on the part of cities and communes, thus carriers are forced to adapt their transport offer to the requirements of both public transport managers and passengers [12]. The requirements can be met by transforming and developing communication bus systems both in the organization and management of transport as well as equipment of communication companies in the appropriate rolling stock both in terms of its quantity and technical and operational parameters.

2. Transport Needs in Public Transport

Transport need is the willingness or necessity of moving a person from one place to another by means of transport. With regard to the urban transport market, the classification of transport needs divides them according to the criterion of regularity (rhythmicity) on occurring systematically and unsystematically [18, 20]. This classification can be related to the division of transport needs into obligatory (systematic) and optional (non-systematic). The transport needs occurring systematically include those related to daily trips in the same relations and hours. Optional transport are occasional services and result from one-off needs. The classification of transport needs according to the spatial and functional criterion may also have practical significance in relation to the urban transport market. On the basis of this criterion, one can distinguish, referring to the area of functioning of public transport, the needs concerning intra-city relations and those related to crossing the administrative border of the city. Demand for public transport services is

combined with specific requirements regarding travel conditions, which are communication preferences. Externalization of these preferences on the market are transport postulates, which are also criteria for assessing the quality of transport services in public transport. The scope of transport postulates reported for public transport is wide. Many empirical studies and theoretical arguments have been devoted to determine them. The most frequently mentioned transport postulates in the literature of the subject are [3, 4, 8, 13, 16] punctuality, security, speed, convenience, availability, frequency, immediacy, cost, rhythm, information. Apart from the above demands one can distinguish: intimacy of traveling, adapting timetables to needs, an appropriate standard of stops, an understandable system of information on routes and timetables, protection against attacks at stops and in vehicles, service culture, appropriate transfer conditions, the opportunity to relax while traveling, luggage space, simple tariff system, easy getting on and off, choice of transport means.

The quality of transport services in public transport is the degree in which the natural features of the transport service meet the reported and identified customer needs and expectations. In quantitative terms, it is a set of criteria for which a carrier of a transport service is responsible in public transport, declaring compliance with the standard. Important parameters characterizing the quality of transport services in public transport that affect the assessment of the carrier are punctuality and timeliness of the course. Punctuality in public transport is expressed by the punctuality factor w^{punkt}, which is interpreted as the percentage share of the number of departures from stops recognized as punctual, in the total number of departures observed in a given period and is expressed by the following relation:

$$w^{punkt} = \left(1 - \left(U_D + U_S + \frac{U_M}{ZK}\right)\right) \cdot 100\% \;, \tag{1}$$

here U_D - delays in the implementation of courses on lines with high freedom of movement; U_S - delays in the implementation of courses on lines with medium freedom of movement; U_M - delays in the implementation of courses on lines with low freedom of movement; ZK – number of all completed courses.

The departure of the vehicle from the stop, which is within a certain range, e.g. <+ 1 ÷ -4> minutes, can be considered as punctual. The value of the interval should be determined by the public transport manager.

The timeliness of the course implementation in the case of public transport is measured by the timeliness ratio w^{term}, understood as the ratio of the number of defective half courses p^{wad} to the total scheduled number of half courses in a given month p^{rozk}, taking into account all ad hoc changes and is expressed in the form:

$$w^{term} = \frac{p^{wad}}{p^{rozk}} \cdot 100\% \;. \tag{2}$$

A half course made correctly is the half course made entirely in accordance with the current timetable or the order received from the transport manager. In such cases, there is usually a time tolerance at the end of the line, taking into account the earlier or later arrival of the vehicle. Contractual penalties calculated due to the timeliness of the course are calculated from the dependence:

$$KU = KW - \left(KW \cdot w^{kor}\right). \tag{3}$$

here the value of the correction factor w^{kor} is taken from the Table 1, while KW is the amount due for the transport services provided.

Table 1

Relations between the value of the timeliness ratio and the correction factor

No.	The value of the timeliness coefficient	Value of the correction factor
1	$0{,}00 \div 0{,}05$	Indicator not included
2	$0{,}05001 \div 0{,}25500$	$4 \cdot w^{term} - 0{,}2$
3	$0{,}25500 \div 1{,}00$	$1{,}00$

The implementation of transport in public transport requires the carrier to have means of transport with certain technical and operational parameters and in an appropriate quantity. The means of transport during their operation lose their functional properties, which requires appropriate technical services. In addition, the exclusion of means of transport from traffic may result from failures and other random events [7, 10, 11, 14, 17]. Therefore, it becomes reasonable to have adequate surplus of transport means in transport companies called a reserve.

3. Reserves of Vehicles in Public Transport

The implementation of public transport at a high level of quality of transport services requires the introduction of vehicle reserves. Spare vehicles take over the tasks of the rolling stock used to carry out transport tasks at the time of

their failure. The determination of a rolling stock reserve in a public transport enterprise is an important element of fleet management. A public transport company undertaking activities determining the number of rolling stock necessary to perform transport tasks should analyze the factors affecting the disruption of the rolling stock operation. The factors influencing on the rolling stock reserve in a public transport enterprise are scheduled technical inspections and rolling stock repairs, failures and damage, disruptions in the area of transport tasks [2, 4, 5].

In order to properly manage the fleet inventory held in a public transport enterprise, it is necessary to determine the place where the needs for the use of reserve rolling stock are created. We distinguish two basic sources of disruptions in the performance of transport tasks: disturbances arising before the commencement of transport tasks - in public transport enterprises these are places of bus depots, disturbances arising during transport tasks - disruptions in vehicle traffic.

Disturbances arising before the commencement of transport tasks are: technical defects of the vehicle created earlier in its operation, accidental failures, planned technical inspections and ongoing repairs.

The second type of disturbances are disturbances arising during transport tasks, i.e. disruptions in vehicle traffic. This disturbance group includes: technical defects arising during transport tasks, collisions and accidents in motion, other. In addition, factors that should be taken into account when determining the size of the rolling stock needed to carry out transport tasks in the city are: the size and structure of transport tasks and the time of their implementation, the structure of the rolling stock needed to perform transport tasks, requirements for rolling stock determined by the customer, expected costs operational, technical and maintenance infrastructure, traffic conditions in the area of carrying out transport tasks, expected value of return and expected weather conditions and other.

Reservation can be modeled with a reliability structure with a non-loaded reserve. In this structure, transport means are reserved in a waiting state - they are not burdened until they are included in the work in place of the inefficient means of transport, which is the primary means of transport. In the case of systems that require high reliability and technical readiness, reliability structures with a non-loaded reserve are used. Such systems are urban transport systems whose task is to provide transport services at a high quality level.

Reservation of rolling stock enables the performance of transport tasks in public transport at a given quality level, and the amount of this reserve is integrally connected with the technical reliability of the means of transport. Reliability is the property of an object that characterizes its ability to perform specific functions, under specific conditions and at a given time. In technical terms, the reliability of the system is defined as a set of properties that describe the facility's readiness.

To assess the reliability of technical facilities, characteristics are used, which are called reliability indicators. These indicators are understood as a measure, in relation to a probabilistic description of reliability, a function or quantity used to describe a random variable or a random process. One of the indicators characterizing the correct operation of the means of transport is the reliability function $R(t)$ which determines the probability of correct operation up to the moment t, which takes the following form:

$$R(t) = P\{T \geq t\} = exp\left[-\int_0^t \lambda(x)dx\right], \tag{4}$$

where T is a random variable defining the time of failure-free operation of the means of transport, while $\lambda(t)$ is a function of the intensity of damage.

The probability of the suitability of the means of transport R (t) can also be determined statistically by subjecting the tests to a sufficient large number of vehicles. Assuming that the research has been subjected to N^{poj} and after some time $t(k)$, a certain number of NU^{poj} (k) is damaged, then the discrete statistical estimate of the probability R (t (k)) is the dependence:

$$R\big(t(k)\big) = N^{poj} - \frac{NU^{poj}(k)}{N^{poj}} = 1 - \left(\frac{NU^{poj}(k)}{N^{poj}}\right), \tag{5}$$

while for continuous time functions, the statistical estimation of the probability R (t) is the dependence:

$$R\big(t(k)\big) = N^{poj} - \frac{NU^{poj}(k)}{N^{poj}} = 1 - \left(\frac{NU^{poj}(k)}{N^{poj}}\right). \tag{6}$$

The reliability of repairable facilities, which are public transport means, is characterized by the technical readiness indicator ξ^{got}, which takes into account both the damage and the serviceability of the means of transport and is expressed in the form of:

$$\xi^{got} = \lim_{t\to\infty} \xi^{got}(t). \tag{7}$$

In practice, due to the fact that the means of transport are subject to both current services caused by random

damage as well as preventive services resulting from service schedules, two types of technical readiness are applied. In the first case, it is operational technical readiness $\xi_{oper}{}^{got}\left(t\right)$, in the second actual technical readiness $\xi_{actual}{}^{got}\left(t\right)$. In operational readiness, the time taken by the means of transport in a state of inability caused by damage is taken into account, while in the calculation of the actual technical readiness, the time of stay of the means of transport in preventive maintenance is additionally taken into account. Formally, the operational readiness indicator at time *t* has the form:

$$\xi_{oper}{}^{got}\left(t\right)=\frac{\sum_{r\in R}\sum_{i\in I}T^{zdat}\left(t\left(r,i\right)\right)}{\sum_{r\in R}\sum_{i\in I}T^{zdat}\left(t\left(r,i\right)\right)+\sum_{r\in R}\sum_{i\in I}T^{nzdat}\left(t\left(r,i\right)\right)}, \tag{8}$$

where $T^{zdat}(t(r,i))$, is the residence time of the *i*-th transport means *r*-th type in a state of ability until time *t*, while $T^{nzdat}\left(t\left(r,i\right)\right)$ is the residence time the *i*-th transport means *r*-th type in a state of inability until such time as due to the realization of service caused by the damage.

Taking into account, in addition, the residence time of the means of transport in prophylactic service, the technical readiness indicator has the form:

$$\xi_{actual}{}^{got}\left(t\right)=\frac{\sum_{r\in R}\sum_{i\in I}T^{zdat}\left(t\left(r,i\right)\right)}{\sum_{r\in R}\sum_{i\in I}T^{zdat}\left(t\left(r,i\right)\right)+\sum_{r\in R}\sum_{i\in I}T^{nzdat}\left(t\left(r,i\right)\right)+\sum_{r\in R}\sum_{i\in I}T_{oprof}{}^{nzdat}\left(t\left(r,i\right)\right)}, \tag{9}$$

where $T_{oprof}{}^{nzdat}\left(t\left(r,i\right)\right)$, is the residence time of the *i*-th transport means *r* - th type in a state of inability due to the provision of preventive service resulting from the service schedule.

Public transport enterprises have a fleet of different structure resulting from the nature of transport tasks being performed and their various operational periods. This has an important impact on the damage to the rolling stock and, consequently, on the value of the technical readiness indicator, both operational and real.

4. The Case Study

Research on the estimation of parameters characterizing the quality of transport services in public transport and the reliability parameters of means of transport was carried out on the basis of a public transport company providing services in one of the Polish cities. Transports are carried out by the company on 67 different types of communication lines, the total length of which is approx. 960 km. The lines are served at transport peaks by 263 buses with different technical and operational characteristics. The communication company has a well-developed technical and social infrastructure, which ensures an appropriate standard of technical efficiency and cleanliness of the means of transport. In the current organizational layout, the communication enterprise consists of two Transport Units, located in various districts of the city.

The conducted analyzes show that both the values of punctuality and timeliness indicators as well as reliability functions are diversified in a transport enterprise depending on the analyzed Transport Department. The course of volatility, punctuality and punctuality indicators for 2015 is shown in Fig. 1.

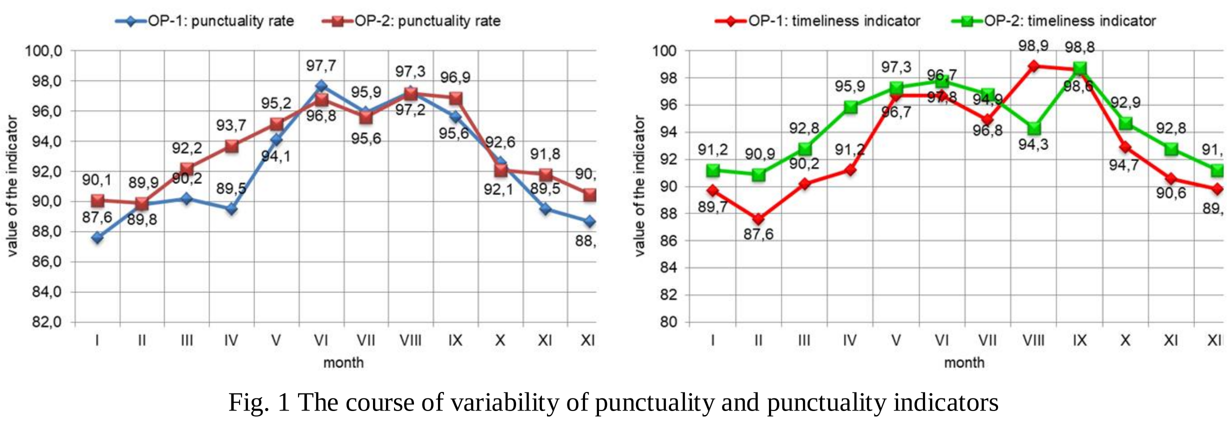

Fig. 1 The course of variability of punctuality and punctuality indicators

The highest punctuality rate was obtained in OP-2 (93.5%) and timeliness in OP-1 (93.2%). The average value for a communication company punctuality indicator is 92.9, while the forward rate indicator is 92.6%.

The lowest values of both punctuality and punctuality indicators were observed in Transport Departments in

autumn and winter periods, the highest for spring and summer months. There are also differences in the value of the reliability function for individual Transport Units. The average value for OP-1 is 0.79, while for OP-2 it is 0.80. The course of variability and values of the reliability function for 2015 are shown in Fig. 2. Both OP-1 and OP-2 ratios are differentiated, the minimum value of the indicator for OP-1 is 0.7 (March) and the maximum value 0.87 (August). The average value for OP-1 in 2015 was 0.79. The minimum value, the index for OP-2 is 0.74 (November), while the maximum 0.82 (June), the average value for OP-2 in 2015 was 0.80.

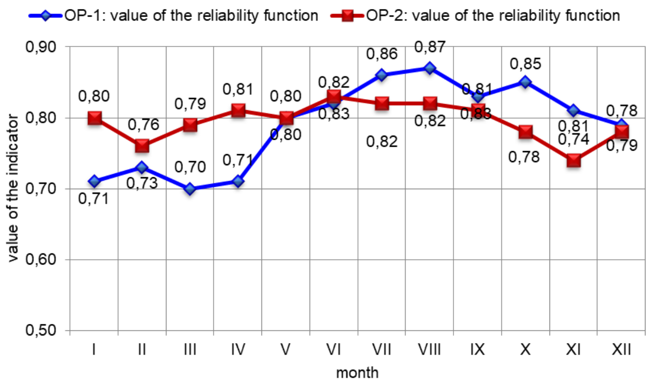

Fig. 2 The course of variability of the reliability function values

The diversification of the value of the reliability function for the most part results from the age of the rolling stock to a lesser extent from the collision situations on the roads. The average age of rolling stock in a transport company is 9.8 years.

The company activities should aim at achieving the goal of reducing the average age of the rolling stock to about 7 years and running within 700,000 - 1,000,000 km. To achieve it, it is necessary to carry out planned purchases of rolling stock and withdrawal of older vehicles and their cassation or sale.

5. Conclusions

Vehicle fleet management in a transport enterprise is a complex decision-making process, especially when the company has many means of transport with different technical and operational characteristics. Ensuring high quality transport services requires decision-makers to respond to various random situations that occur both at the stage of preparing transport means for carrying out transport tasks and during their implementation. It requires having an appropriate reserve of means of transport that ensures the continuity of transport tasks. However, it should be remembered that having surplus means of transport involves additional costs for the enterprise. Thus, the problem of determining the rolling stock reserve in a communication company is important only from a scientific point of view, but also from the operational point of view of communication enterprises.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Vibration Analysis of the Turbocharger considering Low Frequency Excitations

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Abstract

The paper presents an advanced approach to address vibrations and noise of turbocharger with a focus on low-frequency excitations. The proposed approach uses complex computational models called virtual prototypes that allow simulation of significant structural-fluid processes in turbochargers. A virtual turbocharger is the basic module of the proposed approach. This computational model is assembled by the help of a commercial multibody software and it incorporates the specialized features proposed by the authors of the article. The approach is suitable for analysing vibrations and noise already in the development phase of the new turbocharger before a physical existence of turbocharger prototypes. The advanced approach is validated on a turbocharger of a tractor diesel engine.
KEY WORDS: *turbocharger, cranktrain, vibration, multibody, FEM*

1. Introduction

The mobility of people and the transport of goods are the basic needs of modern society. Any approach to meeting these needs must fulfill the criteria of safety, energy efficiency and long-term sustainability and in addition the customer requirements have to be considered. Fulfilling these criteria always influences the powertrain as a key element of all means of transport.

Vibration and noise caused by transport, respectively by means of transport represent negative effects on the environment and cannot be suppressed in principle. Transport noise is one of the most general environmental issue in the European Union (EU) and elsewhere on Earth. Approximately 210 million people, more than 44% of the EU population, are regularly under the influence of traffic noise above 55 dB (L_{p_avg} = 55 dB (A)) [1], a critical level considered by the World Health Organization (WHO) health [1]. People who are negatively affected by traffic noise may increase their levels of stress hormones (increasing their blood pressure) or increase other risk factors that lead to illness and eventually death. It is estimated that fifty thousand deaths and a quarter of a million cases of cardiovascular disease are caused by traffic noise [1]. From the point of view of the environmental burden of health, traffic noise according to the WHO is the second most important in emissions production [1]. Traffic noise therefore reduces the quality of life of hundreds of millions of EU citizens, is the main cause of harassment of urban populations and one of the most common causes of complaints to political leaders. The direct consequence is the creation and tightening of vibration and noise legislation, for example the emission limits for motor vehicles [2], which subsequently significantly affect the research and development of vehicles and powertrains.

Seen from the other side, the sound quality and the noise and vibration problems of the means of transport have become very important for their manufacturers and especially for the manufacturers of cars and trucks. The vibration and noise level of cars and trucks is interpreted as one of the most important factors influencing the perception of product quality and is therefore important for gaining market advantage.

Vibration and noise caused by motor vehicles come from many sources, some of which can be regarded as significant and some don’t cause a serious problem. Also, the issue of dealing with vibration and noise issues involves different approaches. One of these approaches is the computational modeling of machine vibrations using so-called virtual prototypes of these machines. These computational models are designed to address physical processes in the time domain most frequently using commercial multibody systems (MBS).

The powertrain containing the combustion engine is the dominant source of vibration and noise of vehicles. Fig. 1 presents the typical main sources of vibration and noise in the vehicle considering the frequency of the event. The vibration and acoustic performance of the powertrains is mainly influenced by the working cycle running in the combustion chamber, the unbalanced masses of the parts and often also by the torsion or bending vibrations of the cranktrain. Approaches for solving vibration of cranktrain in MBS presents, for example, Drapal at al. [3, 4]. Other subsystems also contribute to the overall vibration level, but their main impact is primarily on acoustic performance of the powertrain. Individual approaches focus on solving the problem of gearboxes [5] and other subsystems. Individual subsystems cannot often be solved separately because they interact. An example of this is the torsional vibrations of the cranktrain and the valvetrain and their interaction over the gearwheels of a six-cylinder engine that have to be solved using more complex virtual prototypes. For example, Novotny [6] suggests such a calculation model.

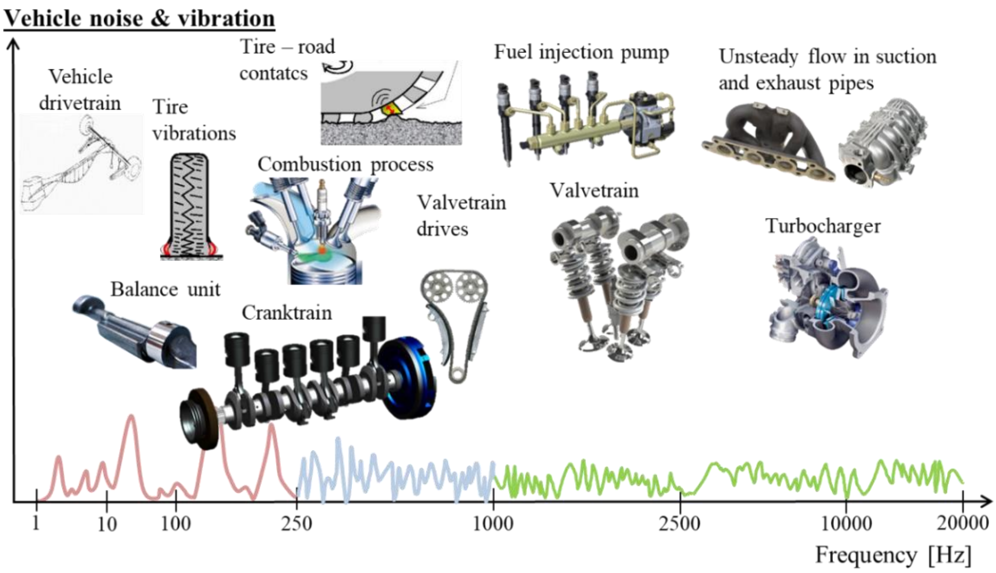

Fig. 1 The main sources of vibration and noise in the vehicle vs. frequency of the event

The combustion engine (ICE) was always the dominant source of noise and vibration, and the turbocharger itself often remained acoustically hidden. At present, acoustic optimization of ICE has progressed and acoustics of turbochargers are becoming more important. In the past, acoustic analysis and subsequent structural design modifications to improve the acoustic performance of the turbocharger were based solely on empirical models. However, for more detailed solutions to these problems, it is necessary to develop more efficient computational and experimental approaches.

There are typical vibration sources with low frequencies in turbochargers. Cranktrain induced vibrations, oil whirling of oil film bearings or unbalance induced vibrations are typical representants of vibration sources. These vibration sources are often rated very negatively and pose a significant problem for vehicle users because the induced vibrations and turbocharger noise excites the surrounding components and are further transmitted to the cabin and vehicle environment.

There are also other typical noises for turbochargers, Nguyen-Schäfer [7] classifies high-order harmonic noise or wear noise for turbochargers with rolling bearings or pulsation whistle, rotational noise, growling noise and whining noise connected to impellers aeroacoustics. Such a noise phenomenon requires different approaches from MBS strategy, some solution approach examples presents Nguyen-Schäfer [7].

2. Aim of the Work

Advanced simulation strategy covering engine excited vibrations and vibrations caused by oil whirling of oil film bearings or rotor unbalance is the main aim of the work.

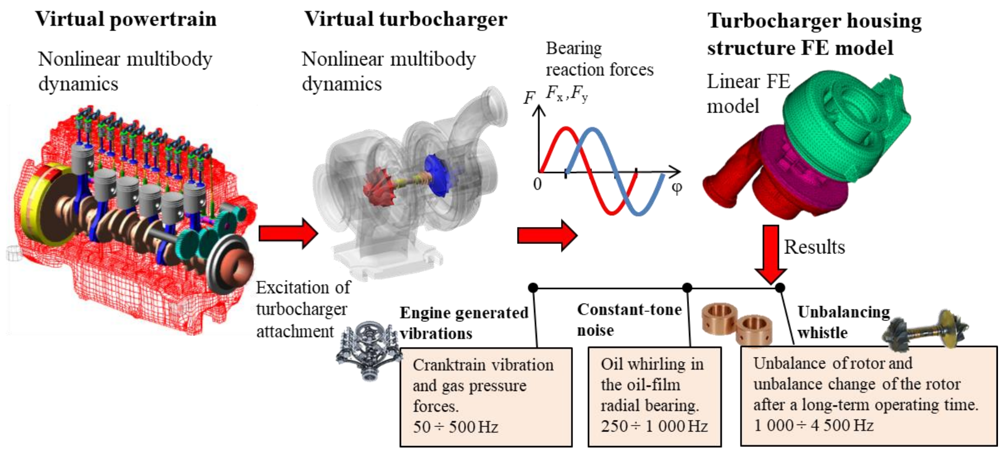

Fig. 2 Main computational models of the advance approach for a solution of turbocharger low frequency vibrations

The proposed approach has to analyse influences of turbocharger design parameters on acoustic performance by means of a fluid-structure computational models based on Computer Aided Engineering (CAE) tools. The solution strategy is graphically presented in Fig. 2.

The basic requirements for the simulation strategy can be defined as:

- Efficiency – solution time efficient and numerically stable model using the principles of multibody

dynamics for transient simulations.

- Modularity – the possibility of being included in larger models represented by the entire powertrain model.
- Scalability – the possibility of model outputs being included into Finite Element (FE) or acoustic software.

3. Modelling of Powertrain Dynamics

The solution of powertrain vibrations requires complex computational models including all significant subsystems. The powertrain model often includes cranktrain, gear train, balancing unit, valvetrain and timing drive models as main modules. This relative complicated powertrain model is solved in the time domain and represents a so-called virtual powertrain. The powertrain computational modelling using virtual prototypes presents Novotny in his inaugural dissertation [8]. Using MBS approach, it is possible to investigate influences of subsystem interactions. The virtual powertrain is prepared as well as numerically solved in commercial MBS ADAMS. ADAMS is a general code for simulation of rigid and flexible body interactions and enables effective integration of user-defined sub-models to be made directly using ADAMS commands or user-written subroutines. An example of a model of the in-line spark-ignition engine of a passenger car is presented in Fig. 3.

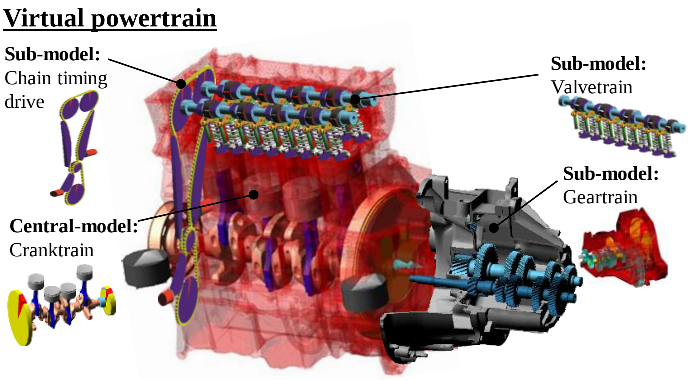

Fig. 3 Virtual powertrain as computational model assembled in MBS

The powertrain model consists of rigid model bodies, linearly elastic model bodies based on FE modelling principles and interaction models (forces and constrains) between them. There are some components modelled by rigid body models, in this case the deformations are not considered. The piston assembly, connecting rod assembly, valvetrain components, gearbox components or flywheel are examples of rigid body models to be used. The linearly elastic models of deformable powertrain components are modelled by FE models modally reduced by Craig-Bampton method as presents Novotny [8]. These are the crankshaft and the engine block. Some cranktrain components having indispensable influence on cranktrain vibrations are modelled by their inertia characteristics or power requirements. The hydrodynamics bearing interaction between the rotating components (e.g. crankshaft or camshaft) and the engine block and gearbox structure is realized by a non-linear bearing model. This bearing model uses pre-calculated force databases obtained when solving separate hydrodynamic problem [8]. The powertrain model is excited by external forces calculated from time dependent cylinder pressure. The cylinder pressure is obtained by high-pressure measurement on real powertrains.

4. Modelling of Turbocharger Rotor Dynamics

Modeling of the turbocharger rotor movement including the bearing system is realized through a computational model called a virtual turbocharger. The virtual turbocharger is a model proposed to simulate processes involving structural and fluid dynamics. In principle, this model is like the model of the powertrain and it is assembled and numerically solved in commercial MBS ADAMS. The virtual turbocharger uses rigid and flexible models of individual components to adequately describe the behavior of the rotor in the corresponding operating regimes.

The model includes a rotor shaft modeled using reduced FE models, as shown, for example, by Knoll et al. [9]. The shaft model is complemented by compressor and turbine wheels. Impeller wheels are modeled as rigid bodies whose deformation is not important to the solution.

The rotor is mounted in a bearing system. The bearing system includes a pair of hydrodynamic radial floating ring bearings and a thrust bearing. The radial bearing consists of three parts – a housing, a shaft and a floating ring. These parts are separated by two oil films – an inner and outer oil films. The thrust bearing utilizes suitably shaped functional surfaces (segments) for axial force transmission. The calculation models of these bearings are the main sub-models of the virtual turbocharger.

The computational model of hydrodynamic bearings in MBS is represented by a set of pre-calculated reaction forces, torques and mass flow rates. These bearing properties are obtained by the numerical solution of the Reynolds equation. The Reynolds equation is based on the modified Navier-Stokes equation and the continuity equation

transformed for cylindrical shapes of the bearing oil gap. The full form of the equation has been simplified and modified based on Novotny et al. [10]. The solution to Reynolds equation is separated from the solution of turbocharger structural problem.

The basic excitation of the model is realized through the unbalanced mass of the rotor, in the model modeled by the mass point. Specific excitation results from the principle of hydrodynamic bearings – self-excitation caused by oil whirl. The last source of excitation comes from the powertrain. The excitation of the model is accomplished through a defined movement of the turbocharger base at the place of its mounting on the ICE and from the action of the gases on the compressor wheels. This excitation is determined by a separate solution of the powertrain model and using technical experiments. The virtual turbocharger assembled in the MBS, including a description of the individual sub-models, boundary conditions and excitation sources, is shown in Fig. 4.

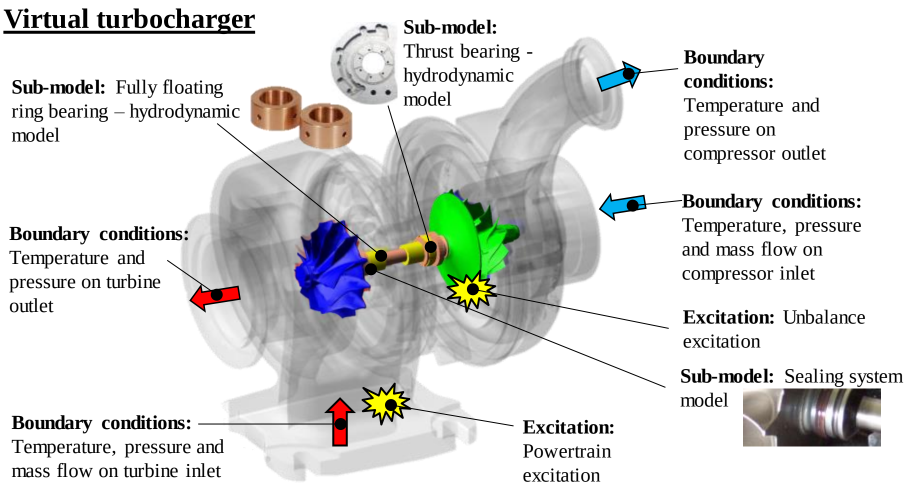

Fig. 4 Virtual turbocharger as multibody model including description of sub-models, boundary conditions and excitations

5. Analysis of Vibrations

The powertrains based on ICE generates structural vibrations and noise in wide ranges. Focusing on turbocharger, however, the cranktrain generated vibrations present a dominant source of excitation. This low frequency excitation has a major impact on turbocharger vibrations at high amplitudes. The other powertrain subsystems only participate in total vibrational level, but they do not usually excite significant amplitudes of turbocharger vibration.

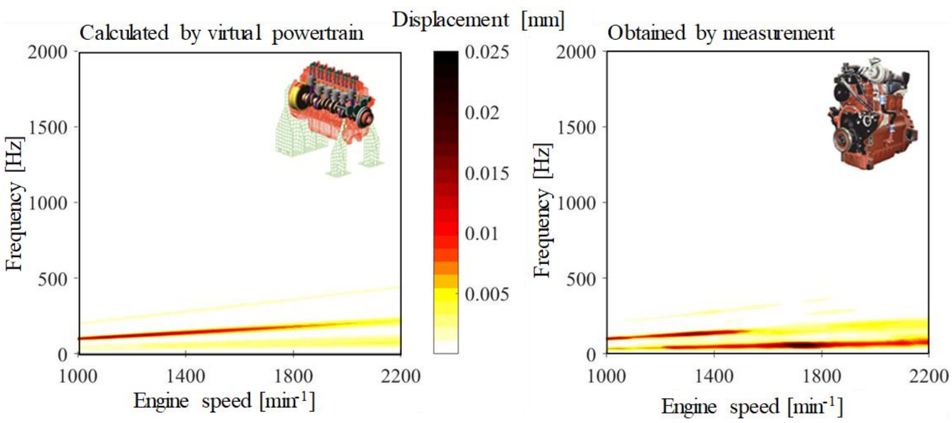

Fig. 5 Frequency analysis of measured and calculated engine block displacements at the turbocharger location

The in-line six-cylinder tractor engine is chosen as an example to demonstrate cranktrain vibration effect on turbocharger. In the case of this engine, the region with the most significant amplitudes of vibration generated is a frequency range between 50 Hz ÷ 350 Hz, as shown in Fig. 5. In the vibration spectrum, an area with an increased vibration level corresponding to the 6th order of torsional vibrations of the cranktrain can be identified. The results also show significant movement of the engine as a whole within its mounting with frequencies up to 150 Hz.

A turbocharger vibration can be generated at many operational states. Typically, run-up simulation is performed by virtual turbocharger. Such a transient state simulation starts from low rotor speed to maximal operational speeds of turbocharger. For the turbocharger of target tractor engine, the rotor speed range starting from 60 000 min^{-1} to 120 000 min^{-1} is selected. The rotor vibration is usually analyzed in frequency domain. A conversion of the time domain signals (vibrations) into the frequency domain can be depicted in a Campbell plot. This type of frequency analysis can find vibration issues connected with specific mechanisms.

There are two vibrational phenomena that are often analyzed more in detail, the description presents for example Pischinger at al. [11] or Nguyen-Schäfer [7]. First phenomena is represented by synchronous vibrations. These synchronous vibrations are mostly caused by the high unbalance of the rotor thru the whole rotor speed range. Results of frequency analysis of calculated compressor nose vibrations presented on Fig. 6 show only low amplitudes of synchronous vibrations on frequency ratio (ratio of excitation frequency to rotor speed frequency) equal 1. Unbalance whistle is a resultant noise of synchronous vibrations and this is one of the most disturbing noise types of turbochargers. The turbocharger rotor has to be high-speed balanced to reduce the unbalance whistle.

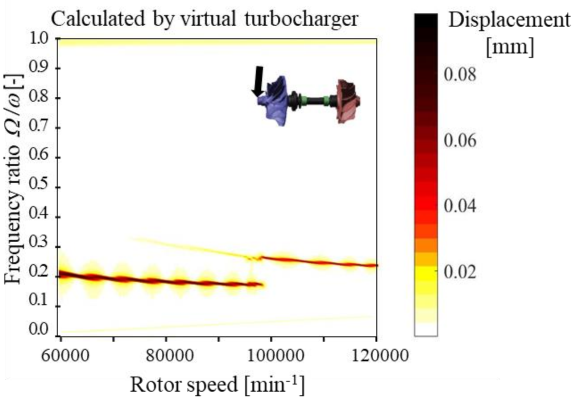

Fig. 6 Frequency analysis of calculated compressor nose vibrations

Second phenomena of rotor vibrations relate to oil film bearings. The rotor vibrations are subsynchronous at frequency less than half of rotor speed frequency. The root cause mechanism is based on oil bearing whirl phenomena, the description of this phenomena presents Hori [12]. Constant-tone noise is the resultant noise type. Oil whirl phenomena is in many cases significant and can cause significant rotor vibrations and noise. There are two typical frequencies in the case of two oil layer bearings, influences of both oil layers can be seen on Fig. 6 with frequency ratio between the ratios 0.2 – 0.3. The outer oil layer mostly generates low frequency noise outside of frequency range sensitive for human.

An analysis of turbocharger housing vibration is next step in proposed advanced approach. FEM harmonic analysis with the commercial software ANSYS is employed to calculated housing responses on harmonic shape excitations. The excitation (bearing reaction forces) is calculated by the virtual turbocharger.

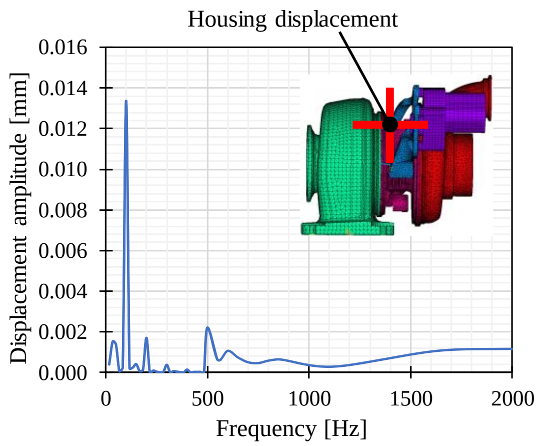

Fig. 7 Turbocharger housing response vs. frequency of excitation

However, the reaction forces obtained by the virtual turbocharger, that is a nonlinear model solving transient state, are not generally of harmonic courses. Therefore, these reaction forces must be analyzed and converted into a frequency domain corresponding to the given turbocharger rotor speed. The resulting harmonic excitation amplitudes are used to excite the FE model of turbocharger housing structure. Fig. 7 presents the result of a harmonic analysis of the turbocharger central housing location in the frequency range up to 2 kHz. The results show that the dominant responses of the structure are primarily due to the ICE generated excitations. Significant responses can also be found in the frequency range corresponding to the rotor speed.

6. Conclusions

The proposed approach is based on a combination of powertrain and rotor dynamics simulations using the virtual powertrain and the virtual turbocharger, both models are assembled and solved in MBS. The MBS solution is followed

by FEM simulations of structural vibrations. This approach allows a fundamental understanding of the mechanisms of turbocharger vibration and noise generation. The advanced approach uses a combination of commercial CAE tools and specialized programs developed by the authors of the article. This interdisciplinary concept is developed to allow effective solutions to the problems arising from the development of a new turbochargers or existing operational and production problems of internal combustion engines with sufficient accuracy. The quality of the calculation models is continuously verified through technical experiments obtained from the complete turbocharged engines. In the future, it is expected to extend the proposed approach to solution of other sources of vibration and noise, particularly the aeroacoustics noise sources.

Acknowledgement

The research leading to these results has received support from the specific university research program of Brno University of Technology, project No. FSI-S-17-4104.

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Proceedings of 22st International Scientific Conference. Transport Means 2018.

Development of Road Safety Status and the Evaluation Criterion Causes of Specific Traffic Accidents

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Abstract

Road transport is due to the operability and the accessibility, as an indispensable part of a comprehensive transport system, one of the most dangerous types of transport. The paper introduction deals with the issue of traffic accidents in Slovakia. Statistics assessment of traffic accidents, in terms of road safety, is one of the important factors. The development of the state of safety on Slovak roads is assessed by the number of traffic accidents becoming on the road over the past period. They are divided into the fatal accidents, accidents with severe injuries, with slight injuries and traffic accidents, only with material damage. Register and statistics on traffic accidents are well-meaning and helps in analysing of causes and consequences of traffic accidents, as well as increasing road safety and preventing the occurrence of traffic accidents. The present paper focuses on the methodology of evaluation of the causes of an accident just when such specific cases. For traffic accidents when one vehicle enter into the opposite direction lane, the criterion for the cause of an accident (for most cases) is the collision place. In most car accidents when a vehicle enters the opposite lane, this happen suddenly, sometimes sliding sideways, and in such cases it is (the collision place) a very good indicator for the causes of traffic accidents. Rarely, however, there are also accidents, where there is not decisive in which lane impact happened. Such traffic accidents, however, occur very rarely and by the experts are often considered for the assessment of the causes of traffic accidents wrong.
KEY WORDS: *traffic accident, the cause of a traffic accident, impact, avoid of traffic accident, expert report*

1. Introduction

Road transport as a phenomenon of the present consists of a large number the successive sub-phenomena constituting the transport process, which interferes almost with all aspects of human life. There are also major problems with road transport related in particular to various complications in traffic situations, not only on motorways and expressways, but also lower class communications. One of the undesirable problems in road transport is traffic accidents, which causes great losses on life, serious and less serious consequences for the health of road users as well as valuable material damage. [1, 2]

Statistical data on the development of traffic accidents by individual criteria have their legitimate meaning, since these data are helpful in analysing the causes and consequences of traffic accidents, in increasing road safety, in the determination of measures to prevent the occurrence of traffic accidents. By analysing traffic accidents, appropriate preventive measures can subsequently be established to reduce traffic accidents, as well as reducing the negative consequences of traffic accidents. [1, 7]

In assessing the causes of a traffic accident a certain criterion value is used, criteria parameter. In the case of a traffic accident type of vehicle – pedestrian and over speeding is one of the criteria determining the cause of a traffic accident, whether or not the vehicle would stop before the crash site from the maximum permitted speed for that section. If the vehicle stopped before the crash site at that speed for that section, then driving speed is an element of the cause of a traffic accident. Criterion parameter for assessing the cause of a traffic accident, including its definition: "The technical cause of a traffic accident is those elements of an accident already, which have arisen in contradiction with the technical interpretation of road traffic rules and either provoked a collision or prevented a traffic accident." Traffic accidents, where it is not critical, in which the lane has collided, occur very rarely. These traffic accidents are often mistaken for the purpose of assessing the cause of a traffic accident, not only by the law enforcement agencies but also by the experts. [3, 5]

2. Development of Traffic Accidents on Place of Slovak Republic in the Period 2007-2017

On the territory of the Slovak Republic (hereinafter referred to as SR) is paying attention to the trend of traffic accidents through statistics on traffic accidents, because it is not essential to monitor only the number of traffic

accidents alone, but also related negative consequences. It is a significant difference if a road user is killed in a traffic accident, if a participant is difficult or easy to hurt, or if the participant is not injured and only material damage has occurred. [1, 8] Development of traffic accidents in the Slovak Republic during the period 2007-2017 is processed through the statistics in Table 1.

Table 1

Breakdown of traffic accidents by number and the consequences of injury in the period 2007-2017 [8]

year	number of traffic accidents	Killing	severe injury	easy injury
2007	61071	627	2036	9274
2008	59008	558	1086	9234
2009	25989	347	1408	7126
2010	21611	345	1207	6943
2011	15001	324	1168	5889
2012	13935	296	1122	5316
2013	13586	223	1086	5225
2014	13307	259	1098	5519
2015	13535	274	1091	5624
2016	13507	242	1057	5884
2017	14013	250	1127	5757

According to the above table, that the development of the number of traffic accidents in the SR during the period 2007 - 2017 has a decreasing trend. The greatest decrease in traffic accidents is recorded until 2014. Compared to 2007, (47 764) less accidents occurred in 2014, which represents a decrease of 78%. With the number of deaths of traffic accidents, as well as the number of traffic accidents resulting in heavy and light injuries it is also possible to notice the apparently decreasing trend. The most traffic accidents involving the death of road users were in 2007, up to 627. On the contrary, at least the traffic accidents involving the death of participants were in 2013, up to 223. This finding reflects 404 traffic accidents with the death of road users less, a drop of 64%. Traffic accidents resulting in severe injuries were the highest in 2007 and at least in 2016. The development of traffic accidents has thus been recorded o 979 less traffic accidents resulting in serious injuries, which is a decrease of 52%. Traffic accidents resulting in minor injuries were the highest in 2007 and at least in 2013. The development of traffic accidents has thus been recorded by 4 049 less traffic accidents resulting in minor injuries, which represents a decrease of 44%. The safety measures have managed to reverse the negative trend of the development of traffic accidents from previous years, when the number of traffic accidents and the number of deaths, difficult and easily injured road users were much higher. Through these data, that 2007 was the most critical from the point of view of the development of the traffic situation in the SR. This year, the most traffic accidents with the greatest number of road deaths were killed, and also the greatest number of heavy and light injuries to road users were recorded in traffic accidents.

According to available statistics, it can be mentioned and other attractions related to the occurrence of traffic accidents, as well as road users. In the context of traffic accidents occurring in 2017 more road users were killed during the day than at night, especially on the roads of I, II. and III. classes. In terms of sex, 186 men and 64 women were killed, of which 112 men and 18 women were killed by their own fault. Taking into account the seasons, the deadliest accidents occurred in autumn, between October and December (long nights, short days) and at least in the spring season, from April to June (longer days and shorter nights). The most common causes of accidents occurring in 2017 violations of the driver's duties, disproportionate speed, non-compliance with distance between vehicles, incorrect cross-country and ride lanes, violation of the obligation of road users, incorrect prevention and deviation, incorrect behaviour on railway crossings, etc. [2, 8].

3. Example of Traffic Accident No. 1

In most cases of traffic accidents, when the vehicle goes into the opposite lane, it will suddenly pass sometimes in side skirt) with a very good indicator of the cause of a traffic accident is the criterion of precipitation (Fig. 1).

An example of the traffic accident shown in Fig. 1 it can be noticed when the red vehicle made a lateral skid passage to the counter-lane. It is clear, that the cause of a traffic accident is the wrong driving technique Red Vehicle Driver. he courses of a traffic accident (when one of the vehicles crosses the opposite lane and the vehicle collides) is generally such that, that the crossing is done suddenly and the driver is moving the technical possibility of a traffic accident is no longer avoided in its lane. In determining the cause of a traffic accident, which one of the drivers passed into the opposite lane. This is a certain simplification, when the definition of the cause of a traffic accident is not directly used as a procedure for determining the cause of a traffic accident. Despite the use of a simplified criterion "Which of the drivers has gone into the opposite direction" in most cases leads to the correct determination of the cause of the traffic accident. However, this simplified criterion cannot always be used, since in some cases it may apply this

criterion lead to an incorrect determination of the cause of a traffic accident. [3, 5]

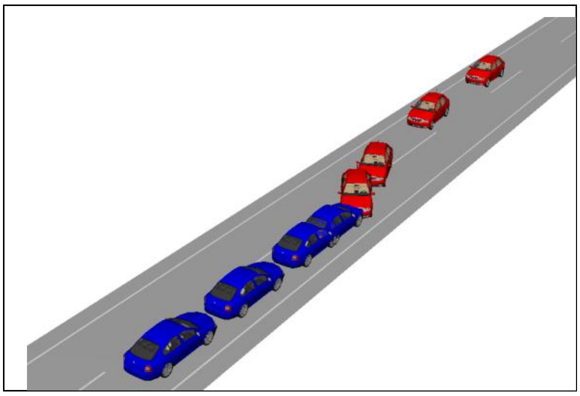


Fig. 1 Example of traffic accident No. 1 [10]

4. Example of Traffic Accident No. 2

An example of a traffic accident, when it is not essential to determine the cause of a traffic accident, in which the lane has collided, is shown in Fig. Second in the direct section of the roadway under unobstructed visibility conditions, a wagon carrying an oversize cargo stood. For the defect, the wagon had to stop, while the cargo partially affected the dimensions into the opposite lane. Vehicles moving against the standing ride should have a sufficiently wide ride, and therefore a collision was not a consequence of this fact. The driver of the red anti-traffic vehicle was on his way into a side skirt and in a side skid he hit the standing ride (Fig. 2).

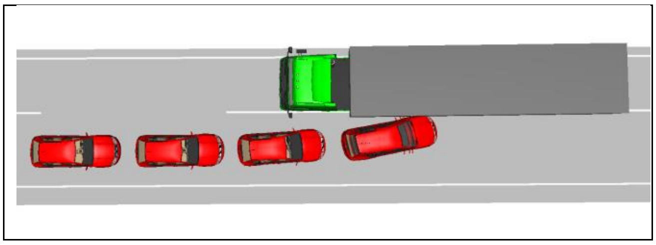


Fig. 2 Example of traffic accident no. 2 [10]

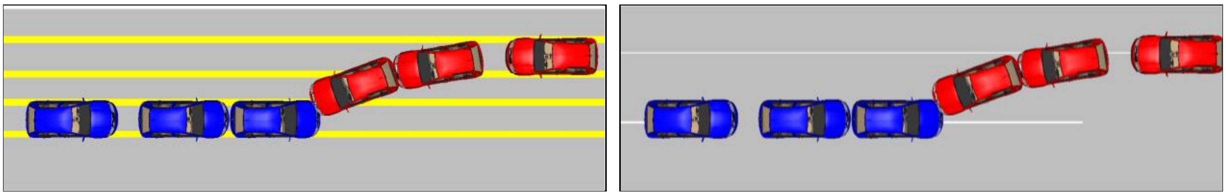
In the example of a traffic accident the technical cause of a traffic accident was the wrong technique of driving a red vehicle driver. The driver led the vehicle in such a way, that there was a lateral skid and an impact on the standing ride. The collision occurred in the red lane. Nevertheless, that the carriage load partially engages in the opposite lane, is not the cause of a traffic accident. In this example, it is not right to use the cause of a traffic accident as a criterion place of the collision (who hit the moment of the collision to the counter). Partial load interference in the upstream lane did not cause a collision, and therefore cannot be the cause of a traffic accident. The collision was due to the loss of directional stability of the red vehicle. It is this element of an accident already forming the cause of a traffic accident [3, 5].

5. Example of Traffic Accident No. 3

An example of another traffic accident, when it is not (to determine the cause of a traffic accident) in which the lane has collided, is shown in the following figures. A traffic accident occurred in a section, where they were marked on the road (horizontal road marking) two lanes and one extreme. Before the traffic accident, it was snowing and the horizontal traffic sign was not visible (as it was under a continuous layer of snow). Vehicles at the scene of a traffic accident took the tracks in a snow layer, which are in Fig. 3, a) marked with yellow color. The drivers of the red and blue vehicles moved in such a way, that the wheels were copying the excavated tracks. While riding, the Red Vehicle driver came into a side skirt and hit a blue vehicle (Fig. 3, a).

The red vehicle left behind its tracks in the snow, which photographed the blue vehicle driver. While the police arrived at the scene of a traffic accident (with a delay of more than 1 hour), the snow melted down the road. According to the final positions, that in relation to the lanes, who were recognizable by the police when viewing a traffic accident site, there was a collision in the lane of the red vehicle. [5]

In the case of this traffic accident, the technical cause of a traffic accident was an incorrect technique of driving a red car driver. The driver led the vehicle in such a way, that lateral skidding and impact occurred into the blue vehicle in the red lane. Before the accident occurred, the blue vehicle driver moved, insofar as it relates to horizontal road signs into the opposite lane, but this cannot be considered for element accidentally already. During accidental drivers, they were unable to see horizontal traffic signs and thus did not have the ability to see the marked area of the right and left lane, respectively shoulder [3, 5].



a b

Fig. 3 Example of traffic accident no. 3 [10]

The guides moved along the exhausted tracks, in which there was direct contact of the road with the tire. Driving these guides gave higher directional stability while driving their vehicle, thereby reducing the possibility of side skidding. The transverse positioning of the track allowed for safe assembly of the vehicles. Driving cars did not have a collision situation, the driver of the blue vehicle was partially interfering with the technique beyond the centreline, but the line could not be seen by the driver. If the transverse position of the vehicles is tight no collision occurred before the side skirt (red vehicle) then this accident cannot be the cause of a traffic accident. In the example in question, therefore, it is not used properly again as the criterion of the cause of a traffic accident instead of the precipitation, respectively. who hit the moment of the collision in the counter-lane [3, 5]?

6. Example of Traffic Accident No. 4

Traffic accident no. 4 is another example of a traffic accident, when it is not (to determine the cause of a traffic accident) in which the lane has collided. A traffic accident occurred in a section with marked lanes. The red vehicle got into the side skirt and traversed the opposite lane where it caught the rear of the blue vehicle (Fig. 4).

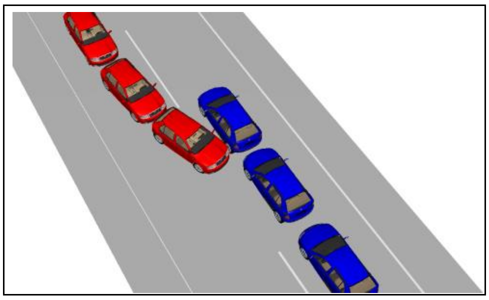


Fig. 4 Example of traffic accident no. 4 [10]

In the present case the wrong driving technique of the Red Vehicle driver was the cause of a traffic accident, namely its passage to the opposite lane. It was an accidental element of the accident, which caused a collision. The blue vehicle driver did not move at the right edge of the road, which, in connection with the provision of Act no. 8/2009 Coll. Road traffic is considered incorrect. Under the law, the driver should move as follows: "The driver is required to ride on the right or on the right side of the road or lane on the road or in the lane; this does not apply when circumventing, preventing, rotating or turning." If it would move at the right edge of the roadway, then there would be no encounter of vehicles and a subsequent traffic accident [3, 5, 9].

Nevertheless (according to the authors of this article) wrong driving technique of a blue vehicle driver is not in a causal connection with the emergence of an accidental already. If the accident element did not already cause a collision, then the issue of preventing a traffic accident must be addressed by the driver of the blue vehicle in relation to the moment, when this driver could detect a collision situation. t this decisive moment the blue vehicle driver could not to prevent accidents, and therefore the wrong driving technique of a blue driver is not an element of the cause of a traffic accident, because it does not meet the criteria for defining the cause of a traffic accident [3, 5].

7. Example of Traffic Accident No. 5

In the example of traffic accident No. 5 occurred to a traffic accident under conditions of unobstructed visibility, outside the village. Driver of Skoda Octavia when driving at a speed of 80 km / h during the trip he slept, and thus a partial lateral shear occurred and then left the road to the left. There was a collision when the vehicle oved in the area to the pedestrian, who moved in the direction of his walk along the right side. (Fig. 5).

If we evaluate the wrong elements of driver and pedestrian driving techniques to assess the technical cause, we would come to these conclusions. Driver driving technique was wrong (the driver did not direct the vehicle and left the carriage ride), and the way pedestrian communication was used was not correct (the pedestrian moved on the wrong side of the road). It is therefore clear that if the driver would correctly guide the vehicle, the accident would not occur. In the same way even if the pedestrian is on the left side, the accident would not occur. It could be shown, however, that the wrong pedestrian movement on the wrong side was an accidental element already, which fulfils the conditions for defining the cause of a traffic accident, because it was created in violation of road traffic rules and prevented the pedestrian from avoiding a traffic accident [3, 5].

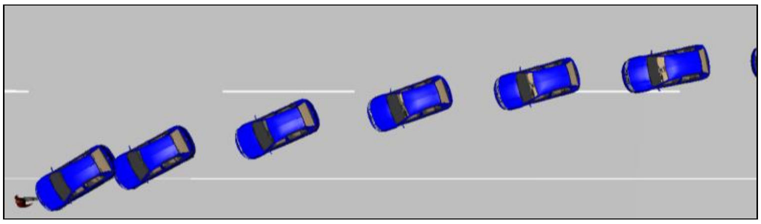


Fig. 5 Example of traffic accident no. 5 [10]

To determine the cause of a traffic accident, this example is unambiguous, the cause of a traffic accident was only the wrong technique of driving a driver. The walker did not cause a collision. When assessing the possibilities of preventing a pedestrian traffic accident (in relation to determining the cause of a traffic accident), it is important to evaluate the moment, when the pedestrian was able to detect a collision situation and in relation to this point, the pedestrian should be able to assess the possibility of a traffic accident at that time. The evaluation shows that, at the moment, when the pedestrian could detect a collision situation no longer had the technical possibility of preventing a traffic accident, and therefore its incorrect communication movement does not meet the terms of the definition causes of a traffic accident [3, 4, 5].

8. Discussion on Specific Traffic Accidents

We have presented examples of traffic accidents in individual parts of the paper, when a simplified criterion for determining the cause of a traffic accident (determining where the lane has collided) may lead to an incorrect determination of the cause of a traffic accident. When is the simplified criterion of the cause of a traffic accident? (where the collision occurred and who crossed the opposite lane) to use correctly and when not?

To correctly evaluate the cause of a traffic accident it is important to apply the definition of the cause of a traffic accident, (in the case of a traffic accident when one of the vehicles passes into the opposite lane): "The technical cause of a traffic accident is those elements of an accidental accident that have been created in contravention of the technical interpretation of road traffic rules and have either caused a collision or prevented the occurrence of a traffic accident"

This procedure requires the evaluation of each driver his technique of driving. In the event of a wrong driving technique, it is necessary to assess it whether the incorrect element caused a collision, or whether this feature prevents a traffic accident from being avoided. It is also important to correctly evaluate the moment in relation to which we deal the possibility of avoiding collisions by the driver, which by its incorrect driving technique does not cause a collision. The decisive moment for the driver is an instant, when it has the opportunity to detect a collision situation [3, 5].

If the driving technique used by the driver was correct or, that his technician was wrong (contrary to road traffic rules), but did not trigger a collision nor did it prevent the driver from avoiding a traffic accident, then the driving technique of the driver is not an element of the technical cause of a traffic accident. If the driving technique of the driver was incorrect (in violation of road traffic rules) and at the same time either provoked a collision or prevented it prevent the driver from causing a traffic accident, then the driving technique of the driver is an element of the technical cause of a traffic accident [3, 5].

In the article in question, the term "usual" driving technique has been used several times. By this term, the authors also refer to the technique of driving drivers, which is wrong with the interpretation of the Road Traffic Act, but is generally "tolerated". However, it is always a technique of driving, which does not cause a collision situation. This is, for example, the driving technique, which does not move constantly and it lasted at the right edge of its lane. The reason for the technique of driving is, the driver perceives the direction (curvature) of the roadway, which driver is driving the vehicle by steering the steering wheel (constantly correcting the direction of movement of the vehicle to copy the curvature of the roadway). The directional guidance of the vehicle is a continuous, continuous process, during which the driver corrects his driving direction, responding to a particular traffic situation, as well as on the given road curve [3, 4, 5].

The actual driving of the vehicle within its lane is also influenced by the fact that, that the driver does not pay attention only to the directional guidance of the vehicle while driving, but evaluates the whole complex of events, situations and circumstances. It must evaluate the movement of other road users (pedestrians, bicyclists, vehicles), traffic signs, light signalling, as well as data, which are displayed on the dashboard or evaluate the situation in the rear-view mirror. During this evaluation the driver is not primarily focused on the directional guidance of the vehicle, even though this fact is perceived secondary. Given the overall traffic conditions take the driver in his lane (whether intentionally or unintentionally) smoothly and slightly transversely moves to the right, or left, so it does not move constantly to the right edge of its lane [3, 4, 5].

This fact is generally known and is "Tolerated" as "normal" driving, when road users are not sanctioned for, that they did not move constantly to the right edge of their lane. Another example "Normal" driving techniques (which are tolerated, that he is wrong about the interpretation of the Road Traffic Act), is a motorway ride on a wet road surface, in the dark, when driving in a row with sufficient longitudinal spacing (over 110 m). In such a drive, the guides generally move with dipped-beam headlights on (to avoid dazzling the vehicle's vehicle ahead through the rear-view mirrors, or glare of anti-conductor drivers). Driving with dimming lights on a wet road is a viewing distance typically 50 to 60 m.

Speed corresponding to this distance is 67 to 76 km / h (for a reaction time of 1.0 s, braking action time of 0.2 sand deceleration of the vehicle during intense braking 6 m / s2) [5, 6].

In road traffic, however, it is common that under these conditions the drivers are moving at speeds above 75 km / h - at a faster speed, such as the speed appropriate to the view under the given conditions. Under these conditions, however, the technique of driving a driver is moving with a speed exceeding 75 km / h, contrary to the provisions of § 16, 1 of the Act No. 8/2009 of Collection of laws – The Road Traffic Act, which states, inter alia: "The driver must drive only at a reasonable speed to be able to stop the vehicle at a distance to which he has a view." Again, such a technique is generally "tolerated" and the drivers are not said technique of driving the sanctioned [5, 6, 9].

9. Conclusion

Road transport brings, in addition to a number of advantages, a large increase in the load on the road network and increasingly demanding transport and security requirements, which is a transport, economic and socio-economic problem. Traffic accidents are associated with great material damage, with permanent consequences for the health of road users, as well as with irreplaceable losses on human life. Road safety and its individual agents, which affect it is paying extra attention not only on place of Slovak Republic, but also in the countries of the European Union or in countries around the world [1, 7].

Based on the processing of available statistical data on the development of traffic accidents in the Slovak Republic during the period years 2007 - 2017 can be seen, that the number of road accidents, the number of road users killed, as well as the number of heavy-traffic accidents even slight injuries have a decreasing, later stable trend. The most significant decline was recorded in the number of traffic accidents, up to 78%, the number of deaths dropped by 64%, the number of participants with severe injuries was down 52% and the number of participants with light injuries decreased by 44%. In terms of the development of traffic accidents, 2007 was the most critical year, as this year saw the greatest number of road accidents, most road users were killed, and also hardly i easily injured.

In the present paper, there were 5 examples of traffic accidents with a description of the occurrence of a traffic accident, the display of a traffic accident, by explaining the cause of a traffic accident, which has been added as appropriate comments by authors. To correctly evaluate the causes of a traffic accident it is important to apply the definition of the cause of a traffic accident: "The technical cause of a traffic accident is those elements of an accident already, which have arisen in contradiction with the technical interpretation of road traffic rules and either provoked a collision or prevented a traffic accident."

It is also important for each driver to evaluate his driving technique. If the technique of driving was incorrect, it is necessary to assess whether the wrong element caused a collision, whether or not to prevent a traffic accident. It is also necessary to correctly evaluate the moment in the relationship to which we address the possibility of avoiding collisions by the driver, which by its incorrect driving technique does not cause a collision. If the driving technique of the driver was correct [3, 5].

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Using Risk Analysis to Explain Failures on the Example of a Loading Point for Road Tankers

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Abstract

The article presents the use of risk analysis to explain the causes of real technological failures on the loading of organic liquid into road tankers. The first part of the article presents description and characteristics of the warehouse base and the loading point. In the second part, the authors focused on performing a risk analysis to identify the causes of emergency events. In the third part, solutions optimizing the process are recommended in order to avoid potential failures in the future.
KEY WORDS: *transportation of dangerous goods, risk analysis*

1. Introduction

In the literature, we can often find the opinion that one of the most dangerous operations in the chemical and refinery industry are operations of storing, filling and emptying either railway or road tankers or individual packages of hazardous materials (e.g. IBCs).

In the methodology of research on process safety one of the key roles is risk analysis. It is an element of support for activities at each stage of the life cycle of a given technological installation. The result of risk analysis is to determine all the factors that create the possibility of dangerous situations for the object [1]. The article uses error tree methods and events to determine the causes of emergency situations for the storage node under consideration.

2. Characteristics of the Storage Node and Security Layers

2.1. Storage Node

The storage system under consideration consists of: three non-pressure tanks for storing liquids (flammable, poisonous, organic) - each with a volume of 50 m^3, pouring and draining devices[1], a transfer pump, piping with required fittings and control and measurement devices.

Tanks: made of chemical resistant steel, equipped with a line of pressure equalization completed by a flame arrestor, a transmission line of the finished product and a drain line. The liquid from the tanks can be transferred between them or sent for loading. Each tank also has level, pressure and temperature transmitters - which are sent to the digital computer support system (DCS).

Another of the key devices of the considered system is the pump. It is a centrifugal pump with oil seal. The whole device due to the type of medium transmitted is made in the Ex classification. The fittings are made of chemically resistant steel, seam pipes with flange connections. All valves present on the node are manual ball valves. The exact diagram is presented in Fig. 1.

The operations carried out on the node are:

a) pumping liquid from one container to another;

b) stabilization of the product (alignment of the organic and inorganic phase is carried out so-called mixing process;

c) loading the finished product for export.

2.2. Layers of Security

Due to the high risk associated with the occurrence of failures at the loading point as well as the storage base, a number of solutions have been applied to increase the condition and level of security.

The technologies and solutions used are aimed at constant process control and early detection of deviations from the norms adopted in normal operation, and after their detection, implementation of appropriate rescue procedures. Additional protection in this installation are systems designed to protect and limit the negative consequences of emergency events.

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[1] More about filling and emptying equipment online:
http://prawo.sejm.gov.pl/isap.nsf/download.xsp/WDU20120001468/O/D20121468.pdf

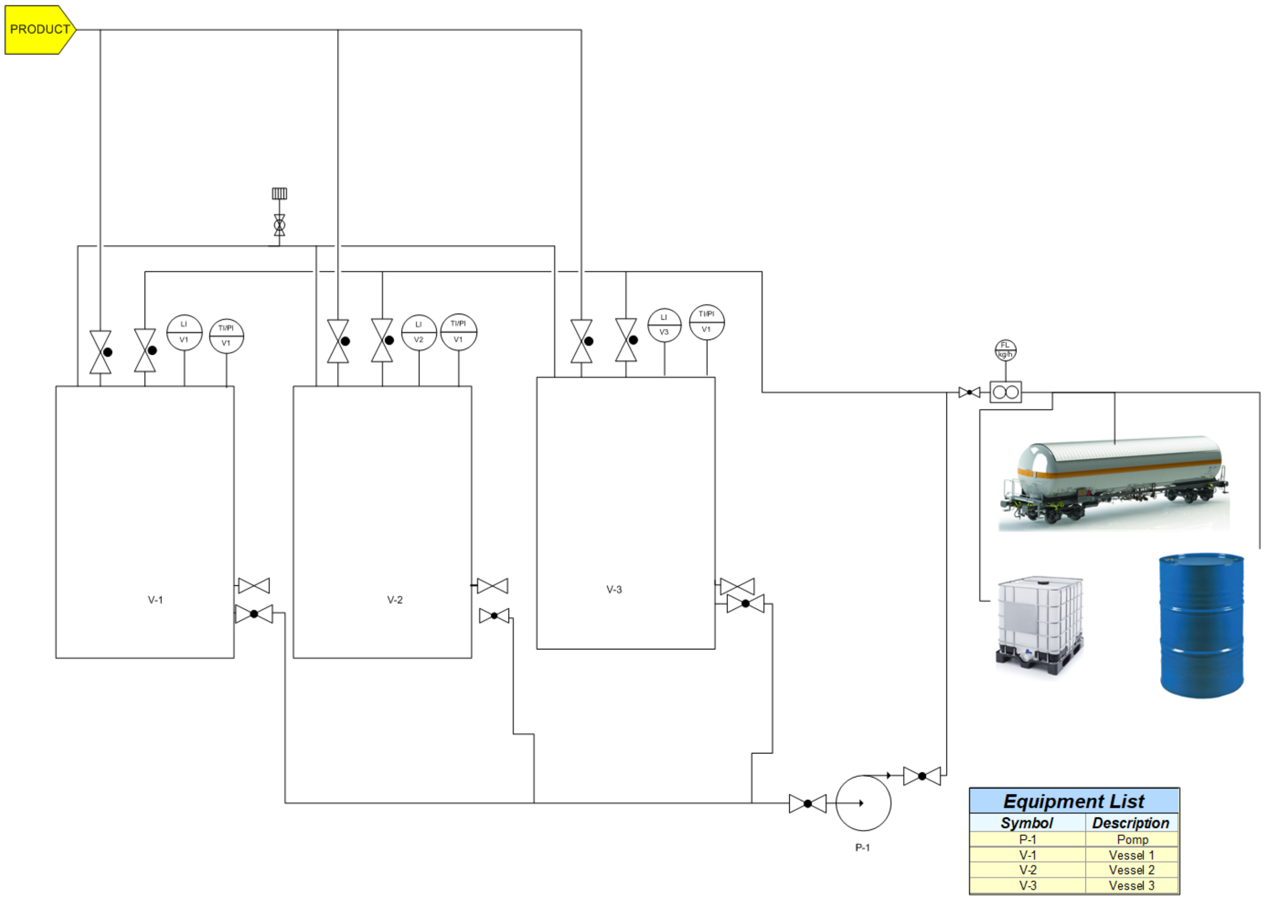

Fig. 1 Considered technological node

Table 1

Layers of security

Layer	Element of the layer	Description of the action
Prevention	Sound and light signaling of exceeding the established technological parameters	Issuing warning sounds for DCS operators
	Message about finished loading	Protection against overloading of the tanker
	Position, technological, safety and fire instructions	Standards for normal operation and emergency conditions
	OHS and UDT trainings [2]	Normalized rules of conduct in the conditions of normal work and emergency conditions
	UDT check tests	Checking the technical condition
	TDT[3] check tests	Checking the technical condition
Protection	Concrete tray on the railroad tanker parking place during loading	Protection against outflow outside the loading point
	UPS power supply [4]	Protection against loss of electricity
	Wedges / skids for loaded tanks	Preventing shifting of the tanker during loading
	Sealing of cargo arm connections	Prevention of emission to the environment in case of leaks
	Manual valve on the pipeline	Prevention of emission to the environment in case of leaks
	Water curtain	Limitation of evaporation in case of emissions
	Emergency shutdown of the installation	Reduction of the effects of failure
Counteraction	Counteraction Hydrants network	Providing water for emergency services
	Handheld firefighting equipment	Liquidation of ignition sources, extinguishing small fires
	ROP[5] system	Reduction of the consequences of failure
	Gas masks	Personal protection of employees
	Emergency services	Specialized rescue units

[2] UTD - Technical Inspection Authority (polish: Urząd Dozoru Technicznego)
[3] TDT - Transport Technical Supervision (polish: Transportowy Dozór Techniczny)
[4] UPS – Uninterruptible Power Supply
[5] ROP – manual call point (polish: ręczny ostrzegacz pożarowy)

The list of collateral is presented in Table 1 in accordance with the three-tier security model used for the analysis of the security layers [2]. It is based on the specification of three security groups, they are:

I. prevention layer;
II. layer of protection;
III. counteraction layer.

The first layer is to prevent the emergence of emergency events leading to process disturbances. Another is to protect the employee / operator and installation in the event of an undesirable event. The last one, i.e. the counteraction layer, affects the limitation and minimization of the effects of damage to the installation.

3. Risk Analysis

The following undesirable events were taken for the system under consideration:

a) overflow of the storage tank;
b) improper loading of the product for export
- ✓ reloading the packaging;
- ✓ failure of the export packaging.

These events were adopted on the basis of own experience and interviews with long-term employees of the chemical industry.

3.1. Characteristics of Risk Analysis Methods

In the article, in order to perform the risk analysis, the error tree analysis method was used.

Fault tree analysis (FTA) presents "a logical sequence of events from a peak event (e.g. pipeline break, pump failure, etc.) to the causes that cause this failure" [3]. The purpose of this method is to "quantify the probable frequency of adverse events in systems consisting of a number of elements with determinable reliability" [4].

The analysis of the event tree (ETA) is a method closely connected with the FTA. It allows to examine and determine the path from the peak event to the final result of the failure (e.g. from the release of hazardous materials to the environment, by activating individual security layers to define the scale, the amount of substance and damage caused by it).

Note that the ETA method is the opposite of FTA analysis. In the event tree, we are looking for the source of the peak event (i.e. what caused the pipeline to burst?). Meanwhile in the second analysis we focus on the inductive approach, i.e. forward thinking, idefining events occurring after the occurrence of a threat (e.g. as a result of unsealing the pipeline to the atmosphere the substance was dangerous in small amounts).

3.1.1. FTA

For the needs of the work, two analyzes were performed using the fault tree method (Figs. 2 and 3).

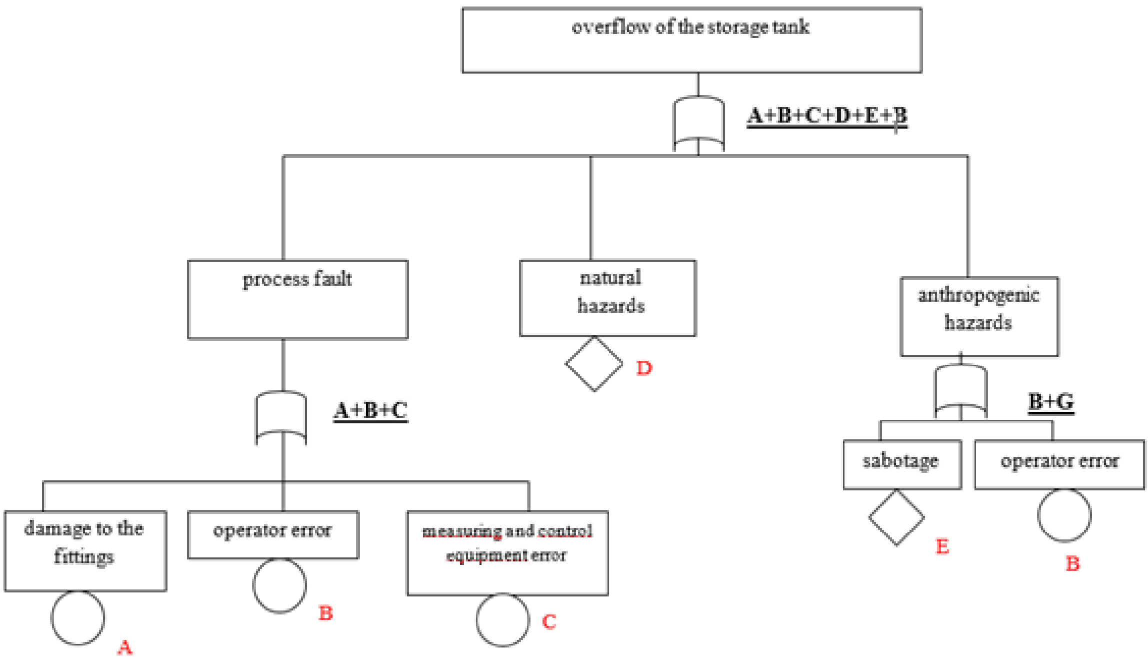

Fig. 2 FTA for overflow of the storage tank

The operations performed allowed to define potential basic events that could eventually lead to a failure. In each

case analyzed, several of the same threats appeared. They are:

a) natural hazards - to which we have no influence;
b) errors in control and measurement equipment;
c) errors of operators - human errors.

3.1.2. ETA

One analysis was made for the needs of the work using the event tree method (Fig. 3). The operations performed allowed to define potential basic events that could eventually lead to a failure. It shows the sequences of correct or faulty operation of individual layers of security. In addition, the probability of its occurrence was determined for each of the final events. In the probabilistic development of the occurrence of individual event sequences, the data available in the subject literature and reliability data obtained in the UDT were used.

Performing the analysis of the event tree showed that the key element limiting the outflow of a dangerous substance to the environment is a quick response to the identification of the process deviation. Therefore, it is crucial to identify deviations from normal technological conditions as early as possible. The quick response of employees is therefore an extremely important element of safe work.

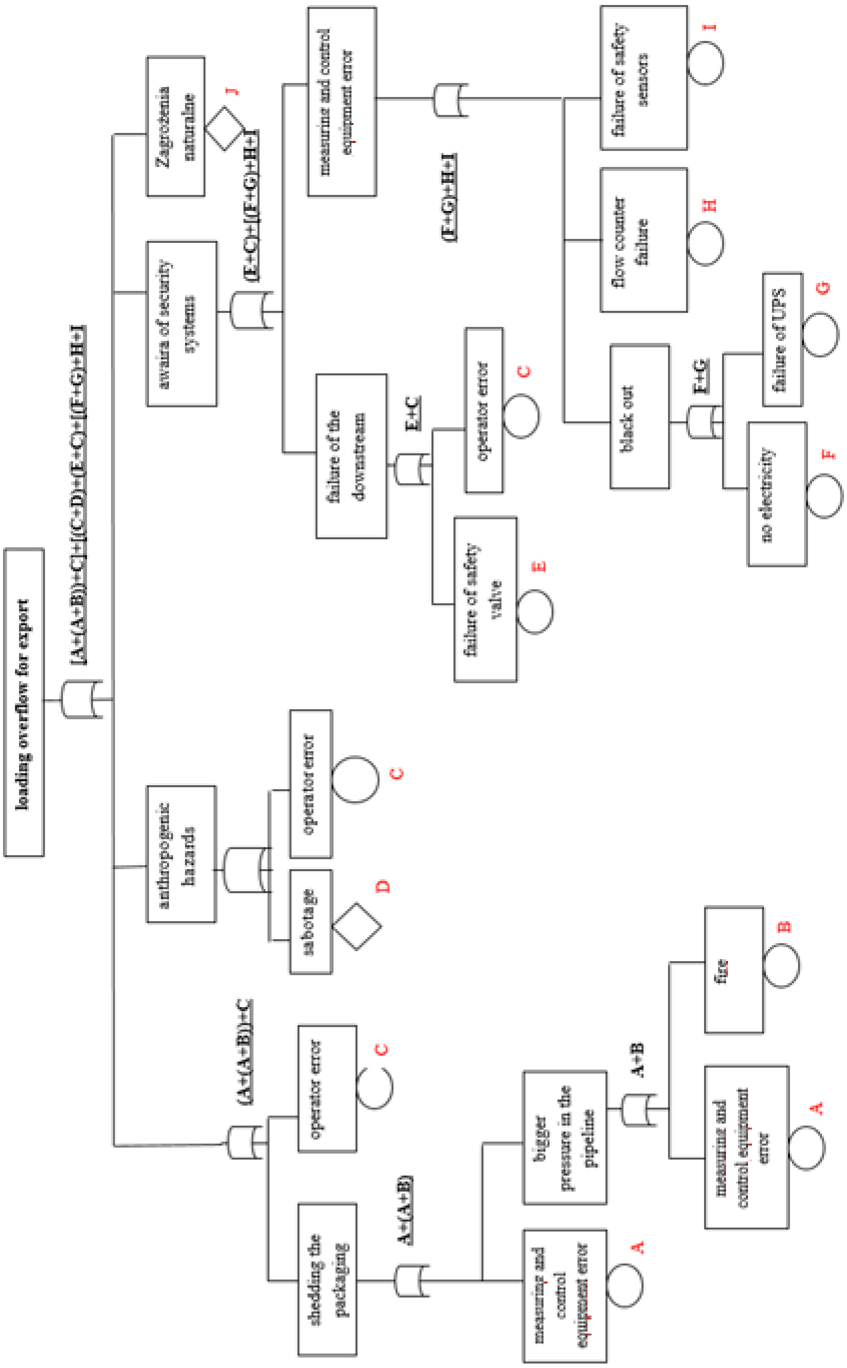

Fig. 3 FTA for overflow of the storage tank

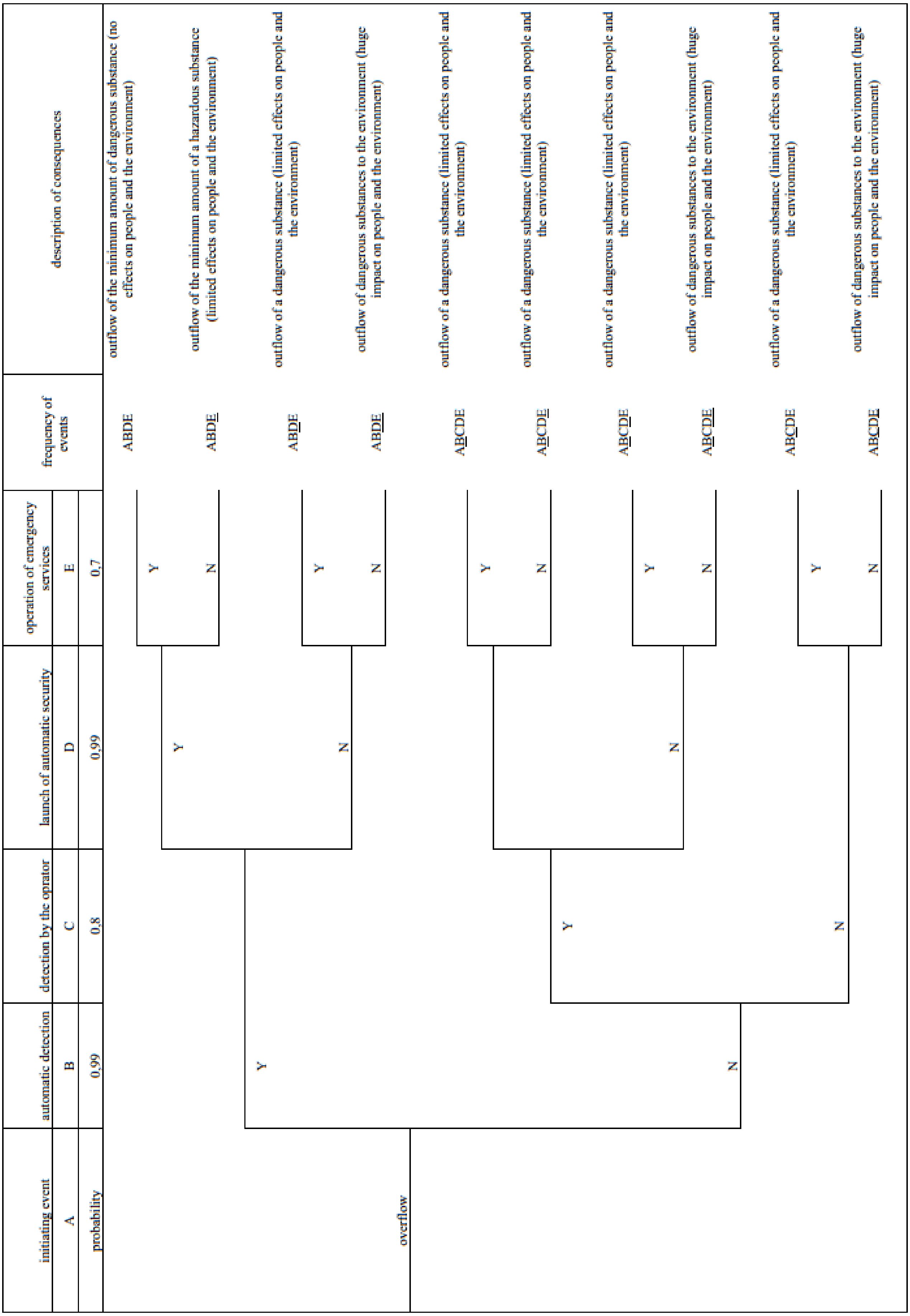

Fig. 4 ETA for overflow

4. Optimization to Improve Security

The performed risk analysis shows that the most common errors contributing in consequence to adverse events are:

a) human errors;

b) failure of control and measurement equipment.

In order to reduce the risk of future failures, the following modifications of the existing warehouse and loading system were proposed (Fig. 5):

a) addition of safety locks that disable the loading pump from the high and low level alarm in the tank (as a consequence of avoiding siphoning or sucking warehouse scrap) - the red line;

b) on manual valves, adding position indicators of the valve (viewing the valve opening position in the DCS system) - valve marked in blue;

c) adding pump start blocks depending on the given process sequence (green line):

- ✓ mixing of tanks - blocking on the valve (valves in the closed position) for loading for export;
- ✓ loading for export - blockage on valves used for mixing tanks (valves in closed position).

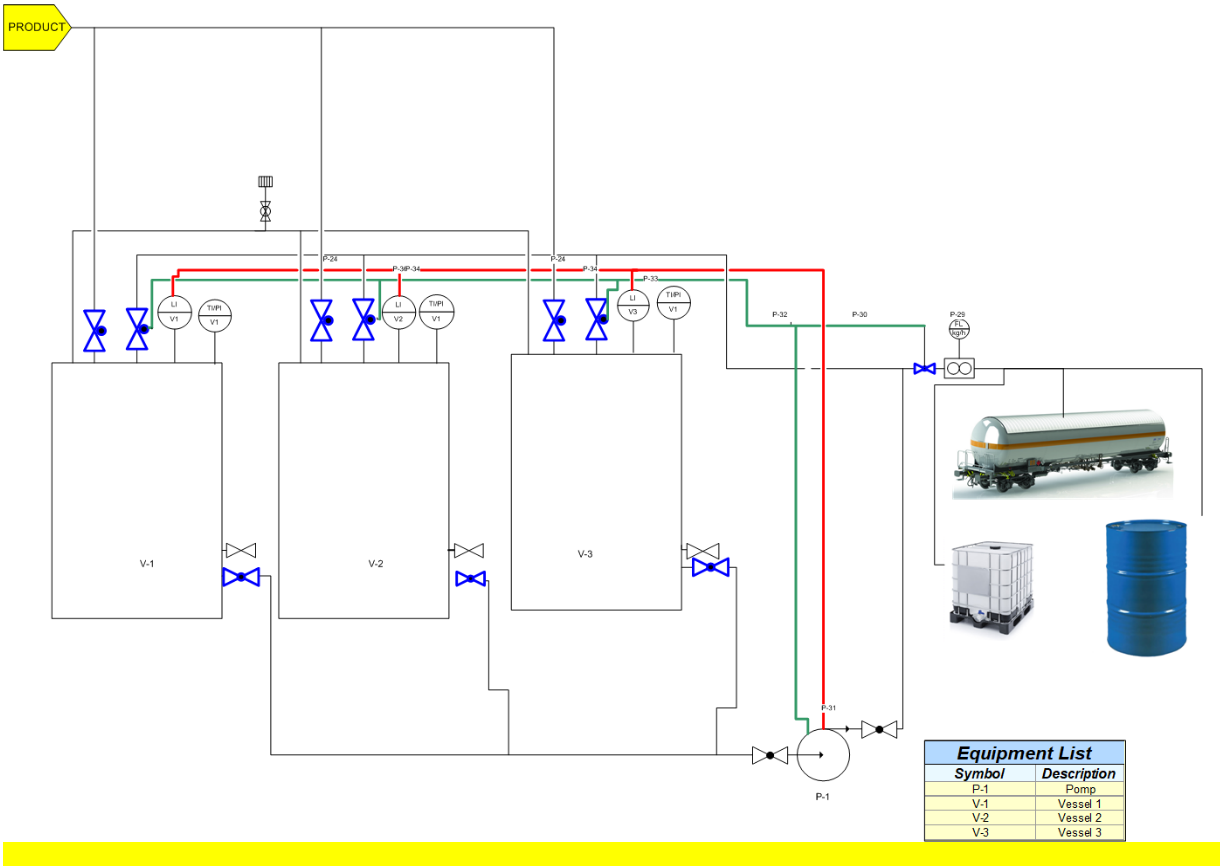

Fig. 5 Optimized installation

5. Conclusion

The presented article presents a modification of the control and measurement system that increases the level and safety status. To solve the problem which posed the risk of shedding the shed of the tank or packaging with the finished product, two of the many risk analyzes (ETA and FTA) were used. Thanks to them, basic events that were the causes of dangerous events were identified and the impact of individual security layers eliminating or limiting the occurrence of an undesirable event was determined.

Risk analysis methods, thanks to their diversity and universality, are used in many fields of industry and science. Thanks to their use, we can often reduce the risk of a breakdown or a dangerous situation in a simple way. What is most important, however, can contribute to reducing the risk of danger to the environment and people.

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The proceedings of 22nd International Scientific Conference: Transport Means 2018.

The Statistical Analysis of Passenger Transport Between Selected European Airports

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Abstract

The aim of this paper is to analyse the situation of aviation and air traffic in three European countries and to present the relation between the number of passengers at selected airports on the Old Continent and the trends in the number of passengers in relation to time and direction of travel. Such an analysis may be helpful in preparing airports for increasing traffic in critical times. A statistical analysis of selected aspects may enable to reveal the situation related to air transport in Europe and the predictions might visualise expectations in the following years. In this paper, the methods of statistical analysis and interpretations of studies presented in a graphical way, were used. The aim of the research was to estimate air traffic in the following years.
KEY WORDS: *passenger transport, forecast, statistical analysis*

1. Introduction

Air transport is an important part of the global economy. Since 1980, air transport of passengers has become more available for casual people [7]. Air transport involves the movement of passengers and freight from point A to point B, using all types of flying equipment. It is one of the fastest growing means of transport. Air transport can be divided into two types: civil aviation and military aviation. Civil aviation is a generally available mode of air transport. Civil Aviation is a part of this framework: Sports aviation (e.g. sailplanes), General Aviation (private aircraft) and Transport aviation (both passenger and cargo transport).

The growth of the aviation industry is conditioned by the global economic situation, which stops or stimulates the development of national economies and contributes to the procurement of aircraft or aviation components. In addition, the growing number of people using the same mode of transport, and the willingness of people to travel, are making the aviation industry to experience a period of its decline or development. The number of passengers has been growing for several years now and will continue to increase with slight fluctuations according to analysts' predictions.

The positive aspects of air transport also include the possibility of rapid transfer from one continent to another, the comfort of travel and safety (the relatively safest out of all means of transport since air transport has recorded the lowest number of fatalities for many years, as air accidents are the least frequent). The location of airports is usually close to large population centres - urban agglomerations, which are a market for air services. The number of the Poles using air transport is increasing from year to year. In 1995, the number of people using airplanes was 700,000. According to the data of 2003, there were about 6 million people travelling by air, and now it is about 10 million [4].

2. The Description of Analysed Airports

In this contribution, the passenger traffic between four airports has been analysed. The representatives of different kinds of airports, have been chosen which include the following four airports: Frankfurt, Munich, Budapest and Warsaw. The first two have a significant role as transfer airports. The Chopin airport was selected because of its great importance for Polish transport, while the Budapest airport due to numerous analogies between Poland and Hungary.

The Frankfurt am Main Airport is a Frankfurt airport located 12 km south-west of the city centre in the airport district. It is the largest airport in Germany. As many as 55% of passengers are transit passengers. According to the data of the Airports Council International [8], it is the third busiest airport in Europe, after Heathrow in London and Charles de Gaulle in Paris, and the eleventh in the world. By 2021, its two terminals will have exceeded their capacity. At

present, the airport uses 80% of its maximum capacity, its four runways together operate 100 takeoffs and landings per hour, while its maximum capacity is 124 and 108 airlines use the services of the Frankfurt airport.

The Franz Josef Strauss's Muenchen airport is Germany's second largest airport. It is located 28 km north-east of Munich and covers an area of more than 1,500 hectares. It has two parallel runways, 4000 m long and 60 m wide. In 2007, it handled 33.96 million passengers and is the 30th largest airport in the world in terms of passenger traffic. In the World Airport Awards 2014, the Munich airport was named the best airport in Europe and ranked third in the world. Currently, it handles approximately 42 million passengers annually and offers connections with 223 destinations in 62 countries [9].

The Ferenc Liszt Budapest Airport is Hungary's largest international airport, located 16 km southeast of the centre of Budapest. It offers flights all over Europe, as well as to Asia, to the Middle East and to North America. In 2017, the airport handled 13.1 million passengers. It has two runways and more than 40 airlines are operating at the airport [10].

The Chopin airport is located in the Okęcie estate, about 8 km south-west of the city centre of Warsaw. It operates scheduled, charter and cargo flights. It is the largest airport in Poland. In 2016, it handled 12.8 million passengers. In 2016, the number of passengers increased by 15.5% compared to the previous year [11].

3. Methodology

Time series modelling [2, 3, 5] and statistical forecasting can be fundamental methods to understand trends in the modern aviation. In order to perform statistical forecasting, it is important to divide the data into two subgroups: training and test one. The first one is used to develop a model which will be then used to predict data retention outside its scope.

Two models based on a linear description of time series often appear in the literature: the Autoregressive AR model and the Moving Average MA model. The combination of these two models resulted in the autoregressive model with the moving average (ARMA) which was then modified to the autoregressive integrated moving average (ARIMA) model. It appeared, however, that many processes are seasonal in nature, for example, certain structures are repeated at certain intervals. SARIMA is an ARIMA model [6] that takes into account the seasonality component. Taking under consideration the nature of changes, two different types of models are generally used for a times series: Multiplicative and Additive models [6]:

Multiplicative Model:	$Y(t) = T(t) \times S(T) \times C(t) \times I(t)$
Additive Model:	$Y(t) = T(t) + S(T) + C(t) + I(t)$

where $Y(t)$ is the observation and $T(t)$, $S(T)$, $C(t)$ and $I(t)$ are respectively the trend, seasonal, cyclical and irregular variation at time.

Multiplicative model is based on the assumption that the four components of a time series are not necessarily independent and they can affect one another, whereas in the additive model it is assumed that the four components are independent of each other.

4. Passengers Traffic Between Chosen Airports

The analysis based on the data collected on the Eurostat web page is presented below [12]. The selected periods include the data collected between 2004 and 2016.

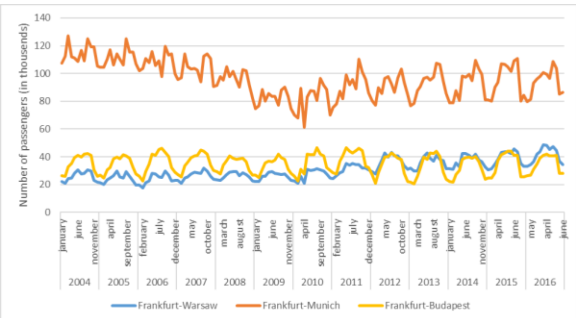

Fig. 1 Number of exchanged passengers between Frankfurt and other three chosen airports [1]

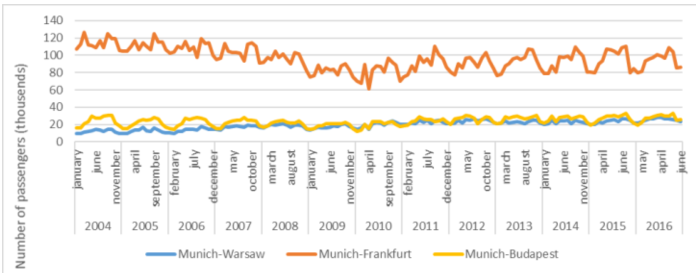

Fig. 2 Number of exchanged passengers between Munich and other three chosen airports [1]

In Fig. 1, the number of passengers travelling per month from Frankfurt to one of the following destinations: Munich, Warsaw and Budapest, is presented. It can be observed that the number of passengers on the route Frankfurt-Munich was the most affected by the World Financial Crisis between 2008 and 2009. The connections to Warsaw and Budapest seem to be unaffected. An analogical conclusion can be assumed while analysing the Fig. 2. The seasonality is also less regular for the connections from and to Munich as for the other analysed routs.

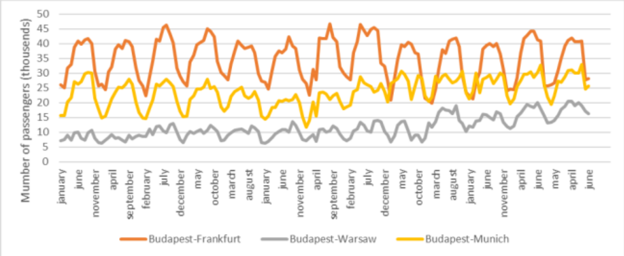

Fig. 3 Number of exchanged passengers between Budapest and other three chosen airports [1].

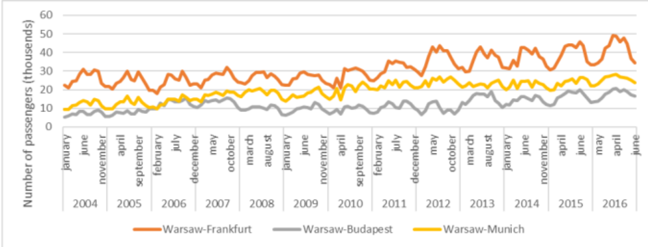

Fig. 4 Number of exchanged passengers between Warsaw and other three chosen airports [1].

Fig. 3 shows that in the examined period, the number of passengers travelling from Warsaw airport on investigated routes is increasing. As it has been concluded on the basis of the Fig. 2, the number of passengers travelling to Munich is less seasonal compared to the number passengers using other destinations.

On the basis of the data presented on the Fig. 4, it can be concluded that the change of the number of passengers has revealed a high seasonality of departures from the Budapest airport. The biggest seasonality is observed on the route Budapest-Frankfurt, on which the number of passengers in summer months is almost twice higher as during the winter months.

5. Forecast Analysis

In this paper, the times series are used as a prediction model. A time series in general is supposed to be affected by four main components, which can be separated from the observed data. These components include: Trend, Cyclical, Seasonal and Irregular components. The cyclical variation in a time series describes the medium-term changes in the series, caused by circumstances, which repeat in cycles. The duration of a cycle extends over longer period of time, usually two or more years. Most of the economic and financial time series present some kind of cyclical variation [6]. The seasonal change of the number of the passengers has been also observed for the air traffic. The higher number of travelling people is in summer comparing to winter.

On the basis of the number of passengers presented in Figs. 1-4 and using time series model, the estimated number of passengers has been provided. The analysed data have been divided into two samples: training and testing. The first one is the data period which has been used to develop a model, the second one to test it. The number of the passengers between two airports compared with the test period, as well as the forecast, are presented in Figs. 5-10 as a function of time. The forecast analysis is performed in the Mathematics programme with the use of the SARIMA model. The predictions are provided until 2020. An important parameter of forecasting is the period on which the model has been trained. As an example, two forecasts for the route from Budapest to Frankfurt are provided in Figs. 5 and 6. The different training periods have been taken under the consideration. It can be concluded that for the data with a similar structure over the time, a longer training period is slightly better. However, when the number of the passengers had been changed rapidly, as for example, on the route from Warsaw to Frankfurt in 2010 (Figs. 7-8), a shorter training period provides more exact predictions. One of the factors which forced to shorten the period on which the model has been developed, was the global financial crisis.

On the basis of the Fig. 5, it can be concluded that currently the mean number of passengers should be the same as well as the amplitude of the seasonal changes. The predictions are comparable with the testing period. According to the above results, the major changes are not expected in the future.

According to fig. 8, it can be expected that the number of passengers travelling from the Frideric Chopin airport will be increasing in the future.

In Figs. 9-10, the numbers of passengers from Munich to Warsaw and Budapest to Warsaw are presented respectively. Fig. 10 shows the difference between the forecast and the reference period. The forecast of such data is influenced by many factors, like the volcano eruption in Iceland, in 2010. Other factors may include also a financial crisis and a political situation. The aim of this paper is not to explain reasons of such situations, but to indicate some trends and problems from a statistical point of view.

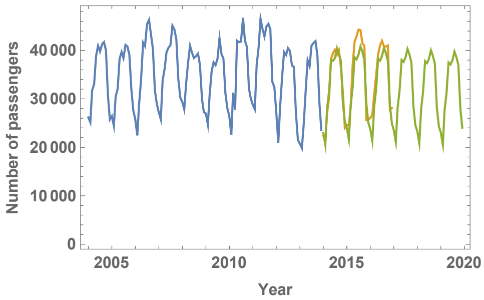

Fig. 5 Forecast number of passengers between Budapest and Frankfurt. The training period are between 2004 and 2013 [1]

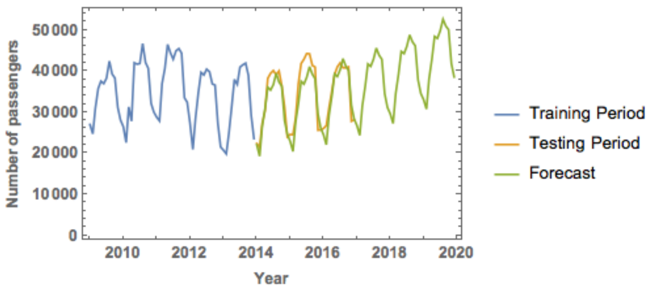

Fig. 6 Forecast number of passengers from Budapest to Frankfurt. The training period are between 2009 and 2013 [1]

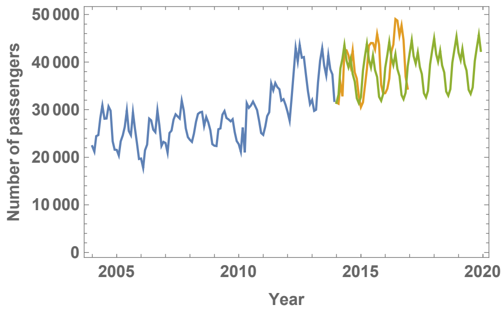

Fig. 7 Forecast number of passengers from Warsaw to Frankfurt. The training period between 2004 and 2013 [1]

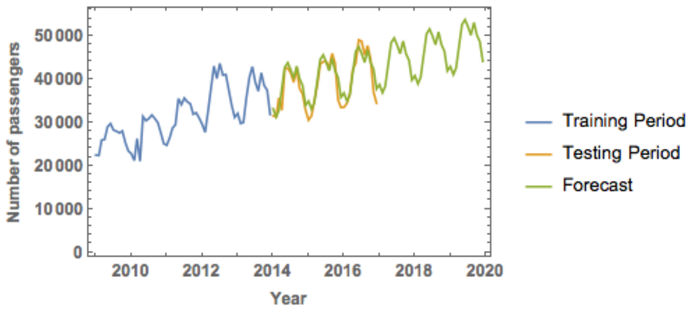

Fig. 8 Forecast number of passengers between from Warsaw to Frankfurt. The training period between 2009 and 2013 [1]

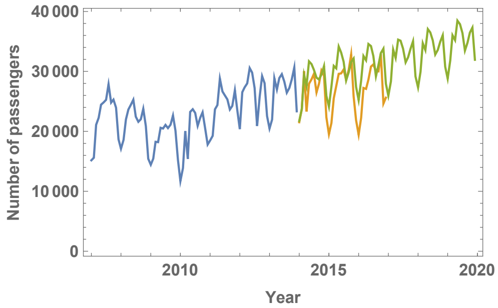

Fig. 9 Number of passengers travelling between Munich and Warsaw in 2007

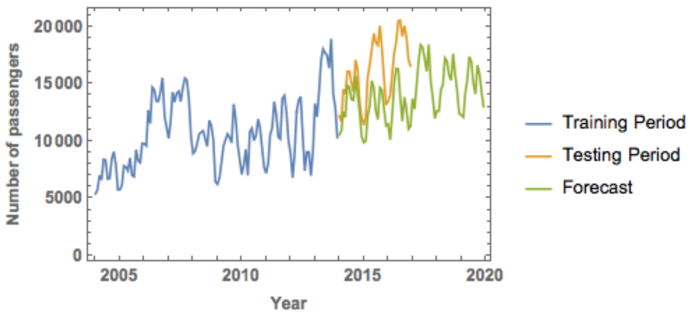

Fig. 10 Number of passengers travelling between airports from Budapest to Warsaw. The start year for the model build was 2009 [1]

6. Conclusion

The forecasts emphasize the expected trend in the number of people using air transport on the selected routes, however, the predictions cannot always reveal the exact assumptions. Due to various random phenomena which cannot be predicted, deviations from forecasts are possible in many areas, however a general outline of predictions is probable.

The predication for Poland shows that the Chopin airport will operate more air traffic in the following years. For the routes from Budapest and Munich to Frankfurt, there is also an expected increase in the number of passengers, although less than the expected increase at the Chopin airport. The Frankfurt-Munich route has been remaining stable over time and its forecast is to remain at the same level. In order to conduct more accurate, specialized forecasts, it would be necessary to take into account more parameters. It should be stressed that such models and analyses are often used in business analyses, and therefore the results obtained in this paper can be considered as valuable from aviation infrastructure planning point of view.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Driver Education as a Way to Improve Road Safety in Poland

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Abstract

Improving road safety has been one of the priorities of the European Union's transport policy for many years. The number of road accidents involving personal injury in the European Union is decreasing year by year, despite the growing number of vehicles in motion and the volume of traffic. Still, it exceeds one million a year. Over 25,000 people died on EU roads in 2017. The high number of fatal accidents is a serious problem in social and economic terms. The objective of the EU policy indicated in the White Paper of 2011 is to reduce the number of accidents in road transport by half in 2020 and to approach close to zero fatalities in 2050. One of the ways to achieve this goal is training and education of all road users.

The article presents statistics on road accidents and their perpetrators in Poland, against the background of the EU. Poland belongs to the countries with the highest number of road accidents and their fatal consequences. The high rate of motorization in Poland makes traffic conditions more and more difficult. Most road accidents with fatal consequences occur in good road conditions and are caused by experienced drivers, and their victims are increasingly older people and pedestrians. Therefore, raising the level of education and shaping a morally responsible attitude of the drivers is the important direction of activities planned for the years 2013-2020. The article discusses various forms of education and training aimed at changes in the behavior of road users, including drivers, and presents the current offer of training centers for drivers in Poland.

KEY WORDS: *EU road fatality figures, causes of road accidents, drivers education*

1. Introduction

The number of vehicles in motion and the volume of traffic in the EU countries is growing year by year. In 2015 the stock of registered vehicles (passenger) amounted by 254 235 thousand, more by 5,9% compared to 2010 and the performance of the passenger cars only grew by 2% in this period [3]. Over 25,000 people died on EU roads in 2017 and the number of serious injuries is five times higher than the number of road deaths [road safety]. Each death on roads and traffic injury causes unnecessary human suffering and high economic costs. The costs of fatal accidents are estimated to be in the order of EUR 50 billion per year for fatal accidents only and EUR 120 billion, when serious accidents are included [10]. Of particular concern is the number of fatalities and serious injuries among pedestrians and cyclists. Therefore, improving road safety is one of the 10 priority goals of European transport policy, included in the White Paper 2011: to reduce the number of road casualties by half in 2020 and to approach close to zero fatalities in 2050 from the 2010 baseline. In the EU road safety strategy, preceding the White Paper, the Commission stressed that the effectiveness of the road safety policy depends ultimately on the users' behaviour. Seven objectives have been identified for the next decade and the first is: Improve education and training of road users. The Commission proposes a wider approach and view education and training as an overall lifelong process, with a special focus on young novice drivers, most vulnerable users, persons with disabilities and elderly people [9]. The three main areas of education on road safety, mentioned in the EU policy documents, are pre-exam education, the driving test itself and the continuous trainings for non-professional drivers, after obtaining a driving license [8].

In the "Valletta Declaration on Road Safety" adopted in March 2017, the EU transport ministers reconfirm their commitment to improving road safety, as stated in the White Paper of 2011 and accepted a new target for serious road traffic injuries: 50 % reduction in period 2020 - 2030. Measures to achieve this include better enforcement of traffic rules and improvement of technical infrastructure and vehicle safety as well as better education and raising the awareness of road users. The transport ministers stressed that particular attention should be paid to improving road users' behaviour and to actions for the safety of vulnerable road users and safety in urban areas. The vision is - a Europe-wide road safety culture based on shared values [10].

The purpose of the article is to present the forms of education and training of road users in Poland in the context of this vision, against the background of the analysis of the fatal road accidents causes.

2. Road Fatal Accidents in the EU

Despite the growing total number of vehicles in motion and the volume of traffic the number of road accidents involving personal injury in the European Union is decreasing year by year. The EU road fatality rate in 2017 was the lowest ever with 49 dead per million inhabitants, against 174 deaths per million globally, 106 deaths per million in the USA and 93 deaths per million in geographical Europe [6]. It can be thus concluded that the actions taken to improve

road safety bring about the expected effects, as reflected in the figures in Table 1.

Table 1

Road accidents involving personal injury and fatalities in the EU-28 [3, 6]

	1990	1995	2000	2005	2010	2015	2017
Accidents [thsd.]	1 502,077	1 433,020	1 505,653	1 341,981	1 130,398	1 090,042	n.a.
Fatalities	77,337	57,082	45,943	35,362	31,456	26,134	25,300

The number of people killed in road accidents in 2017 decreased by 20% compared to 2010. The mortality rate in 2010 was 62 people per 1 million inhabitants. In 2017 only two EU Member States recorded a fatality rate higher than 80 deaths per million inhabitants, Romania (98) and Bulgaria (96), against seven in 2010. The lowest fatality rate was recorded in Sweden (25) and the United Kingdom (27). However, the dynamics of the drop in the number of victims has slowed down in the recent years and amounted only 2% compared to the previous year. A reduction rate of 14% would be necessary every year from now on to reach the safety policy goals.

Not all road user groups are equally at risk of accident and death. The group with the highest exposure to this risk are young people, aged 18 to 24, who constitute only 8% of the EU population, but as much as 14% of fatal accident victims. The disproportionately high share of young drivers in road accidents and the number of fatalities in these accidents is a serious public health and social problem. Table 2 presents the relevant data

Table 2

The distribution of fatalities by age group in the EU-28

Age group	Death share [%]*	Population share [%]**
< 17	< 4	18.2
18 – 24	14	8
25 - 49	35	54.7
50 - 64	20	
> 65	27	19.1

*[1]

**[7], numbers for each range not available

Two groups of road users, young people aged between 18 and 24, and the oldest road users, over 65, are the groups most exposed to the risk of death as a result of a road accident in the European Union.

Most accidents took place in the summer months, in July and August, due to the usual holiday season in Europe; and when it comes to weekly schedule, most accidents happened on weekend days, from Friday to Sunday. The unfortunate events at the weekend are most affected by young people aged 18-24; the reason is more frequent driving under the influence of alcohol, intoxicants and fatigue during night driving [6].

Pedestrians account for 21% of all fatalities in the EU. The number of pedestrian and cyclist fatalities since 2010 decreased at a lower rate than the number of casualties in other road user groups, by respectively 15% and 2% from 2010 to 2016, compared to the overall fatality decrease of 20% [1]. Together with the growing percentage of the oldest population in the entire population, one should also expect an increase in the share of elderly in road traffic, including an increase of older drivers. This means that ensuring their safety is an important area of research, both in terms of vehicle equipment, proper infrastructure preparation, as well as their behavior as road users.

To achieve the goals set in European transport policy is necessary to maintain and increase the pace of road safety improvement. This applies first of all to those countries in which both the number of accidents and mortality rates are the highest. Among them is Poland.

3. Road Accidents and Fatalities in Poland

In 2017 in Poland occurred 32,760 road accidents, in which 2,831 people were killed and 39,466 injured. This is less by 2.7% of accidents and by 6.4% of deaths than a year earlier. The numbers of road accidents and fatalities are systematically decreasing in the last decade, but despite this fact Poland still reports a higher number of road fatalities than the EU average (75 per million inhabitants compared to the EU average of 49, fourth place among the EU countries). During the period 2008-2017 the number of fatalities decreased by 48% in Poland and this dynamics was slightly higher than the average in the EU (40%) [11].

The general characteristics of accidents regarding time and place of events is similar to that presented for the entire European Union. Most accidents happened in October, June and July. A large number of accidents in the summer months are related to the holiday season, while in autumn the weather and traffic conditions deteriorate. The road accidents happen most often on Fridays and Saturdays, and the number of killed and injured on that days is the highest. Both in 2017 and in previous years, the highest number of accidents occurred between 2.00 and 7.00 pm., that is during the period of heavy traffic associated with returning from work.

Two main types of accidents in 2017 were “vehicle collisions in motion” (52.8%) and “hovering on a pedestrian” (24.1%). The collision of vehicles in motion caused the most fatalities, almost 42% of the total. The

perpetrators were the drivers of passenger cars in the vast majority. They were responsible for 76.6% of accidents in total and 53,2% of fatalities. The victims of accidents were mainly pedestrians (30.8%) and drivers of passenger cars (30%) [11]. Table 3 contains the data illustrating the share of the age groups in total number of killed, in the population and as a perpetrators of the accidents.

Table 3

Share of the age groups in the population and in the fatalities in Poland in 2017 [11]

Age group	Death share [%]	Population share	Share as perpetrators [%]
< 17	3.6	18	1.8
18 - 24	13.3	7.9	19.6
25 - 39	24.5	23.5	28.2
40 - 59	28.3	26.8	22.3
> 60	32	23.9	13.5

The group of young drivers aged 18-24 is over-proportional in relation both as a death victim and as accident offenders to their share in the population. But the largest share as perpetrators of fatal accidents and also larger than its share in the population has a different group, i.e. drivers of vehicles aged 25-39.

The main causes of road accidents in 2017 were: non-adaptation of speed to traffic conditions, non-compliance with the priority of passage, incorrect behavior towards a pedestrian, failure to maintain a safe distance between vehicles. Drivers under influence of alcohol were less involved in the accidents, they caused 6.6% of accidents, in which 273 people were killed (9.6% of the total number). As a result of accidents caused by pedestrians 425 (15%) people died and the main reason was careless entrance to the road (49,8%). The prevailing circumstances of fatal accidents show that they took place most often [11]:

- in a daylight (70% of accidents);
- in the hours from 2.00 to 7.00 pm. (37%);
- in good weather conditions (59%);
- on a dry surface (64%).

Most accidents happened under good weather conditions when drivers feel more comfortable and develop faster speeds, which in the case of an accident gives more tragic results. It seems than that external circumstances, such as bad weather conditions or technical defects of a vehicle or infrastructure have a much smaller impact on the development of the accident situation than the behavior of drivers. Seeking the reasons for the excessive exposure of young drivers to the risk it is indicated that this group of people is characterized both by lack of experience and skills in driving as well as a high inclination to bravado and risk. It concerns especially young men, driving in the company of their peers [4].

However, when it comes to the causes lying on the side of older road users primarily the lack of education is indicated. According to the National Road Safety Program for 2013-2020 in Poland, the low level of driver education is the first of the circumstances favoring the particularly high risk of dangerous drivers behavior in road traffic. Also in relation to accidents involving pedestrians a low level of pedestrians and drivers education, non-compliance with traffic rules and lack of road partnership, manifesting in the superiority of vehicle drivers compared to unprotected road users (pedestrians, cyclists) are indicated as real causes behind the accident [5]. This leads to the conclusion that measures aimed at improving road safety in Poland, as far as drivers are concerned, should be aimed at changing their behavior and this applies above all to drivers from two age groups: 18-24 and 25-39.

4. Forms of Mandatory Education and Training on Road Safety

Various concepts and programs of education have been adopted in European countries to improve road safety. One of the best known is the Vision zero concept developed in Sweden, implementing the Safe System approach. The basic idea of the Vision Zero concept is based on the assumption that it is unacceptable for a man to pay the death penalty for a mistake in traffic, committed by himself or another road user. This approach assumes that making mistakes on roads is natural and cannot be eliminated. People will make mistakes, so the system should be designed in a manner eliminating or minimizing these errors. Consequently, it is the politicians, road administrators and designers, not drivers, who are responsible for the safety of the road system. It means that the road system should be created for the fallible and unprepared drivers, whose only duty is to comply with the rules. However, drivers should demonstrate their willingness to improve safety. This concept has been also adopted in Poland, as a long-range and ethically legitimate vision of road safety.

Given this approach and the human tendency to make mistakes and deliberately violate traffic regulations, the main goal of education on road safety should be to develop an appropriate moral attitude, obliging road users to comply with the law. The first of the five pillars of intervention envisaged in the National Road Safety Program for 2013-2020 concerns shaping safe behaviors of road users. It has also been indicated as one of four strategic directions on road safety in the Transport Development Strategy until 2020 and in related programs. All educational and training programs should fulfil this goal.

The European Commission guidelines on education and training of road users, and in particular the training of candidates for drivers and professional drivers, are implemented in Poland primarily through the provisions of the Act

on Drivers. Over the past few years, changes have been introduced to improve the quality of driver training, strengthen supervision of young drivers and tighten sanctions for risky driving behaviour.

Such behaviour include in particular:

1. Exceeding the speed by more than 50 km/h in a built-up area;
2. Driving under the influence of alcohol, causing an accident under the influence of alcohol;
3. Committing a crime or three offenses against the safety of communication by young drivers (during 2 years after obtaining a driving license): consequence - losing a driving license.

There are penalty points for violation of traffic regulations. From 4 June 2018, if there are more than 24 points on the driver's account, they will be directed to a re-education course devoted to road safety in the form of lectures and workshops. The topics of the courses will include among others the effects of accidents, factors affecting road safety and psychological aspects of vehicle driving and participation in road traffic, The re-education course is to last a total of 28 hours for 4 days and will cost the driver PLN 500. If the driver does not take part in it within one month of the delivery of the administrative decision, then he will lose the driving license.

The same procedure will relate to the young driver who committed at least two offenses against communication safety during the trial period. The courses will be run by Voivodship Road Traffic Centers (WORD) for a fee. If, over the next five years, the driver exceeds the 24-point limit again, the driving license will be withdrawn [2]. WORD organizes also re-education courses in the field of anti-alcohol and anti-drug issues. The course is directed to people who were driving a vehicle after using alcohol or another similar substance and received an administrative decision to do so. Referrals will also be given to those who are found to be under the influence of drugs.

The range of mandatory trainings offered so far by the WORD includes courses and trainings for professional drivers, drivers with penalty points, candidates for examiners, teachers. The second and widespread area of education in the field of road safety is the education of children and youth, sometimes treated as the most important target group of activities. The most popular forms of education of children and youth include the different kinds of competitions and knowledge about road safety, cycling events, including exams for a cycling card, organization of "traffic towns", etc.

As part of promotional social campaigns, competitions and shows for adults are organized, during which volunteers can check their state of knowledge about traffic regulations, test themselves in situations simulating an uncontrolled slip of the vehicle or experience driving in goggles, imitating the state of intoxication. However, according to media reports, these occasional competitions checking knowledge reveal the real state of ignorance: many contestants, including drivers with a longer driving experience, would not pass the driving test.

A case of a rescue transport company confirms this observation. In order to test the knowledge and skills of professional drivers who drive rescue vehicles on a daily basis, the company carried out a trial test for driving license. It turned out that almost half of the drivers would not pass the theoretical exam, and the test of practical skills was also not the best, as for people considering themselves very good drivers.

This situation leads to conclusion that longer driving experience do not necessarily translate into knowledge of traffic regulations and driving culture, but it can lead to routine and disrespect of other road users, considered as inferior and disturbing on the road. This is clear consistent with lack of road partnership, listed in the National Road Safety Program as circumstance conducive to accidents.

5. Forms of Voluntary Education and Training on Road Safety

The analysis of road accidents shows that the direct cause of these events in majority is the inadequate to the situation behaviour of rod users. The term “inadequate behaviour” generally means behaviour that is not adapted to the current traffic conditions. This is due to other reasons, among which the most important is the erroneous assessment of the situation resulting from psychophysical limitations of the human, wrong decisions resulting from lack of knowledge and training, and conscious risky behaviour resulting from the attitude of the road user. Although completing the training combined with the exam prepares the driver for efficient and safe driving, however, it is focused on typical road situations and the average candidate, so it is inevitably unable to cover more difficult situations or take into account the specific predispositions of individual candidate. With the increase of technical capabilities of vehicles and their number on the roads, as well as under the pressure of a hurried lifestyle, the number of difficult traffic situations increases, in which standard training and acquired experience for some drivers turn out to be insufficient.

The offer of trainings and courses directed towards the so-called “ordinary”, non-professional drivers who for various reasons would like to broaden their knowledge or improve their skills are rare. Some offers of such trainings include improvement of safe driving skills for those who feel uncertain as a driver, due to a longer break in driving. Thus, the largest group of drivers, contributing to the largest number of accidents, remains out of the reach of systematic and intentional interactions. It is difficult to include promotional and informational campaigns. Someone convinced being a very good driver will not see himself as the recipient of a social campaign.

In this context, it is worth looking at the various forms of training and courses offered for drivers in Germany. The website www.verkehrssicherheitsprogramme.de run by the German Road Safety Council presents a wide range of courses and trainings implemented by various Council member organizations (around 200), which are addressed to particular groups of road users - children, young people, young drivers, mature drivers, older road users, professional drivers, drivers committing offenses. The subject matter of courses for mature drivers includes a wide range of training, among them such as: eco-driving, safe driving, driving skills improvement – driving a delivery vehicles up to 3.5t, campers or vehicles with camping trailers, safe and healthy driving.

Very interesting is the seminar titled „Apropos Verkehrssicherheit” which draws attention to factors such as stress and emotions affecting the drivers behavior and driving skills. The seminar consists of two parts. The aim of the first part, entitled “Stress in road traffic” is to discuss the factors causing stress and to recognize the personal stress response, as well as working out ways to eliminate or reduce stress, which should lead to a reduction in the psychological burden of driver. Reduction of stress is important for safe and healthy driving. Not less important is the second part of the seminar called "The world of emotions in road traffic". Strong emotions can cause temporary loss of self-control and nervous, anxious or aggressive reactions that affect driving. During the training, participants recognize their own reactions and learn strategies leading to their mitigation or change. This training does not require a maneuvering area, so it can be organized by qualified moderators or trained employees in workplaces. It is worth paying attention to this form of reaching the public with knowledge about road safety.

With the growing rate of motorization more and more employees are drivers who commute and overcome considerable distances every day, often in traffic jams, in stress and tired. In the lack of time, by a good opinion about themselves as a driver and confronted against the payment for training, people may find it difficult to sign up for a special course in WORD. In contrast, training on road safety in the workplace, for example as a part of mandatory training on Health and Safety at Work, could eliminate this barrier and be of great interest for many, especially if it would be possible to obtain financing for these courses by insurance companies. Various kinds of trainings, e.g. concerning car rage, stress on roads or first aid might help developing the desired safety culture.

6. Conclusions

Minimizing the number of fatalities in road accidents is an important goal of European and Polish social and transport policy. Despite significant progress in recent years, Poland still belongs to the EU countries with the highest fatality rates, especially among pedestrians. As the analysis of the causes of road accidents indicates, the behavior of drivers is decisive for the development of the accident situation. Therefore, raising the level of drivers education and shaping their morally responsible attitude against other road users is one of the main directions of activities envisaged in the National Road Safety Program for the years 2013-2020. However, the range of voluntary training and courses currently offered by WORD seems to be too poor. Thus, the largest group of drivers, contributing to the largest number of accidents, remains out of the reach of systematic and intentional interactions.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Assessment of Defence Technologies as a Part of Operational Capabilities Fulfillment's in National Security System

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Abstract

The fulfillment of operational capabilities and requirements is possible in many cases by acquiring defence technologies and creating conditions for support them. One part of this process is prioritizing of operational capabilities. It gives the opportunity to focus only on those capabilities that are most important to the national security system. Prioritization is the main process for defining the operational requirements that are necessary to achieve and maintain. This involves the assessment of defence technology. This article shows the selected element of analysis of the operational capabilities and requirements and assessment and choice of defence technology in the national security system.
KEY WORDS: *national security system, operational capabilities and requirements, defence technology*

1. Introduction

National security – that is the greatest value, nation's need, major aim for the functioning of state, individuals and social groups, and simultaneously it is the process of various measures that guarantees permanent, and free from any distractions existence, as well as development of nation, national security and defence as political organ and security of individuals, as well as security of whole society, it's goods and natural environment against any threats that significantly limits it's functioning or makes damage to any special values [8].

National security system includes formation within the state and its relations with exterior subjects, as well as involves various spheres and areas: political, legal, military, economic, social, cultural and scientific relations etc. [1].

National security system consists of forces, measures, and resources designated by the state to realize tasks in that field, which are adequately organized, maintained and prepared. It is composed of managing subsystem and executive subsystems, including operational subsystems (defence and security) and support subsystems (social and economic) [13]. National security system is described by Fig. 1.

NATIONAL SECURITY SYSTEM
COMMAND AND CONTROL SUBSYSTEM
OPERATIONAL SUBSYSTEMS
NATIONAL DEFENCE SUBSYTEM – *fulfill of operational capabilities* – *assessment of armament systems* – *aquisition of armament systems*
NATIONAL SAFETY SUBSYSTEM
SUPPORT SUBSYSTEMS
SOCIAL SUBSYSTEM
ECONOMIC SUBSYSTEM

Fig. 1 National security system [13]

Requirements of the modern security environment, technological development and advanced modernization of armed forces of neighboring countries and the North Atlantic Alliance – they are determinants of major challenges that are undertaken by Polish Armed Forces. Alliance's obligations and social requirements force Polish army to undertake transformational actions in order to achieve faster development of operational capabilities. Modern evaluation of security environment cannot be determined only by threats but should be based on capabilities. Those capabilities are measures of value and utility of armed forces as the tool of national security system. The task of the capabilities is to enable effective and successful undertakings of challenges in the area of military security that would guarantee the success of national or allied defence in case of military aggression, as well as during crisis.

2. Define Capabilities and Operational Requirements

The ability is a predisposition to easily possess certain skills, gain knowledge and learn. This is a potential

efficiency, ability to achieve something, proficiency in something [12]. According to Military Operations Research Society (MORS), the ability is a skill to achieve a desirable effect in given conditions and norms by the realization of certain tasks by the help of adequate and matched aims, measures, and resources [5]. The ability is a measure to achieve operational results needed for successful military missions [9].

In reference to the development planning of armed forces the term of „operational capability" is used. Is it defined as potential proficiency, subject's ability that is a result of its characteristics and features, which enables it to undertake activities in order to achieve desirable results. The functional components of the ability are doctrine, organization, training and education, material, personnel, leadership, facilities, and interoperability [10]. Presented definition includes model components of ability, according to NATO standards – DOTMLPFI model.

Operational capabilities result from tasks that are realized by armed forces. The first stage of their identification is environmental security analysis and the level of national ambitions. The outcome is a set of scenarios which describe the use of armed forces possible to create in given time.

In the next stage, based on organizes set of scenarios a set of tasks is created. As a result, capabilities that armed forces should possess in order to manage defined variants of their use are created.

The list of capabilities is comparable to the potential (abilities) of armed forces and restrictions that can influence their achievements. Consequently, the list of capabilities with the exact description of every one of them is formed. It can happen that the potential of armed forces, even with the existing restrictions, is able to achieve defined capability, however, it is also assumed that there are some capabilities, which require acquiring of additional resources. In the second case, an operational program is formed, which task is to fulfill the requirements essential to achieve developed operational capability. The final result is a presentation and defining of those capabilities that potential of armed forces is unable to achieve in a given time.

Decisions on which capabilities should be developed and on what level and for how long must involve satisfying current needs, the realization of projects and programs (ex. in the field of researchers and technology), as well as financing (ex. conducted scientific-development researches).

Every capability has its own lifecycle, which management should be crucial in terms of planning process and programming of the armed forces' development. There are various capabilities, like one-time capabilities, short-term capabilities, and capabilities that must be maintained and developed for a longer time. They are often interfusing with each other i.e. they influence each other and should not be examined separately. The main issues are prioritization. That is an ability to define not only crucial aspects of operational capabilities but also to compile their hierarchy. Fig. 2. describes a simplified scheme of prioritization process of operational capabilities.

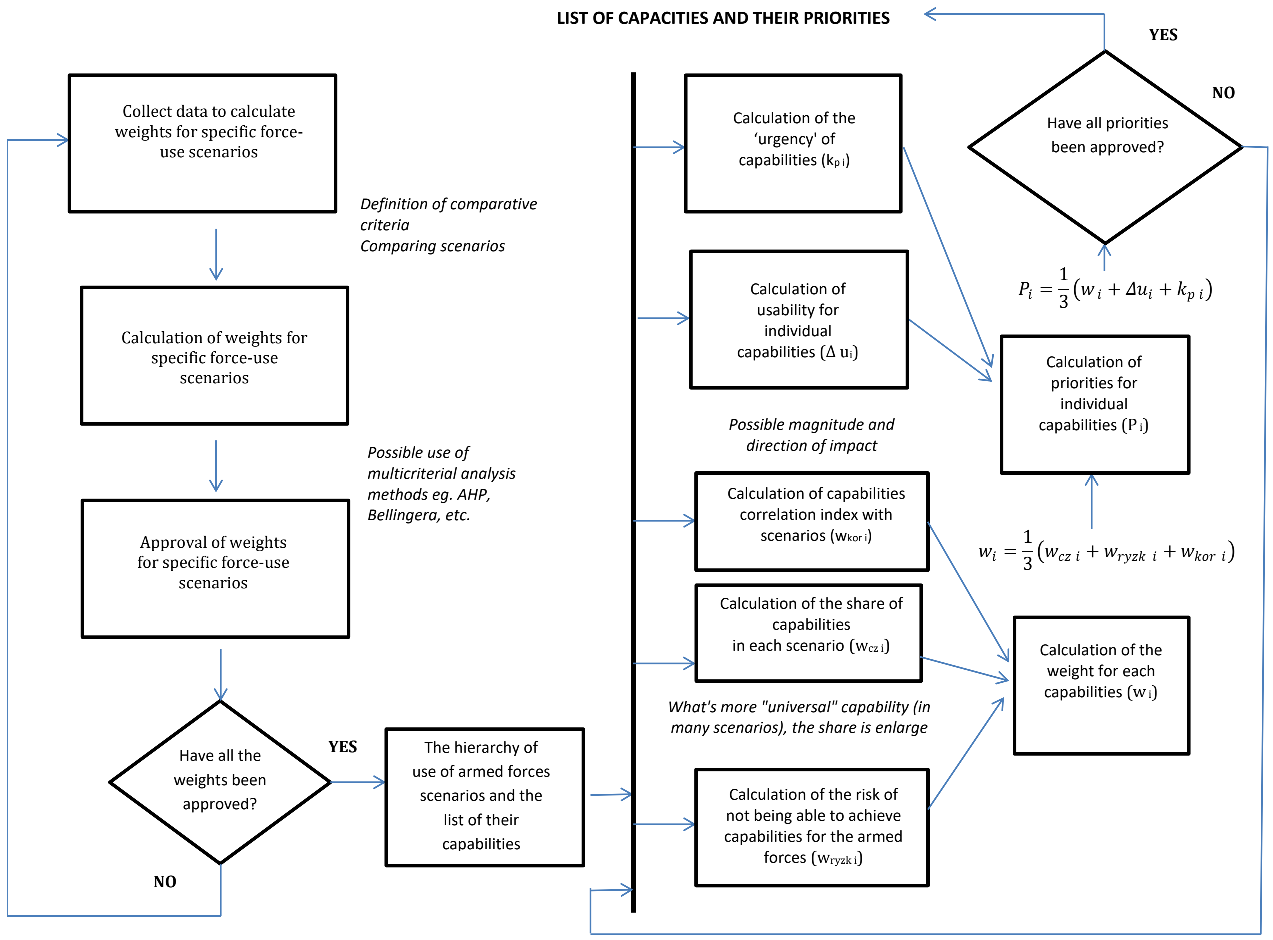

Fig. 2 Schema of capabilities prioritization process [11]

From the set of the capabilities arises particular needs that must be fulfilled in order to accomplish given ability. Operational needs is an identified set of needs in matters of achieving assumed operational capabilities of The Polish Armed Forces, which is developed based on planning scenarios and calculation modules. The realization of (material and non-material) tasks, activities, and undertakings that ensure the operational capability of Armed Forces guaranteeing the effective accomplishment of depicted tasks and assignments [2]. Fig. 3 describes a simplified example of capability accomplishment.

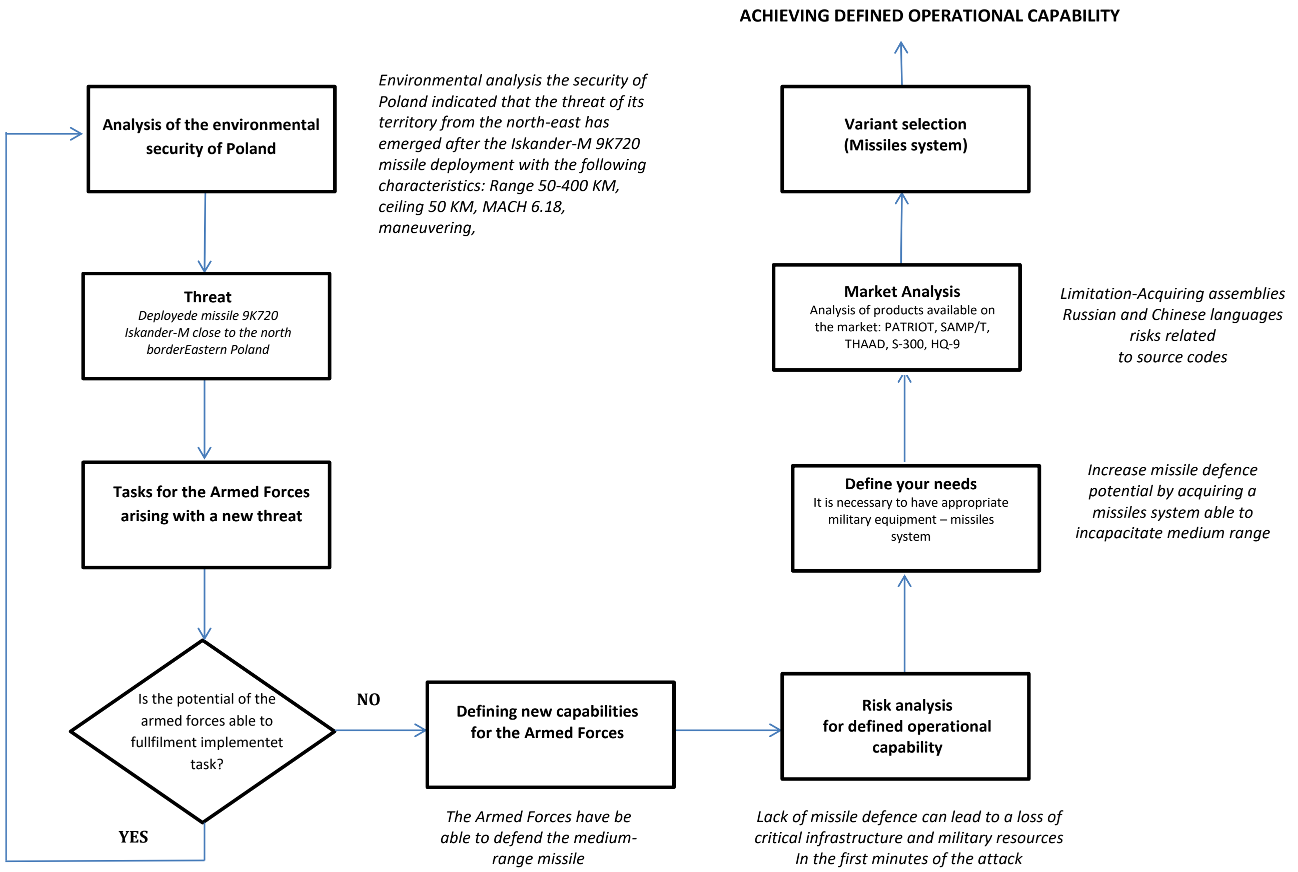

Fig. 3 An example of an operational capability process [11]

The purpose of determining operational needs is i.a. to depict the optimal requirements for military equipment that would ensure the realization of tasks, as well as achieving required goals, often difficult to predict.

The accomplishment of the specific capability, and therefore defined needs, can be realized in the material (ex. purchase, modernization of military equipment) or non-material way (ex. training and workshops).

3. The Example of Achieving Operational Requirements Through Assessment and Selection of Military Equipment

Below, there is an exemplary way of achieving capabilities by Armed Forces, which is the capability of anti-missile defence of the medium outreach. In order to achieve such defined capability, there is a need to possess Air Defence System that would be able to increase the potential of Armed Forces in the matters of anti-missile defence. As a result of market analysis and adoption of restrictions, it was decided that four sets (Fig. 4.), available on the market, would be evaluated. The parameters are described by Table 1.

Fig. 4 Evaluation missile systems [3, 4]

Table 1

Overview of the missile systems accepted for evaluation

Feature [i] / Missiles system	K_1 Operating range [km]	K_2 Threshold [m]	K_3 Speed [Mach]	K_4 Overload [G]	K_5 Weight [kg]	K_6 Fire azimuth [^{0}]	K_7 Number of launcher [Pcs.]
W1. Patriot PAC-2	160	24000	5	30	900	90	4
W2. Patriot PAC-3	160	20000	5+	30	320	90	16
W3. STUNNER	250	25000	6	60	350	360	12
W4. Aster-30	120	20000	4,5	60	510	360	8

Source: [3, 4]

Using algorithm of PROMETHEE II method, depicted on Figure 5, we can estimate compared variants. The final rank is described in Table 2.

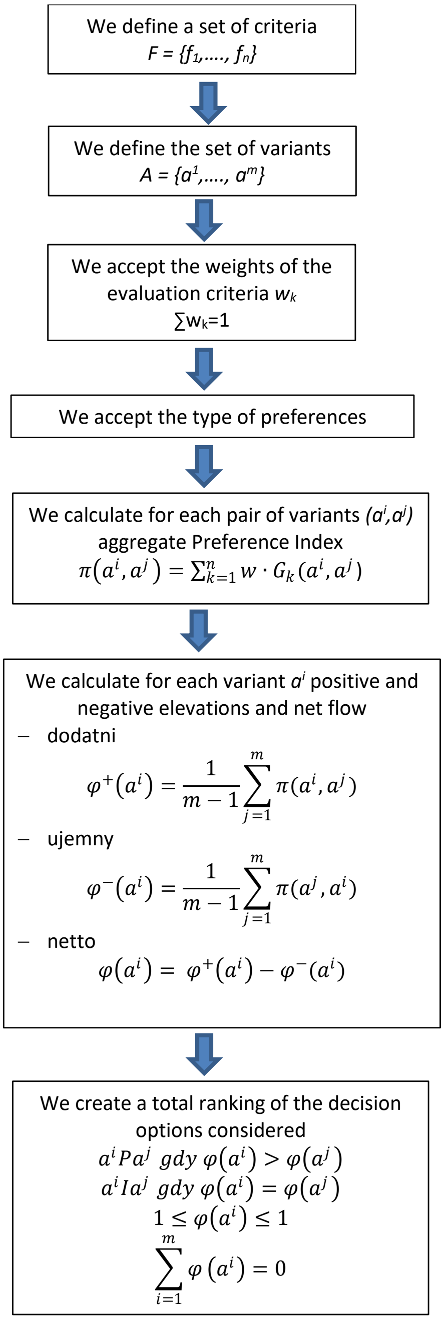

Fig. 5 Algorithm for evaluating military equipment using the PROMETHEE II method [13]

Table 2
A summary of the total evaluations
of the missile systems

Missile systems	$\Phi(a^i)$	Ranking
W1. Patriot PAC-2	- 0,13	2
W2. Patriot PAC-3	- 0,17	3
W3. STUNNER	**0,53**	**1**
W4. Aster-30	- 0,23	4

4. Conclusions

Meeting operational requirements is one of the elements of the national security system. This is crucial because well-defined capabilities are the basis for defining operational needs. One of the possible ways to achieve that is to obtain defence technologies. In order to make it possible, multicriterial methods must be used that would simplify estimation, comparison, and selection of defence technology, which is a way to accomplish operational requirements. Selection of the right defence technology has an impact on the functioning of the Armed Forces, and thus on the level of the national security system. It is also worth noticing that meeting operational needs does not only refer to the acquisition of defence technologies but also to create appropriate conditions for its use in an operational environment.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

The Issue of Parking Areas Conditions in Surrounding of Logistics and Production Facilities in Slovakia and Poland

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Abstract

The paper deals with the issue of trucks parking in logistics and industrial areas of companies, which is a problem occurring in several countries. Herein, the study of situation is given for Slovakia and Poland. In the paper, the parking policy and chosen domestic acts in these countries are studied. The paper contains references to real problems related to parking alongside selected logistics facilities in both countries. The surrounding of logistics and production facilities were researched during field tests in Slovakia and with use of Google maps and Google street view in both countries. Based on all the research, the actual formula for daily needs in number of parking lots is given.
KEY WORDS: *road transport, parking area, parking lot, freight vehicle, truck*

1. Introduction

The issue of trucks parking in logistics and industrial areas is a problem that occur in several countries. Not all companies that are the estuary or source of freight flows consider the issue of the construction of parking area next to the facility. This problem situation is more pronounced in case of old-time-long functioning companies. However, some newly built industrial companies do not have any parking spaces for trucks when these drive into an enterprise's area. Often, these types of operations also require adherence to time windows prior to loading or unloading operations. In practice, it is often encounter the fact that companies are not interested in complying legislation. This means that compliance with the driver's driving legislation is left exclusively to the carrier. As an effect, companies often rely on public parking places. But public car parks for road freight transport are insufficient across Europe [15, 9].

Because of lack of parking policy for trucks from the point of view of companies, the congestion, the restricted entry to the premises and the parking of trucks on public roads and threats of non-compliance occur. However, it should be remembered that there are many companies or logistics centers that have sufficient secure parking for trucks. Some of them are mentioned later on in the paper.

This paper is also based on authors' research conducted in Slovakia and Poland on specific cases. These cases were connected to the entry of trucks into logistics and industrial areas. Arrangements of work drivers of road freight transport were also included in deliberations, accordingly to set timetables for transport, including freight operations [4]. It is done, because logistics managers in logistics and industrial enterprises should have in minds the requirements of Regulation of the European Parliament and the Council no. 561/2006 [13]. Designers should have the number of parking spaces for the semi-trailers to design. The authors of this paper suggested to calculate the necessary number of parking places for the tractor trailers and semi-trailer sets based on their research.

2. Study of Road and Urban Transport

2.1. Study of Road and Urban Transport for Mondi SPC. a.s. Ruzomberok

The study deal with the problem of entering trucks into the premises of the company. The main goal was to shorten the waiting time for entering the enterprises' area and the time of stay inside the company [1]. Field tests in the chosen company were conducted due to analyze current situation connected to parking in company's area. The purpose of the field test was to obtain input data for a deeper analysis of the time course of freight traffic, the time spent by these vehicles on each load-related activity, and also for the input gate load analysis.

During the field test, the following time intervals were measured:

- vehicle turnover;
- time spent next to warehouses;
- vehicle turnover next to warehouse;
- waiting time before freight loading;
- freight loading time;
- waiting time after freight loading.

The turnover of all vehicles arriving for loading and unloading operations was measured. In overall, 51 vehicles were observed as entering and also leaving the company. Within the observed vehicles, the minimum time of turnover represented 39 minutes and the maximum turnover time was 4 hours and 9 minutes. The average turnover time was

2 hours and 5 minutes.

If large companies do not address the logistics of entry and parking of freight vehicles incoming into the company, the problems with traffic congestion or violation of social legislation (mainly in terms of adherence to daily and weekly rest periods) may occur. The problems with violation of social legislation arise mostly as a result of waiting time before loading, blocking public roads and staying in the company premises. The output from the expert study was a proposal to change the organization of entry and parking in front of the company. Other proposals included placing the second scale for weighing vehicles at the exit and changing the system of vehicle routing inside the company area. One of the proposals was successfully implemented and it contributed to improving the logistics of entry of freight vehicles into the company.

2.2. The Issue of Truck Parking at KIA Motors Slovakia

At present, 24-hour operation is common in large production plants. Freight transport is directly related to production. Such companies need to be given high freight traffic.

Another study that deals with this issue was given in the paper [2]. In this paper the authors dealt with parking places in KIA Motors Slovakia. Appropriate parking areas for trucks in the vicinity of the company have been investigated. The authors have found that there is a significant absence of such parking spaces around the enterprise. Also, the nearest landing station (truck station) for trucks is approximately 25 km from the enterprise. At this station there are only 12 parking spaces for tractor trailers and semi-trailers. Also, near the city of Zilina, there is no planned motorway stop where they could park the semi-trailers and, depending on the time windows, shift to loading or unloading into KIA Motors Slovakia. The vehicles are therefore parked around the plant area (industrial area). The authors then proposed a theoretical formula for calculating the number of parking places for trucks. This formula was designed from field test for KIA Motors Slovakia and published in slightly different form in [2].

The mentioned research were based on two traffic field tests. The first was to examine the intensity of trucks on the entrance and the exit to the facility area. This test lasted 24 hours and were connected to monitoring of all 4 entrances to the KIA Motors Slovakia company. The data for N_3 category vehicles (Category N_3 – vehicles used for the carriage of goods and having a maximum mass exceeding 12 tones [8, 12]) were used for the field test.

The next part was a field test that examined the number of N_3 vehicles parked in the vicinity of the company. The second test found the number of vehicles (incoming and outgoing) that taken into account weekly and daily rest of drivers.

Subsequently, the following formula was established:

$$PPM = I_{mean} + \frac{PV_{DO}}{k_{pd}} + PV_{TO} \cdot k_{pt} = \frac{\sum_{n=1}^{N} I_n}{N} + \frac{PV_{DO}}{k_{pd}} + PV_{TO} \cdot k_{pt}\,,\ \ n = \overline{1, N}\,, \tag{1}$$

where: PPM – necessary number of parking lots per day; I_{mean} – mean value of vehicles intensity on entry in 2-hour intervals [vehicles]; I_n – value of intensity of entry of vehicles in 2-hour intervals in the case of n-interval [vehicles]; n-number of 2-hour intervals; PV_{DO} – number of vehicles, drivers of which draw a daily rest period [vehicles]; k_{pd} – coefficient of the use of a parking space by vehicles, the drivers of which take daily rest periods (value of the coefficient is individual for a company); k_{pt} – coefficient of the use of a parking space by vehicles, the drivers of which take weekly rest periods (value of the coefficient is individual for a company); PV_{TO} – number of vehicles, drivers of which draw a weekly rest period [vehicles].

Formula (1) is modified and updated version of formula given before in [2]. It must be underlined that the coefficients k_{pd} and k_{pt} are individual per companies. The proposed formula will be improved further. The authors of this paper will use this formula as a basis for further research and its own improvement.

2.3. Legislation on the Construction of Parking Areas for Trucks in Slovakia and Poland

2.3.1. Legislative Conditions in Slovakia

Firstly, we will deal with the legislative conditions of the construction of parking areas for trucks in Slovakia. There is Slovak Technical Standard STN 73 6110 [14] which regulates parking and parking policy. However, there is no regulation in the Slovak Republic which would give instruction to the production companies in order to design parking spaces for its construction. Therefore, it is necessary for companies to build parking areas in the construction of the complex on their own. The most appropriate alternative is to incorporate this obligation into a regulation or technical standards.

2.3.2. Legislative Conditions in Poland

In Poland, there is a similar situation as in Slovakia. According to authors best knowledge there are no actual regulations that would require the company to provide parking spaces for trucks. [5] However, the Ministry of Building and Industry has issued a document on in-plant design. This document helped the company properly design in-house communications and parking areas [11]. It can also help the whole process of introducing the obligation to build parking

spaces for trucks, however it is outdated documentation and some parts of it needs to be actualized.

2.4. Research on Parking at Logistics Centers in Poland and Slovakia

2.4.1. Logistics Centers in Poland

Logistics centers are an indispensable part of freight transport. This is the reason that authors decided to explore the possibilities of parking trucks in the vicinity of such centers.

In Poland, 77 logistics facilities called as logistics centers were selected and examined around Warsaw. All these centers were selected with use of the platform [16]. These centers were investigated at first through Google maps where parking areas were checked in order to overwrite whether it exists or not. With use of Google street view [7], additional research has been carried out to target vehicles on public roads. Data given on map are referred to 2018. The results are shown in Table 1. In case of 16 so-called logistics centers, it was not possible to find these logistics facilities by use of Google maps [6] or Google street view [7], although the platform [16] offered the exact address and lease of storage space.

Table 1

Effects of the on-line analysis of logistics centers in Poland

	Parking place in a given number of facilities	**Separate parking place for trucks**	**Parking of vehicles on public roads (street view)**
Number of warehouses	61	3	1

While maps and websites review, it was found that 77 logistics facilities could be explored from 77 logistics centers. Parking spaces for trucks inside the premises had all 61 centers. Three logistics centers (Logicor Teresin, Centrum Logistyczne AB Logistyka and P3 Błonie) has the dedicated parking lot for trucks. Parking of trucks outside the premises was found only in one center (Ursus Logistic Center) but only in small quantities.

The maps and websites review showed that logistics centers have built up sufficient number of parking areas for trucks in the area of the company. Therefore, it is not necessary for vehicles to park outside the premises. Some centers have parking facilities for trucks outside their premises as well. This good parking policies can be attributable to the very essence of the logistics centers. They may also be affected by their later construction and the need for parking facilities for freight transport.

2.4.2. Logistics Centers in Slovakia

The survey in Slovakia was carried out in the same way as in chapter 2.4.1. The only difference was the choice of logistics centers. Since there is no web browser for the facilities in Slovak Republic area, which brings together most of the logistics centers, the authors proceeded from the paper [3]. In the case of Slovakia, 41 logistics centers were examined. One logistics center could not be identified by use of Google maps [6]. Results of analyses are given in Table 2.

Table 2

Effects of the on-line analysis of logistics centers in Slovakia

	Parking place in a given number of facilities	**Separate parking place for trucks**	**Parking of vehicles on public roads (street view)**
Number of warehouses	40	8	1

Field tests revealed that all logistics centers have parking places for trucks in their parking areas. Another 8 centers have a separate parking place for trucks. At one center (Europa logistik, Zvolen), parking of vehicles on public roads was also found.

Previous investigations of parking areas at logistics centers in Poland and Slovakia were as follows. Of the 101 centers reviewed, there were a sufficient number of parking areas in case of 99 companies. Out of the total, 11 parking lots were available outside the companies areas. Only at two centers, parking was available on public roads.

2.5. Research of Parking Spaces at Large Production Companies

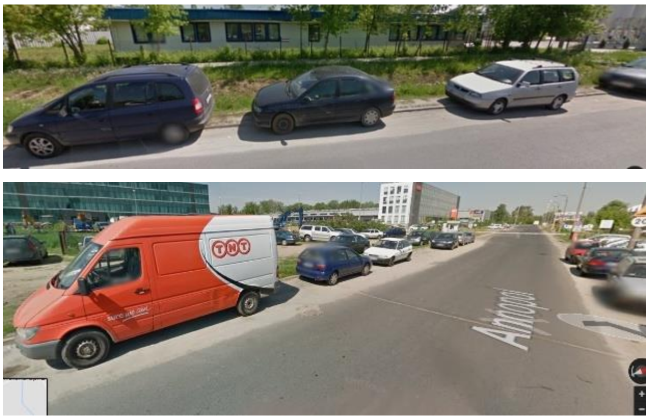
Research of parking spaces for trucks at logistics centers has identified only very minor drawbacks (see Chapter 2.4). Therefore, the authors have focused on other types of companies. This chapter deals with the research of car parks at seven companies producing cars. In addition, two other production companies Reckitt Benckiser (PL) and Coca-Cola HBC Poland Sp. z o.o. were analyzed. The research was carried out in a similar manner as in chap. 2.4 The survey results are given in Table 3.

Table 3

Survey of factory-owned car parks

	Parking place for trucks in object	**Separate parking place for trucks**	**Parking of vehicles on public roads**	**Parking place for cars**
Volkswagen Poznan sp. O.o. (PL)	yes	yes	no	yes
Opel Manufacturing Poland sp. z o.o. (PL)	yes	yes	no	yes
FCA Poland S.A. (PL) (Fig. 3)	yes	no	yes	yes
Škoda Auto a.s. Mladá Boleslav (CZ)	yes	yes	no	yes
Volkswagen Slovakia (Fig. 4)	yes	yes	yes	yes
PSA Slovakia s.r.o.	yes	yes	no	yes
KIA Motors Slovakia (Fig. 2)	yes	no	yes	yes
Coca-Cola HBC Poland Sp. o.o. (Fig. 1)	no	yes	yes (cars)	yes
Reckitt Benckiser (PL)	yes	yes	no	yes

Some more substantial problems with trucks parking have been identified while exploring these research. In the case of Coca-Cola HBC Poland Sp. z o.o. the parking of passenger cars was detected on public roads (Fig. 1). As far as the following companies are concerned, such as: KIA Motors Slovakia, Volkswagen Slovakia, FCA Poland S.A., they have extraordinary problems with truck parking (Figs. 2-4). Volkswagen Slovakia also has a parking space deficit for passenger cars not only parking lots for trucks. No other public car parking lots were found in other car parks. The parking policy of trucks must continue to be tackled in authors opinion. Problems connected to trucks parking can be seen in all figures given in the paper.



Source: [7]

Fig. 1 Coca-Cola HBC Poland Sp. z o.o.

Source: [2]

Fig. 2 KIA Motors Slovakia

Source: [6, 7]

Fig. 3 FCA Poland S.A.

Source: [7]

Fig. 4 Volkswagen Slovakia

Based on the Table 3, the following proposal can be stated. The Table 3 is a proof, it is worth to examine Polish situation and – after some improvements – to implement it in Slovakia. That will be a matter of future research as well as the development of formula (1). It is worth to consider some analogies to other logistics facilities design, as warehouse design. In future research, the analogous transfer method can be used for transferring inventory way of calculation used in warehouse design method into number of parking lots. This way is given as formula (2).

$$PPM_Y = k_{RR} \cdot \frac{S_Y \cdot N_D}{D_Y} + INV_R\,, \tag{2}$$

where PPM_Y – necessary number of parking lots per year [places]; k_{RR} – the coefficient of rail and road traffic which indicates what percentage of supplies is realized by road transport (it is because of the fact that this formula is prepared for parking lots calculation for trucks; in the case of KIA Motors Slovakia k_{RR} = 0.6 [16]; the parameter is individual per company); S_Y - structure of annual deliveries / supplies (it should indicate the number of how many vehicles per year entry and exit from company per year; [vehicles/year]); N_D – normative stock in days [days]; D_Y – quantity of working days per year [days/year]; INV_R – reserve inventory of parking lots [places].

3. Conclusion

The objective of the paper was the issue of parking lots' conditions in the vicinity of logistics and production facilities in Slovakia and Poland. The authors have also faded from previous research dealing with similar issues. In the next part of the paper reference was made to the legislative conditions in the field of truck parking in Slovakia and Poland. It has been found that in both countries legislation does not indicate the construction of trucks parking in the vicinity of their premises. The paper also pointed out the problems associated with no or insufficient capacity of parking spaces. These issues also directly relate to social work of drivers legislation.

Authors in the next part of the paper focused on the research of specific companies in Poland and Slovakia. Logistics centers and manufacturing companies have been examined. 61 logistics enterprises were surveyed in Poland. It was found that only in case of one company vehicles were parked on a public road. In Slovakia, 40 logistics centers were

examined. Also, in case of one logistics center, parking was found on a public road. The results of the survey of logistics centers in Poland and Slovakia are presented in tables 1 and 2. It can be said that logistics centers have a sufficient number of parking spaces. This may also stem from the very activities of these companies.

In the next part, the authors surveyed the production companies. Most of them produce cars. Together, there were 9 companies examined in Slovakia and Poland. In four cases, problems were encountered with the parking of both trucks and cars (see Chapter 2.5).

Under the conditions of Slovakia and Poland, there is no guarantee that projects for the construction of new companies are also focused on parking. The authors have also suggested formulas for calculating the minimum number of parking places by means of previous surveys. The formula is intended to serve as a basis for manufacturing companies wishing to build a new business. Of course, every business has specific characteristics. The exact determination of the number of parking spaces depends on the information provided by the companies. This formula could also be incorporated into legislative conditions, whether in the Slovak Republic or Poland.

Acknowledgements

This paper was supported by the statutory work of Educational and Scientific Team of Modeling and Diagnostics of Technical Means of Transport (Faculty of Transport, Warsaw University of Technology), year: 2018.

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Proceedings of 22th International Scientific Conference. Transport Means 2018.

Hybrid Passenger Rail Vehicles the Improviness of the Accessibility of the Rail Public Transport

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Abstract

This paper shows an economic analysis for usage of passenger rail vehicles with the combined driving. As base for the analysis an example of the Lower Silesia Region in Poland was. For some rail lines, the usage of the hybrid passenger rail vehicles is suggested. For these lines, the economic analysis of usage was performed.
KEY WORDS: *hybrid passenger rail vehicles, accessibility, rail public transport*

1. Introduction

The economy of exploitation of passenger rail transport is typically based on relation-ships between incomes and outcomes and an easement of public transport. The problem of public transport is based on analysis of punctuality or coordination transfers of passengers between modes of transport. That is start point of analysis for engineers of transport. For logistics of transport, it is not enough for analysis. Logistics specialists analyse many criteria of the subject. This paper makes an attempt to show a relationships between used technology of transport and effects of its exploitation for many users. This analysis will based on situation of Poland.

2. The Dual Mode Rail Passenger Vehicles

The concept of use a dual mode rail passenger vehicles is not new. A very good ex-ample is a design by Polish engineer Ludwik Eberman (1885-1945) from 1925. He designed an electric locomotive ready to receive power from the catenary with diesel engine with electric generator for use on the electrified and non-electrified railways (Fig. 1) [2].

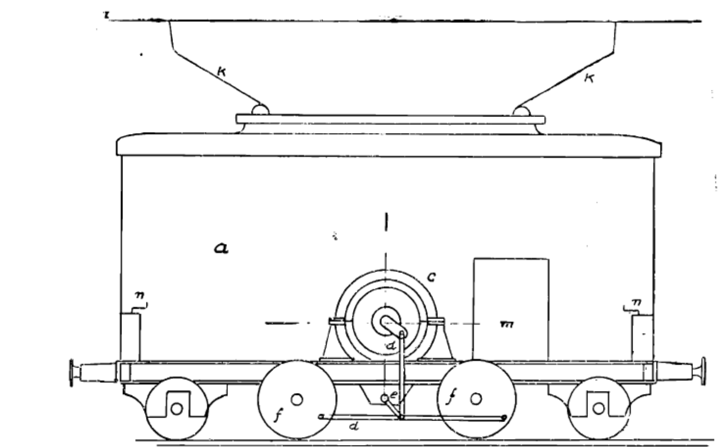

Fig. 1 Design of Ludwik Eberman patent from 1925 [2]

Today we can see these kinds of vehicle on several railways. In the USA in the New York City region since 1956, dual mode locomotives have been used for hauling passengers trains of the electrified and non-electrified railways.

Their motivation for using this new solution in 1956 was the limitation of emissions of smoke from steam locomotives and desire to have high speed trains for passenger service in the New York City agglomeration on electrified and non-electrified railways [10].

In Poland was designed a conception of the diesel locomotive with the hybrid drive system. This project propose to use of high capacity modern construction of accumulators or the fuel cells [8].

In Spain, 15 trains of the high speed class RENFE 730 have been used since 2012. These trains were rebuilt from the classic train type RENFE 130 with two generator cars per set using MTU 12V 4000 R43L engines (1.8MW each). The top speed in diesel mode is 180 km/h [4].

In Spain, the motivation for use was the desire to expand the high speed passenger trains on the non-electrified railways. The classic only electric vehicles class 130 could not serve several cities linked with non-electrified tracks

[11].

From last year’s we have three news.

The first is that the Italian railway in the Aostatal region ordered five dual mode Stadler Flirt-3 vehicles worth 43 million euros. These vehicles will be used between Aosta and Turin [1].

The second is information that the NEWAG rail company got an order from The National Centre for Research and Development to build a bimodal Rail Power car project for classic EMU vehicles. This rail power car can power the classic EMU in electric current on the non-electrified tracks and can be separated from EMU if it is used on the electrified tracks. That may reduce mass of EMU and reduce costs of its exploitation [6].

The newest is information that the Vossloh CityLink electro-diesel tram-train will operate from the existing tram network’s 600 V and 750 V DC overhead electrification around the Chemnitz city in Germany, changing to diesel to reach Burgstädt, Mittweida and Hainichen along railway lines [3].

3. Definition of the Problem

The main problem of the costs of the punctuality of rail vehicles for passengers and transport companies is the delay. The stealing of the metal elements from the rail tracks have generates the very high economic losses and destroy of the punctuality of trains. The bad coordination of the transfers of passengers with change of the trains on the journey from the electrified to the non-electrified railways may generate of the next delays and costs. The passengers have expect with the rail transport of the punctuality and territorial availability and also comfort of journey. The passengers which have the delay may expect the financial decompensations from the transport company. This generates the economic losses for company. Another aspect is the image of transport company.

This may generate a question: is it possible to protect against these events?

Here are several possibilities: the first is high punishment for stealing of metal elements. We can seek the possibility to change it in the of law regulation. Big penalty is a possibility to reduce but it cannot help passengers if these events will happened rapidly.

Another possibility is the use of rail vehicles prepared for exploitation on the electrified and non-electrified railways. The main problem with this is inadequate knowledge and economic analysis of exploitation of the hybrid passenger rail vehicles.

4. The Questionnaire

The subject of coordination transfers of passengers has been known since the first use of rail transport to carrying the passengers in 1830. Thus, analysis from many books from the 19th and 20th centuries describes main problems of coordination of passenger transfers:

a) displacement of platforms for better communication for passengers which changed a train to go for other direction:

– on the same category of two or more main rail lines;

– from main rail line to the secondary rail lines.

b) displacement of platforms on railway station and accompanying other modes of land transport:

–for tramways and buses in cities;

– for horse carts- fiakr’s, and later motor vehicles- buses and taxis. A very good example is the image from Mierszów city in Low Silesia. Here one can see a several horse light carts waiting for passengers from a train from Wrocław [9].

c) time distances of leaving of trains for realization the transfers by passengers which is strongly connected with knowledge of the designing of structure of the railway station and is a base for analysis of coordination transfers of passengers.

An example of the Lower Silesia region shows that even if the structure of the rail-way station was good the main problems for passengers had been:

d) time distances of leaving of trains for realization the transfers by passengers if the arriving train is delayed;

e) non-respecting by railway staff the rights of passengers for coordination of transfers in different categories of railway lines, a coordinated train left the station before a delayed train on higher category line arrived;

f) bad planning of the timetable for transfers of passengers, the bad example is the timetable from Lower Silesia since June 2015 to December 2015 on coordination between directions on station Wałbrzych Główny to Wrocław Glówny to the direction to form Kłodzko Główne. On free days, there were four trains between Wałbrzych Główny to Kłodzko Głowne. The time distances of leaving of trains only for three was been coor-dinated with arriving trains from Wrocław Główny. The total time of the journey to station Bartnica was about 2:20. The first train to Kłodzko Głowne KD 69390 left station Wałbrzych Główny at 6:48. The first express train TLK 26222 from Wrocław Główny ar-rived at station Wałbrzych Główny at 7:05, the passenger train KD 69865 arrived at 7:42 or 8:00. In effect, the total time of journey to station Bartnica has been about 8:06 [14]. Many passengers said that was “the effect of the butterfly” of reconstruction of one railway bridge in Wrocław on Grabiszyńska street.

5. Problems with Reliability of Railway Infrastructure

The another subject are the problems of the reliability of the railway infrastructure linked with the stealing of the

metal elements from the rail tracks. The stealing of the metal elements from the rail tracks is unexpected events. It generates a big problems with the continuous activity on the operational region for the passenger transport company.

The reliability of the railway infrastructure can be defined as realization of the expected goal on the expected track and time. The previous analysis showed that if accidents are unexpected events the main problem is with stealing of the metal elements from the rail tracks. Between 2009 to 2014, an increase in the number of stolen metal elements was observed, which generated high economic costs of their repair (Fig. 2)

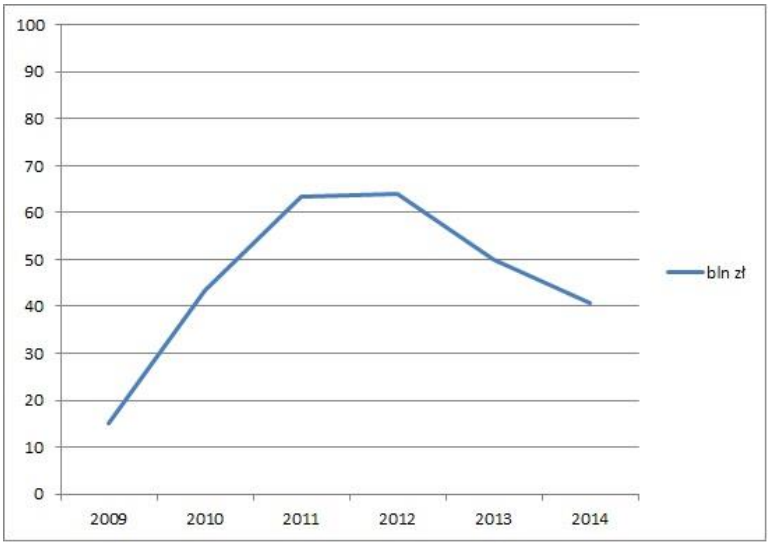

Fig. 2 Economic cost of reparation of the railway, telecommunication end energetic infrastructure in millions of PLN [15]

The stealing of the metal elements from the rail tracks generated a high number of hours of delays of passenger and freight trains. In 2010, all kinds of trains had 107 729 minutes of delays, in 2011 had 176 685 minutes of delays and in 2012 had 184 258 minutes of delays [5]. Only in 2012 the number of trains with delays were 8 thousand of passengers and 1.4 thousand of freight which cost 30 million PLN [16]. Over 1 million of passengers experienced the delays [7].

Damage of the main rail tracks needs to protect of continuation of journey for the passengers by the passenger rail company. Is needed to rent of the busses for bypassing of the failed part of rail tracks. Another possibility is usage of the another rail track. Many times the another rail line is non-electrified. it needs from the railway operator to possession of two different kinds of vehicles. Many rail passenger companies have a diesel and electrified vehicles. It generates a high costs of their maintenance separately. Is possible to reduce these costs be use the dual mode rail passenger vehicles.

This may generate a question: what is relationships of the costs of exploitation of the dual mode and the classic rail vehicles.

We can seek the possibility to reduce the stealing of the metal elements on the rail tracks is change in the of law regulation. Big penality is a possibility to reduce the stealing but it cannot help passengers if these events will happened rapidly

Fundamental question is the cost of use of rail vehicles prepared for common exploitation on the electrified and non-electrified railways in polish conditions.

6. The Economic Principles of Usage of the Hybrid Passenger Rail Vehicles

As the first step to prepare this part of article I asked the some rail passenger companies about the consumption of electric energy of their electric vehicles and the fuel for the diesel vehicles. No one didn't send me an answers. Later I had the unofficial meeting with manager of one of rail passenger company. This person told me that his company may collect information about the consumption of electric energy only per each 15 minutes from the whole railway network. I's impossible to get the consumption of electric energy for each vehicle separately. Information about the costs of the fuel for diesel vehicles is restricted.

Now we may only to analyze, for find answer of the aim this article, the costs based on the structure of the railway network and on the official parameters of the rail vehicles

In Poland in 2014, there were 11,744 km of length of electrified railway lines. The total number of railway lines was 18,516 km. It means that in Poland of 63.42 % railway lines are electrified [12].

For analysis I chose the region of the Lower Silesia in Poland. Here we have several railway lines important for citizens. The problem is that for their service small diesel rail vehicles are used with not enough capacity for passengers. Many times passengers cannot get onto trains. Another problem is very bad accessibility for their home places with the use of the rail transport. Many rail lines are non-electrified. For continuing the journey passenger must change the mode of transport. Below are examples of these relations (Table 1).

Table 1

Relations of rail directions from Wrocław [11]

	km of total connection	km of non-electrified	km of use of electrified	% of electrification section	Expected time of journey on the electrification section [h]
Wrocław Gł. – Trzebnica,	33,336	22,603	10,733	32,19	0,16
Wrocław Gł. – Jedlina Zdrój	82,166	82,166	0	0	0
Wrocław Gł.- Dzierżoniów Sl.	76,885	27,885	49	63,73	0,44
Wrocław Gł. –Stronie Śl.	125,9	30,9	95	75,45	1,37
Wrocław Gł. – Żary	152	77	75	49,34	1,14
Wrocław Gł. – Kępno	80	46	34	42,5	0,42

As the start point I propose to use a percentage of electrified section of the designed railway line to use. For calculation, I propose to use the concept, a priori, that we will use the regional DMU vehicle with a total mass of less than 60 tons and with the electric trans-mission system of power for the drive engines. The original source of power are two diesel engines with a power of 390 KM each, with medium consumption of fuel about 30 liters per 1 hour of work on 100km on a flat line. For driving on the electrified railway lines, this vehicle has 4 electric asynchronous engines with power of 200 kW each by 120 km/h. For analysis of cost, I propose to accept the cost of fuel of PLN 3.89 per liter, and the cost of 1 kW per 1 hour of consumption of electric power PLN 0.55/ 1kWh. Thus, using a simple calculation we can have a proportion of the costs of usage of the driving (Fig. 3)

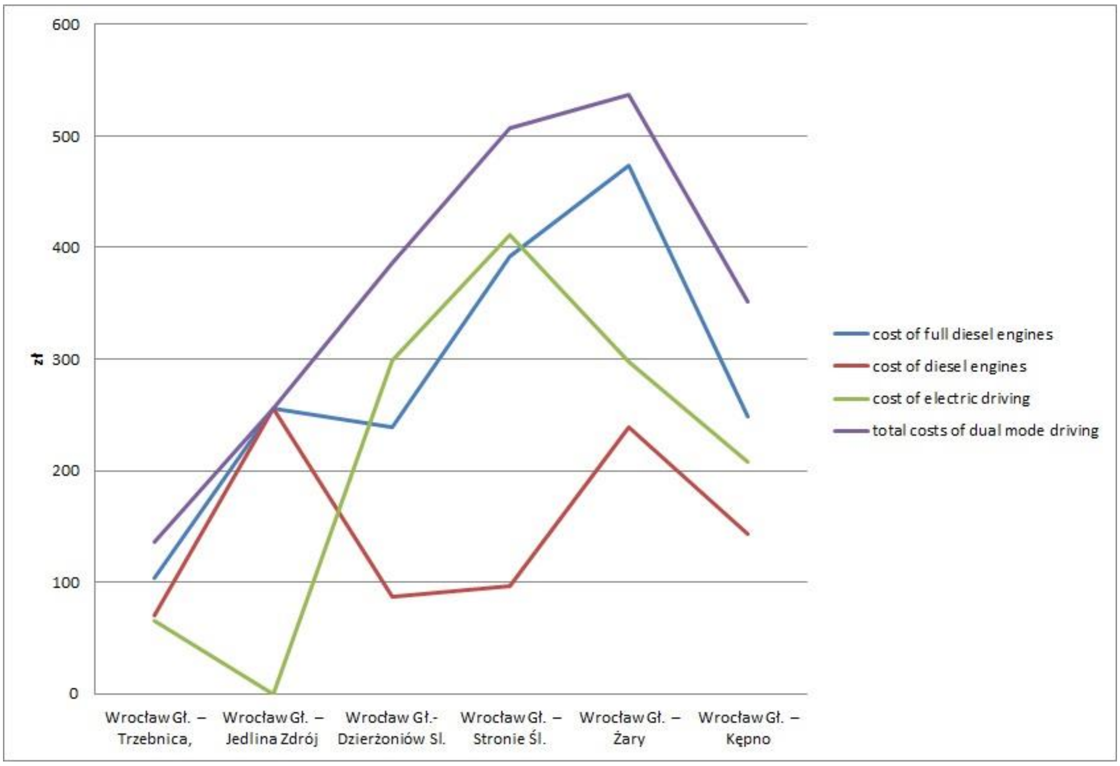

Fig. 3 Proportion of the costs of usage of the driving

We see that costs of driving with dual mode is sum of the each elements of separate driving. This simulation does not contain the costs of entrance for the rail track and cost of creation of the time table for the train what we can order in the owner of this infra-structure - PKP Polskie Linie Kolejowe S.A [13].

The costs are independent from the kind of drive force of rail vehicle. The software of KALKULACJA 2016 does not make it possible obtain the costs of use the electric traction.

7. Discussion

The analysis of results suggests that the total costs of dual mode are more than when a diesel engine is used for each route. That is not fully right. The owners of the infrastructure and railway company who I asked before I wrote this article did not give me any in-formation. Then to take this into account I propose to take the passenger's perspective – the user of railway connection.

If the reader of this article would like to change the passenger car for the train as the first step must go to the rail

station. The next step is buying the ticket. In ticket office the passenger may ask about the time of departure of the train. If the passenger chooses some of the aforementioned routes they may heard that there is no direct connection with the train. That is for relations to Bartnica station on the line Wałbrzych Glówny- Kłodzko Główne through the Jedlina Zdrój and later to Stronie Śl. and Kępno. For Jedlina Zdrój, it is needed to change the train for the second connected with a route to the Wałbrzych Główny station from Wrocław Główny. The presented example of bad timetable planning explains why it is necessary to analyze the direct route. The rail line from Wrocław Główny to Wałbrzych Główny is electrified. The Wałbrzych Glówny- Kłodzko Główne line is not-electrified. To-day, it is necessary to use the second rail vehicle with a diesel engine. A similar situation is on the route to Stronie Śląskie. The rail line Wrocław Główny-Kłodzko Główne is electrified but the Kłodzko Główne – Stronie Śląskie route is not. the same situation can be observed on the route to Kępno from Oleśnica.

These situations make it necessary for passengers to buy a second ticket for the bus. This generates higher costs of the journey. Of course the usage of the dual mode vehicles is on the first time cycle, 5 years, much more expensive than the separate use of modes of transport. The good reasoning is the law rule for the local government to non-exclude the citizens on the region from the good accessibility to the public transport.

Other problems include disturbances caused by stealing metal elements from rail tracks. The resulting losses are shown above. Thus the usage the dual mode rail vehicles is possible to reduce the influence of these events. Classic EMU vehicles should be equipped with a small diesel engine with small power mounted below the floor. This causes a small reduction of the space with the lower floor in the vehicle. This solution may help to move the EMU from the section of the rail line where is damage of the electric traction to the closest station where is the reliable electric traction. This also may help under time of maneuvers in the rail depot. This kind of the electric rail vehicles with the small diesel engine could be called as the EMUd.

The full dual mode vehicles should be used in the regions with combinations of the electrified and non-electrified railways. In Poland, they are outside the agglomerations of the Warsaw and Łódź where all rail lines are electrified. That may help to improve accessibility for the rail public transport.

When we start analyzing the economic principles of the usage of the hybrid passenger rail vehicles at first we should take the point of view of the citizen – the potential passenger for the public transport in the region. Thus good transport communication generates good accessibility for many places in the region. In the total costs of usage of the hybrid passenger rail vehicles for the public transport the priorities are commonness of access, acceptable price and satisfactory travel time. Fulfillment of these conditions results in an increased demand for rail public transport. This reduces the overall cost of operation.

8. Conclusion

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Evaluation of Injuries Caused by UAV Propulsion Units from a Physiological and Legislative Point of View

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Abstract

The aim of the article is to introduce a medical analysis of injuries caused by propulsion units installed in unmanned aerial vehicles (UAVs) and assess whether the current classification of the UAVs by the Czech legislation is appropriate from the safety point of view. Correspondingly, such evaluation is done also with respect to legislation of the European Union. Since the experiment methods and initial evaluation were discussed in a preceding paper, the article summarizes its most important findings in the introduction part. Afterwards, the medical injury analysis and a brief description of treatment procedure are provided focusing on to what extent the injuries are serious and what treatment is necessary in case a person has been wounded by UAV's propulsion units. Finally, the current as well as future proposals of the UAVs classification are evaluated. Finally, an authors' proposal of the classification is presented with regard to the experiment results and the EASA standards.
KEY WORDS: *UAV, RPAS, injury, categorization*

1. Introduction

This article is already a second one focusing on the UAV testing from perspective of human tissue injury. The preceding article was issued at the beginning of year 2018 and its content is summarized in the following section. The research was initiated by the forthcoming European legislation on the UAVs demanding a categorization based on weight and energy that is absorbed by a human body at the time of collision [1]. The authors of this paper hold a view that such a categorization is not sufficient. Hence, an own measurement was taken in order to determine the extent of injuries of human tissue caused by small and medium UAVs, and demonstrate that, at least, the construction type needs to be considered. The results might encourage considerations whether the legislation, with current or proposed categorization of the UAVs, is appropriate.

2. Summary of Current Research

An article on injuries caused by unmanned aerial vehicles, that has been already published by the authors, primarily focused on description of the powerplant testing using pork flesh and bones to substitute human tissue. Firstly, the current state and categorization of the UAVs was briefly introduced together with the authors' view disagreeing with the mere weight criterion. According to the authors, the UAV categorization should also take in account the construction, the propellers' type and size and so on. The research description published in the article aimed on determining whether such categorization was relevant. The second part then provided information on powerplants' parameters that were used. The weakest combination was 2280kV/5x3" (engine designation/propeller dimension), whereas the strongest one was 400kV/15/5,2". Plastic, wooden and carbon propellers were used in testing. During the static tests the spinning propellers were slowly moved towards pieces of pork legs or ribs. The most serious injuries were bone cuts and muscle skin turns. In the last part of the article, the test results were evaluated [2]. For more information on engines used and injury seriousness, we recommend referring to the first article.

3. Injury Analysis and Treatment Description

This section provides medical descriptions of injuries and treatments. Table 1 shows the type of engine, propeller, tissue sample, injury diagnosis, and proposed therapy. The diagnoses and therapies were determined in association with the Medical Rescue Service in Liberec Region, Czech Republic.

Table 1

Engine specifications, medical diagnoses and treatment therapies

	Engine	Propeller	Material	Sample
Engine specification	2280kV	5x3"	plastic	rump
Diagnosis	Excoriation, without damaging the skin cover. Suspected capillary bleeding.			
Therapy	Sine not needed).			
Engine specification	2280kV	8x5"	carbon	rump
Diagnosis	Excoriation, minor laceration. Injury of the epidermis. Capillary and vascular bleeding.			
Therapy	Disinfection, wound cover.			
Engine specification	910kV	12/6"	wood	rump
Diagnosis	Excitation, epidermis injury. Suspected capillary bleeding.			
Therapy	Disinfection, bleeding coverage.			
Engine specification	910kV	12/6"	wood	ribs
Diagnosis	Excoriation, epidermis injury. Suspected capillary bleeding.			
Therapy	Disinfection, bleeding coverage.			
Engine specification	910kV	8/4"	plastic	rump
Diagnosis	Laceration approx. 2.5 cm. Penetration into the dermis. Capillary and vascular bleeding.			
Therapy	Disinfection, wound cover, tissue glue.			
Engine specification	910kV	8/4"	plastic	ribs
Diagnosis	Laceration abt. 5 cm. Penetration into the dermis. Suspectly por. Subcutis. Capillary and vascular bleeding.			
Therapy	Disinfection, wound dressing, sewing.			
Engine specification	650kV	13/4,5"	plastic	rump
Diagnosis	Penetration into the subcutis, shattering bones without fracture.			
Therapy	Disinfection, wound dressing, sewing.			
Engine specification	650kV	13/4,5"	plastic	ribs
Diagnosis	Penetration into the subcutis, shattering bones without fracture.			
Therapy	Disinfection, wound dressing, sewing.			
Engine specification	920kV	9,5/4,5"	carbon	ribs
Diagnosis	Intrusion into subcutis to muscle tissue, bone fracture, suspected fracture (smaller bones).			
Therapy	Disinfection, wound cover. More complicated sewing, even muscle tissue.			
Engine specification	400kV	15/5,2"	plastic	rump
Diagnosis	Intrusion into subcutis, without fracture, skeleton undamaged.			
Therapy	Disinfection, wound dressing, sewing.			
Engine specification	400kV	15/5,2"	plastic	ribs
Diagnosis	Intrusion into subcutis, without fracture, skeleton undamaged.			
Therapy	Disinfection, wound dressing, sewing.			

4. Analysis of Current and Proposed UAV Categorization

In the Czech Republic, the unmanned aircraft must comply with national aviation regulation L2, Appendix X. With reference to it, the UAVs should be classified according to their weight into four categories. No approach considering the potential seriousness of injuries exists. Below, the current weight-based categorization is listed [3, 4].

- up to 0.91 kg inclusive;
- 0.91 – 7 kg inclusive;
- 7 – 25 kg inclusive;
- over 25 kg.

The European Aviation Safety Agency (EASA) is preparing new legislation regulating the operation of the civil UAVs. Being now in the form of a proposal to be reviewed and approved by the European Council, it is expected to come into force at the end of 2018 or in 2019.

This regulation is going to categorize the UAVs with respect not only to their weight but also, where appropriate, its impact energy. The impact energy corresponds with energy that the body receives from the vehicle at moment of collision. In addition to the weight aspect, the categorization has also 'open' and 'specific' categories making the whole classification more complex. Nevertheless, for the research purposes, it is sufficient to take into account only the following weight or energy categorization [1]:

- up to 0.25 kg;
- 0.25 kg inclusive– 0.9 kg or impact energy 80 J;
- 0.9 kg inclusive– 4 kg;
- 4 kg inclusive – 25 kg;
- 25 kg inclusive– 150 kg.

5. Proposal of Categorization Based on Test Results

For measurements, various types of propellers have been tested so as to cover a wide range of products available on market that are used as the powerplants of the unmanned vehicles and aircraft models. Based on the test results that were obtained, it may be clearly shown that the extent of the injury is proportional to the engine power (in this article, referred to as engine specification and being expressed in kV units). The effect of the propeller type is also significant. The aspect of frequent disintegration of the propellers after impacting the tissue was thus also taken in account. Such propeller pieces may pose a considerable risk to human tissues in a form of injuries.

Table 2

Categorization proposal of unmanned aerial vehicles

Type of frame		**Construction**		**Power unit**			**Propeller**		**Take-off weight**	
Airplane	**2**	Foam	**0**	Electric	more than 3001 kV	**0,2**	Plastic soft	**0,8**	less than 0,25 kg	**0,2**
Helicopter	**3**	Carbon	**2**		3000 - 2001 kV	**0,6**	Plastic hard	**1**	0,25 - 0,9 kg	**0,8**
Multirotor	**2**	Wooden	**1,8**		2000 - 1301 kV	**0,8**	Carbon	**2,5**	0,9 - 4 kg	**1,4**
Glider	**1**	Metal	**3**		1300 - 801 kV	**1,1**	Wood	**1,8**	4 - 25 kg	**2**
		Laminate	**2,1**		800 - 501 kV	**1,5**	Laminate	**2**	25 - 150 kg	**3**
					500 - 151 kV	**2,5**				
					less than 150 kV	**3**				
				Gas	less than 20 ccm	**0,5**				
					21 - 100 ccm	**1,2**				
					101 - 200 ccm	**1,5**				
					201 - 300 ccm	**2,5**				
					more than 301 ccm	**3**				

Table 2 shows a categorization proposal with five elementary subcategories. For simplicity, there is one example of how to work with the table.

Table 3

Categories based on point rating

Category 1	less than 3
Category 2	3,0 - 5,3
Category 3	5,4 - 7,6
Category 4	7,7 - 9,9
Category 5	10 -11,9
Category 6	more than 12

Example: evaluation of an aircraft with the following parameters: laminate fuselage, propulsion unit 1250 kV, carbon propeller, take-off weight 2.8 kg. Each cell of the table refers to a point rating. The points from each column will then be added, i.e. 2 + 2,1 + 1,1 + 2,5 + 1,4 = 9,1. Hence having the point rating of 9,1 points, the UAV belongs to category 4 (Table 3). The relevant legislative frameworks will be further applied on each category.

Table 2 is yet indicative only and is going to be refined within the further research so that it corresponds better with the effective classification. The rating of the construction type and the combustion powerplant has been determined empirically as they were not subjects of the research.

6. Comparison of Categories

The following comparison is done with regard to impact of the UAV on the human tissue. The current categorization used in the Czech Republic is inappropriate to a great extent. The analysis of the results showed that the classification according to Appendix X is particularly vague. In the range between 0.91 and 7 kg there may be vehicles which may cause only minor injuries as well as vehicles that may cause very serious injuries including the fatal ones. The new legislative classification that is being prepared by the EASA is more appropriate in this respect. It is more accurate and considers even the energy transferred from the vehicle to the human body although for a single category only.

Undoubtedly, it is more appropriate than the classification defined in Appendix X. However, in addition to the weight factor, the tests results illustrate that the size and type of the propeller, the propulsion engine size, or the UAV type also greatly contribute to seriousness and the type of injury. It cannot be said that the authors' proposed categorization is more appropriate as there is still a need for dynamic testing when the weight of the whole device will be taken into account. However, it is already clear that the weight and energy distribution would be relevant for all categories and not only for the 0.25 to 0.9 kg category (as proposed by the EASA).

7. Conclusion

The static tests and medical diagnoses show that assigning UAVs to the categories by their weight is insufficient when considering the UAV effect on human tissue. Although covering the factor of absorbed energy by human tissue during the collision with the UAV is a positive step, the authors hold the original view claiming that other aspects such as type of engine, type of propeller, or UAV design should be taken into account. Further research in this area including the dynamic tests planned for the second half of the year 2018 is expected to refine the current results and allow to improve the proposed categorization of the unmanned aerial vehicles.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Increasing of Transport Safety by Using the Intelligent Signalling Device RMS

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Abstract

The contribution deals with increasing of the transport safety in light-controlled intersections in connection with the vehicles with preferential rights of ride. The authors of contribution propose possibilities for implementation of the system of intelligent signalling device RMS, description of technical parameters and operating principle.
KEY WORDS: *light signalling devices, vehicle with preferential rights of ride, increasing of transport safety*

1. Introduction

Well-functioning transport safety is the basis of successful solving of the most extraordinary event and it also affects the current traffic situation. This assumption becomes more important especially in the time of saving human life. The arrival time of the rescuers in the place of an emergency event, respectively the time of transport injured in medical facilities is the decisive factor. The statistics on rescue vehicles' outcomes show that the drivers are most at risk in light-headed crossings. When approaching a privileged drive on crossing, drivers are unable to respond properly and there are the collisions. One of the solutions to increase safety in this situation is the RMS intelligent signalling system. The contribution deals with increasing of the transport safety in light-controlled intersections in connection with the vehicles with preferential rights of ride. [6]

The RMS system is designed as a superstructure of the RMS v.01 system, which is used in the Czech Republic to control the speed of vehicles.

2. Importance and Technical Parameters of RMS

The level of road safety as well as the time of arrival of rescuers at the site of an emergency affects the culture of road users. Arrogance, zero tolerance, aggressiveness of road users, as well as powerful vehicles, inexperienced drivers and inattention, are also issues that drivers of vehicles with the privilege of riding a day struggle on the road every day. Traffic control is very efficient by road traffic light signalling. In order to increase traffic safety in terms of optimizing the arrival time of vehicles with priority driving, the implementation of the RMS system appears to be an appropriate solution. [7]

RMS (Table 2) is a road traffic control system for the passage of vehicles with switched light and sound alarm devices, rescue service, police vehicles, fire departments. It is a very efficient, yet simple, device that signals the countdown of the time for which the vehicle has a preferential rights of ride. The traffic light is complemented by a further part of the additional signalling device, which gradually lights up. On the basis of this activity, the device signals and informs the drivers of the arrival of the vehicle with the lights and audible warning devices on and they are forced to create an emergency stripe for the smooth passage of the rescue vehicles in good time before the said vehicle appears in the intersection. [5]

Table 1

Technical parameters of RMS [3]

Material	UV stable polycarbonate
Dimension	50 x 132 cm
Optical	210/300 mm FUTURLEND
Impact resistance	High
Protection against leakage	Resistance to water and dust
Certified	CE Certificate
Classification of protection	Class II – reinforced insulation
Radar unit	RMS v.01 superstructure

The system for signalling the passage of vehicles with priority driving rights through the RMS crossing is shown in Fig. 1. The traffic light, the switchboards and the actual radar unit will be attached to the column via the boom using fastening straps.

Fig. 1 RMS with time and radar for the vehicle with preferential rights of ride

Radar-controlled light signalling devices RMS is an intelligent device designed to increase the driver's reluctance to respect the preferential rights of ride in cities and towns. Complies with European quality standards, size: 50 × 132 cm. RMS can be adapted to any type of light-signalling device used in Central Europe. It is a very efficient yet simple device that signals the time- for which the vehicle with preferential rights of ride through the section. The traffic light is complemented by a further part of the additional signalling device, which gradually lights up.

3. Principle of Functioning RMS

The safety signalling device consists of four parts of the traffic light signalling device - a red, orange, green, blue and GPS radar. The system operates on the principle of GPS - radar and traffic light signalling devices, which respond to the signal emanating from the vehicle with the preferential rights of ride. The dispatcher of the operation centre, based on the shadow-to-line information collected on line 112, will send the relevant rescue service information. The information obtained is automatically loaded into the electronic mobile device (tablet) located in the vehicle before the trip itself [2].

This device incorporates a GPS that displays the shortest possible route with the activation of traffic lights - traffic lights in the driving direction. The entire system is activated when the light and sound alarm device is switched on. As soon as the vehicle approaches the area covered by the radar, the traffic light of the auxiliary part with the time indicator starts countdown for 2 minutes. Road traffic light traffic is carried out without change until the vehicle with the preferential rights of ride does not exceed the boundary distance, which instructs the traffic light to change its original state. At this point, public transport drivers around the junction can also be centrally notified of the current situation. This system modification can be set up according to the customer's requirements. After leaving the light-crossed junction with a privileged vehicle, the traffic light switches to the normal mode in which it was operating prior to its radar activation [1, 8].

The activity of the attachment is divided into four basic phases (Fig. 2):

Phase 1 - The system has recorded a vehicle with the preferential rights of ride that activates the additional signalling device and starts countdown. In the first phase, it is still possible to pass the road traffic smoothly without interruption, taking into account the formation of the emergency lane within 2 minutes.

Phase 2 - After about 30 seconds, the system alerts public transport drivers (radar sensors) to increase caution.

Phase 3 - The system changes the basic setting of the semaphore. Drivers are required to divert the vehicle on the roadside.

Phase 4 - The system has stopped traffic and has created an emergency strip for the smooth passage of a vehicle with the preferential rights of ride. After passing the vehicle, the blue signal will light up for 10 seconds.

The range of the radar must be set to service personnel based on local conditions and the characteristics of the ground communications. In the event that circumstances do not require accelerated transport, the driver of the vehicle with the preferential rights of ride does not activate the intelligent signalling system and drive as a normal road vehicle.

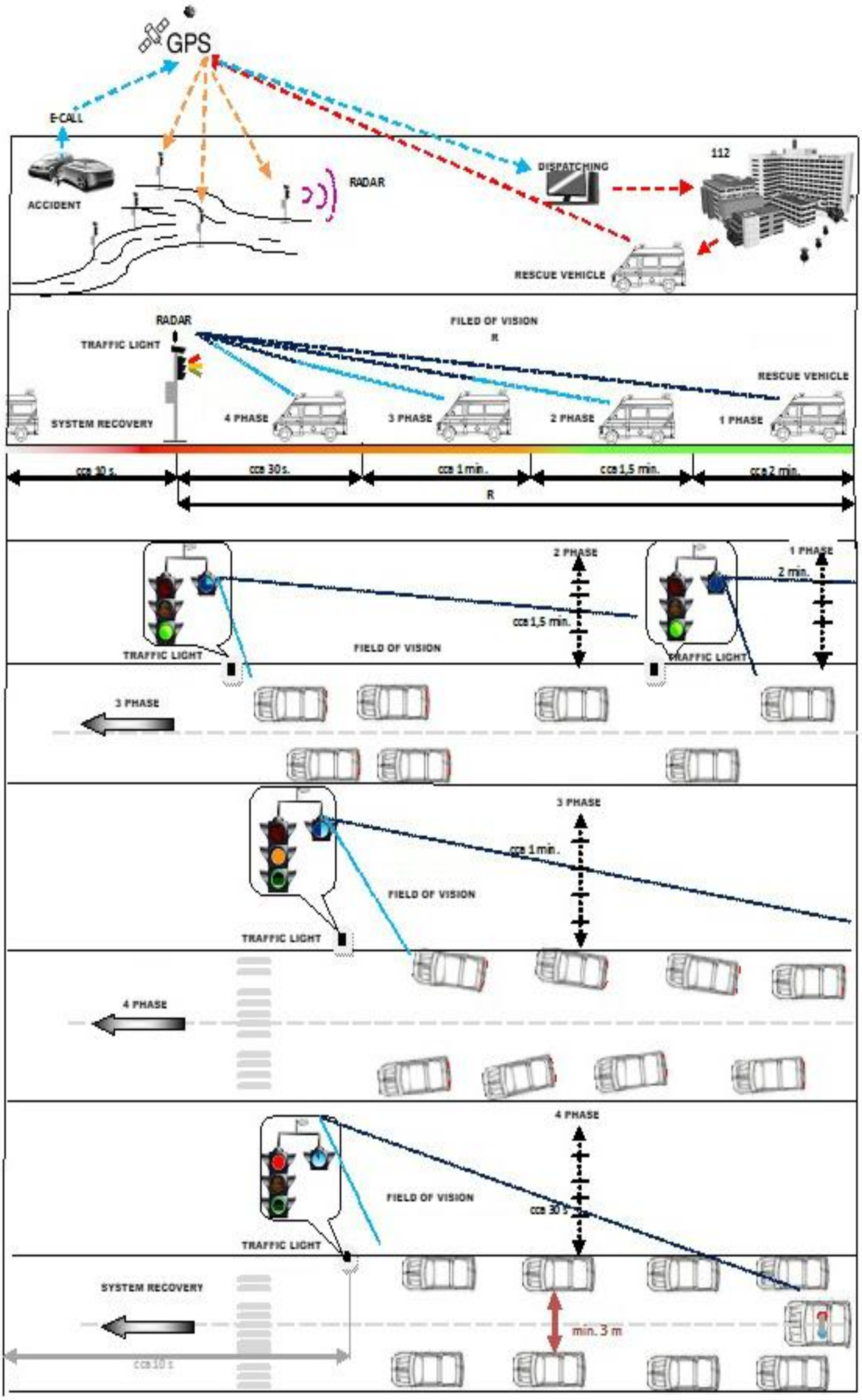

Fig. 2 RMS principle for a rescue vehicle [4]

3. Conclusions

Continuous development of road transport causes overloading of the road network. Continued over time requirements for the capacities of the roads and their facilities are also increasing. This trend is particularly pronounced on roads in densely populated areas. The daily capacity of communications, cross-roads and lack of permeability is becoming a characteristic feature of the road network in the Slovak Republic.

One of the basic preconditions for successful emergency response is to keep the road accessible and safe, to operate and maintain traffic flows in motion and to provide active support to drivers. The introduction of the RMS system can contribute to an overall increase in the efficiency of the exits of vehicles with the preferential rights of ride driving to the scene of an emergency in the riskiest places - the traffic light intersections and thus to increase the safety of road traffic.

Acknowledgments

This work was supported by the research project VEGA grant No. 1/0240/15 named „Process model of critical infrastructure safety and protection in the transport sector" and by the research project VI20152019049 "RESILIENCE 2015: Dynamic Resilience Evaluation of Interrelated Critical Infrastructure Subsystems" supported by the Ministry of the Interior of the Czech Republic in the years 2015-2019.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Theoretical Proposal of the Engine for HALE Unmanned Aerial Vehicles

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Abstract

The turn of the first and second millennium brought development of many technologies. One of these technologies are unmanned aerial vehicles. Success in armies meant an expansion into the civil sector. Requirements for rapid installation into an armament and costs as low as possible meant the usage of current aircraft engines without any further modifications. Especially in an effort to achieve maximal altitude of the vehicle the engine without the modification could be a cause of unsuccessful effort of exploitation of vehicle´s options. Simple analyses of the vehicles and their current propulsion systems were found significant elements of their interconnections. Then the currently appropriate propulsion systems were assigned with a choice justification and its possible alternatives, hazards, various advantages and so on. Then a type of the engine which has not been fully utilized on these vehicles yet was theoretically designed. The point that this engine has not been fully utilized on these vehicles is precisely why it could bring new benefits to this area. It could even outweigh the advantages of the engines currently used on these vehicles and potentially replace some of them. This part of the theoretical engine design is the subject of this article.
KEY WORDS: *UAS, UAV, HALE UAV, unmanned vehicles with high ceiling, propulsion systems, aircraft engines*

1. Introduction

Unmanned vehicles are considered as one of the latest technological advances. Although they have been beside the constructions piloted directly from the deck since their beginnings, due to the technological challenges arising from the specifics, mainly of the remote control, unmanned structures had been pushed away to the edge of interest for decades. Further development of optics and communication tools at the end of the 20th century finally meant extending of their possibilities and with that related roles. Thanks to the military missions as well as the penetration of the civilian market unmanned vehicles were brought to the forefront by both military and potential airline users but also the media and the general public. Another development caused by this current state is the subject of this article.

1.1. Division of Unmanned Aerial Vehicles

One of the most important and most commonly used aspect according to that the unmanned vehicles are divided is ceiling and distance range. These two parameters characterize their ability to perform the most frequent missions and tasks. It is precisely the group that reaches the highest values of ceiling and endurance, named as High Altitude Long Endurance (HALE), of further interest. This group includes vehicles that have at least 15 km ceiling and endurance of up to 20 hours [2].

2. Proposal of a HALE Unmanned Aerial Vehicle

In order to select the appropriate propulsion system used in the subsequent design of the engine itself, the current state of HALE unmanned devices was monitored and then a possible area of interest was identified from this analysis. This would be the uncovered area of speed, ceiling or other characteristics that the proposed engine could potentially provide to the HALE unmanned vehicles. The graph for the power units used by the UAV and their dependency on the Mach flight number and ceiling shows one of these areas (Fig. 1). This area is characterized by velocities ranging from 0.3 to 0.5 Mach and ceiling about 15 kilometers. The above-mentioned speed range at lower altitudes is covered by the turboprop drive. For this propulsion system are currently laid ceiling limits about 15 kilometers above sea level. Unfortunately, in the vast majority of cases this limit is mentioned as a mere fact without further explanation. Therefore, further in the chapter is a discussion about the causes of the current state and the possible solutions that could be made for turboprop motors to be competent for this type of aircraft constructions. However, the complexity of this topic far outweighs the scope of this article and therefore contains only basic information that should be further confirmed and extended by more detailed research and calculations.

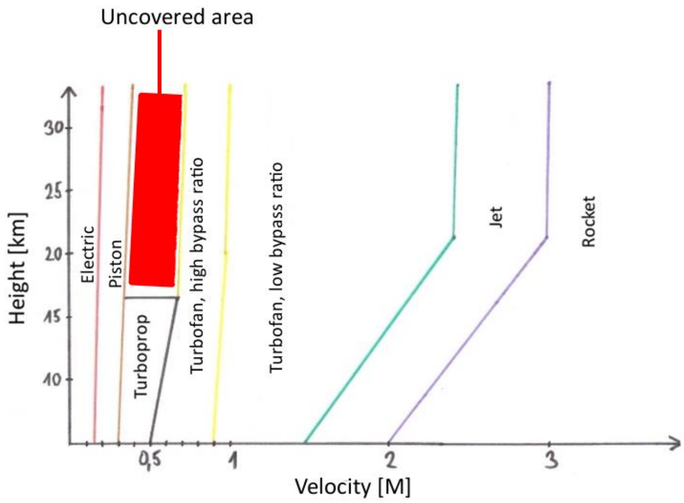

Fig. 1 The diagram of dependency of the use of different engines in unmanned vehicles for different flight velocities and altitudes

Typically, the air engine design process begins with the document of the so-called Request for Proposal (RFP). It lists the customer's requirements for the final flight parameters and capabilities of the airplane that the proposed engine should provide. A simplified demonstrational request for the proposal is the subject of the following lines [4].

2.1. Division of Unmanned Aerial Vehicles

The flight profile (Fig. 2) with the specified phase conditions should be as close as possible to the future use of the vehicle. During making of this model flight it is also necessary to take into account all flight modes that are expected to be very likely to occur in much of the flights. Model flight should therefore be a combination of phases (Table 1) and modes of each flight of different purposes and tasks. This ensures that the propulsion unit will receive the characteristics that will ensure the most appropriate operation for the vast majority of flights. Based on its parameters it is necessary to determine whether the turboprop drive would be suitable and capable of providing the necessary characteristics (Table 2) [4].

Table 1

Flight profile by phases (modes) [4]

Phase	Description, requirements
1-2	Take-off. The airport is located at 380 m above sea level at 15°C. Take-off length ≤ 2 000 m on dry paved runway.
2-3	Pitch. Minimum climb time to the ideal flight height and to achieve the ideal speed at this height.
3-4	Flight to the operating area. Achievement of an operating space 1000 km away at a time of ≤ 4 hours.
4-5	Endurance in the operating area. Circling above the operating area at a height of 14 km at the longest endurance time of the vehicle. Turning time 2 hours.
5-6	Flight in the operating area. Height 15 km, duration 4 hours. Part of payload is thrown away.
6-7	Endurance in the operating area. Circling over the operating area at a height of 16 km at the longest endurance time of the vehicle. Turning time 3 hours.
7-8	Flight in the operating area. Height 16 km, duration 5 hours.
8-9	Flight from the operating area. Minimum downtime to the ideal altitude and to achieve the ideal speed at this height. Reaching the descent space 1000 km away at time ≤ 4 hours.
9-10	Descent and landing. The airport is located at 380 m above sea level at 15°C. Minimum down time to the beginning of the landing approach. Landing length ≤ 2,000 m on dry, paved runway.

Table 2

Characteristics / performance [4]

Element/operation	Requirement
Payload	300 kg of scientific equipment
Endurance	32 hours
Ceiling	17 km
Take off distance*	2 000 m
Landing distance*	2 000 m
* The airport is located at 380 m above sea level at 15°C.	

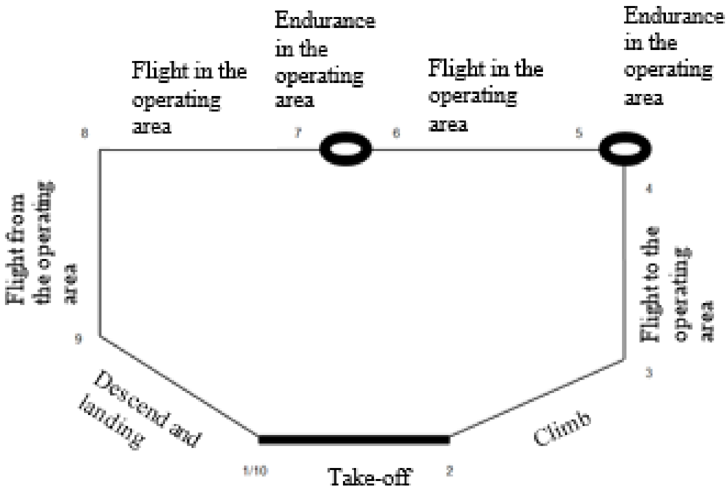

Fig. 2 Model flight profile [4]

Another requirements

Maintenance - The proposed engine must allow easy control, accessibility and disassembly of major elements of all major systems.

Fuel - In the case of a conventional propulsion system, standard fuel such as JP-8, Jet-A, or the like.

2.2. Turboprop Engine

The model flight demonstrates that the turboprop flight could be an interesting alternative because of its low specific fuel consumption especially among its HALE.

As previously mentioned the turboprop engine could fill an empty space between HALE unmanned vehicles. The fact that this area between piston and two-stroke engines is significant proves the amount of low speed requirements for these vehicles. Therefore, it is certainly not the ideal state of non-fulfillment of the range of speeds that at the lower limit is still quite suitable for the purposes of preferring or requiring lower speeds and on the contrary the upper limit already meets the preferences of higher speed purposes. However, this is by no means the only possible reason for go for turboprop engine installation into the HALE.

Ceiling

The turboprop drive consists of an engine essentially similar to a jet engine and a propeller. This kind of propulsion would also be likened to a two-stream engine with a huge bypass ratio. However, while the fan is located inside the engine casing, the turboprop engine propeller is located outside the engine itself. Despite the many differences the parts of the turboprop engine and the engine as a whole work in much the same way as the propulsion systems already used in the HALE. Theoretically, the turboprop engine should be able to reach between 15 and 20 km.

The main problem is a change in the state of a working fluid with a change of flight height. Piston engines turbocharged with multi-stage turbochargers operate at an altitude of more than 15 km with a working fluid whose status corresponds to sea level. Turboprop engines intake the working fluid of a level corresponding to the height of the flight. Increasing flight height deepens the problem. Of course, this problem affects jet and turbofan engines as well. Their advantage over turboprops is that the higher amount of suction working fluid, higher compression ratio and acceleration of the working fluid in the engine [3].

2.3. Construction

The design is done only very roughly by describing the required characteristics of individual components of the engine of the turboprop engine.

Air inlet

The air intake should ensure that sufficient air is supplied during all phases of the flight. It is also very important to minimize the loss of energy of air flow. The intake should be aerodynamically shaped to produce the lowest value of resistance. Due to the speeds of the air flow, it will be a subsonic type of device. This type is in most cases unregulated. From the definition of the mass flow that is the product of the cross section through that the current passes and its density and velocity it is obvious that there are three ways to increase its overall value. Any increase in cross-section, density or velocity value means an increase in the total mass flow rate. However, the speed can only be increased to certain limit values when the supersonic speeds are achieved and the energy losses become disproportionate. Influencing the density of the air flow in and out of the input box without the use of paddle machines is possible in a very limited amount. The last option is to increase the cross section of the incoming air. However, regulating intakes are currently used to

compensate for the effects of supersonic currents on supersonic inputs rather than to compensate for loss of mass flow. For example, the solution may be to install flap valves that could increase the cross-section of the incoming air. If the flaps are also used to reject excess air during other phases of flight, resistance to unstable conditions would also increase [1].

Compressor

In terms of ceiling, the compressor is the most critical part of the engine. It is precisely the compressor part that determines the value of the most important engine parameter in terms of the accessibility and overall pressure ratio of the compressor. This is given by ration of the compressor outlet pressure to the compressor inlet pressure and it is a numerical representation of compressed air compression during compressor passage too. The significance of this parameter can be proven by comparing to a different propulsion unit. The ceiling provided by the piston engines is directly related to the turbocharger installation. The piston engine turbocharger performs very similarly to a turboprop engine compressor. The increasing number of its stages means an increase in the value of the ceiling. Therefore, there is a direct dependence between the value of the overall compressor ratio of the turbocharger and the ceiling of the piston engine. It is important to note that even this dependence has its limitations. Unfortunately, even the overall pressure ratio of the turboprop engine compressor cannot be targeted to the highest possible value. The high value of this ratio has disadvantages in the form of higher weights or high temperatures that are produced by compressed air and can reach the limits dangerous for some of the parts of the compressor. Choosing the compressor construction itself is a matter of compromising the advantages and disadvantages of different arrangements. For example, the radial compressor provides a higher compression in one stage than the axial compressor. However, it is more advantageous for the axial compressor from the point of view of humidity. The humidity is the second very important parameter of the compressor [1, 3].

Combustion chamber

The problem of the danger of being exposed to the combustion chambers of all turboprop engines moving within the limits of their ceiling is the extinction of the flame. This state of course leads to an interruption of fuel burning that ultimately means interruption of the entire engine function. Since the starting of the engine from the point of view of the correct thermodynamic values is an even more demanding process than the actual operation itself. The problem could force the HALE to reduce the flight level to restart the engine function. The possibility of starting the engine is another problem that should be carefully thought out when designing the engine. The cause of flame extinction is shown in Fig. 3. It is clear that for a stable operation of the chamber is necessary to observe certain limits of the mixing ratio and the pressure. The minimum pressure value to achieve stable combustion backwards confirms the significance of the overall compressor pressure parameter [1, 3, 5, 8].

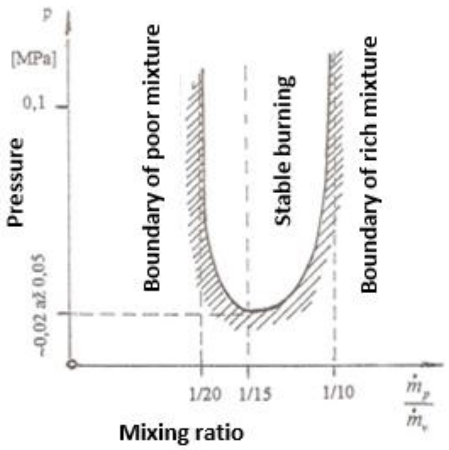

Fig. 3 Stable burning area of kerosene and air mixture [3]

Turbines

Turbines are part of the turboprop engine that allows not only the compressor but also the propeller to work. With each of these two parts at least one of the turbines is connected by a shaft. Through this connection the mechanical work carried out in the turbine section is transmitted. From the principle of activity in the context of the entire system it is likely that the most important parameter of the turbines will be their efficiency. It is defined as the ratio of the real and the ideal state. In this case it is defined as the share of the work actually acquired and the work that could be obtained under ideal conditions. The turbine part will significantly influence the choice of shaft arrangement. Although multiple shaft turboprop engines are currently more common, single-shaft turboprop engines that are installed on unmanned vehicles that reaches over a 15 km ceiling prove that this could be the optimal choice of arrangement for the HALE vehicles as well. One of the biggest advantages of the engine is the use of the working fluid to produce a considerable secondary thrust in its outlet [1, 3, 6, 9].

Air outlet

This part is far less important than at jet and turbofan engines. The primary thrust is created by a propeller and the outlet creates a thrust of only lower values or even none. In spite of this it is necessary to optimize the system in order to obtain the maximum value of the energy transformation of the gas flow to the force and hence to the total thrust when utilizing the system for creating the secondary thrust as discussed in the previous part [1, 3, 7, 8].

3. Conclusions

Theoretically, it seems that even turboprop propulsion unit could be a suitable propulsion system for the unmanned HALE vehicles. In spite of the improved ceiling limit it would rather be a vehicle somewhere between the HALE and a MALE (Medium Altitude Long Endurance) classification. The ceiling would most likely not exceed 20 km but due to the distribution of current HALE UAV availability, it is an absolutely acceptable value. However, in order to confirm the feasibility many further studies, calculations and tests are needed to confirm or refuse this conclusion.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Identification of Risks in Transport Infrastructure and Geographic Information Systems

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Abstract

Infrastructure is important to ensure the security of the state, its economy, public administration and life needs of the population. Disruption of any infrastructure, or its destruction may have a negative impact on the provision of basic functions of the state. The article discusses the conscious of the importance of transport infrastructure in the within the European union in terms of funding and also the risks that it affect. This raises the question of the importance of monitoring and mapping of the risks of the transport infrastructure on a global scale. Mapping the risks of infrastructure networks using technologies of geographic information systems is problematic, but within the anti-crisis measures effective. The contribution describes a simple example of how can be used the process of mapping the risks using geographic information systems within the mapping of the risks of the transport infrastructure network. The aim of this contribution is to show the importance of infrastructure in the state and on the basis of this fact, the need for monitoring and mapping the risk due to the protection of this infrastructure.
KEY WORDS: *infrastructure, transport, mapping of the risks*

1. Introduction

The development of human society is accompanied by the development in the field of its protection. Mankind was initially threatened by the extraordinary events caused by natural forces, later by the development of industrial production, transport, chemistry and other industries, and the extraordinary events of anthropogenic nature. In relation to extraordinary events has every developed society an adopted set of legal, technical, organisational, educational and other measures which leads to the minimization and overcoming of the consequences of extraordinary events and crisis situations. Ensure the security of the state, the functioning of the economy, the functioning of public administration and secure the basic living needs of the population is dependent on the specific infrastructure of the state. Its disruption has a negative impact on ensuring of the basic functions of the state. Damage, disturbance or destruction of any infrastructure can be caused by natural disasters or by the influence of the human factor. It may be a failure of machinery and technological procedures, or intentional event involving terrorism and organised crime. Disturbance in the functioning of systems such as drinking water supply, current supply, gas supply, use of the telecommunication systems, transport and others should be a major influence on the functioning of the state. Because it is the infrastructure of mutually connected, failure of one element may cause a failure of the other, which can lead to failure of the entire system.The aim of the protection of the infrastructure must to be the minimizing of the impacts of the outages of the activities of these infrastructures that disruption of functions, activities and services will be short-term and manageable at the very least created provisional or in an alternative way, and the territorially limited so as to hit the number of the population as low as possible. However, so that we could protect infrastructure, we need to know the risks and the threats which it affects and can have a major impact on its functioning. Since is the importance of infrastructure and its protection crucial for the functioning of the state, I consider necessary to devote to the issue.

2. Investments in Infrastructures within the European Union

Definition of the concept so as the difference of understanding of the infrastructure is dependent on the perspective of the author, and from the purpose of its examination. The importance of infrastructure is indisputable and claims for its existence and purpose are becoming more and more gradual. Indeed, even the European union (EU) considers its development and building as crucial and translates her intentions into long-term strategies.Investments in infrastructure had over the last decade a decreasing tendency, but the impact of the economic and financial crisis caused a renewed interest in investing in infrastructure. During the economic crisis, the targeted investments for the rehabilitation or construction of infrastructure have become an important part of the stimulus plans or recovery plans at level of EU and the member states. The crisis has shown that infrastructures have a crucial position for the economic future of Europe and its individual states. The investment incentive was comprehension, that a truly integrated single market doesn't works without the smooth interconnection of all its components. Roads and other transport links, gas pipeline network, as well as broadband networks are essential for the functioning economy and also for social and

territorial cohesion. Regulatory integration of markets is advancing, while the cross-border physical interconnection is lagging behind. The missing links cause the emergence of substantial differences between the center and the peripheries of the EU. The consequence of this fact is that the development of internal trade and the growth of new economic sectors is limited. The need for creating new infrastructure is therefore an important topic which is necessary to pay sufficient attention to, and this is the reason why it is also part of the *Strategy Europe 2020* [1].

The European union despite significant investment has currently a network of interconnected cross-border transport infrastructure, that would have been enough interoperabil and efficient from point of view of resource use. The fact, that the transport infrastructure is essential to guarantee the functioning of the single market, was also highlighted in the *Road-map to a single European transport area* (White paper) [2].

Transport infrastructure must serve as support for the competitiveness and sustainable growth. Completion of the core network is scheduled to 31. December 2030 and will be financed through the *Connecting Europe facility* (CEF). In the Table 1 there are data on the budget intentions and objectives in the areas of investment in the trans-european transport infrastructure under CEF-u [3].

Table 1

Data on the budget intentions and objectives in the areas of investment
in the transeuropean transport infrastructure [3], edith author

Title	**Budget**	**Goal and aim**
Connection of Europe: traffic	**31,7 billion euro** - 10 billion euro from cohesion fund - 21,7 billion euros for all member states	- to improve connections between different parts of the EU - with the aim to facilitate the free flow of goods and persons between countries - focus on less polluting modes of transport - increasing the sustainability of the transport system - to create corridors to cover the most important cross-border projects
The real estimate for the budget by 2020 is 500 billion, including 250 billion euro for elimination of bottlenecks and addition of missing links in the main network.		

The costs associated with the lack of investment in future networks could be for Europe very high. The increased pressure on the existing systems of the infrastructure is causing by growing interdependence of european economies and also change the direction of trade flows. After all, i new business opportunities and also the needs of citizens require a modern, intelligent and flexible network. Slovakia specializes in export-oriented production, i.e. on the sector, which is highly dependent on road transport networks. Obstacle to production and mobility is poor road infrastructure especially in the regions of central and eastern Slovakia. Poor infrastructure can cause a barrier, discourage investment, and thereby exacerbate regional differences. Assessment of the World economic forum of 2015 showed that the index of quality of infrastructure of the Slovac republic was in 2013 significantly below the EU average. The figure is a reflection of the fact that the density of the motorway network of 8.6 km per 1 000 km2 is among the lowest in the EU. Sparse motorway network may explain also the fact that member states with a lower density of motorways (all except Poland) have significantly lower well as population density. The exception is the republic of Poland.

In the Fig. 1 shows two graphs. The first shows the existing highway network of the Slovak republic in the framework of the european states, the second shows significant regional disparities in the Slovak republic. There is only one dashed highway in the regions of central and eastern Slovakia. The result is that the preferred placement of the manufacturing facilities is in western Slovakia, which is one of the reasons of deepening the economic gap between regions [4].

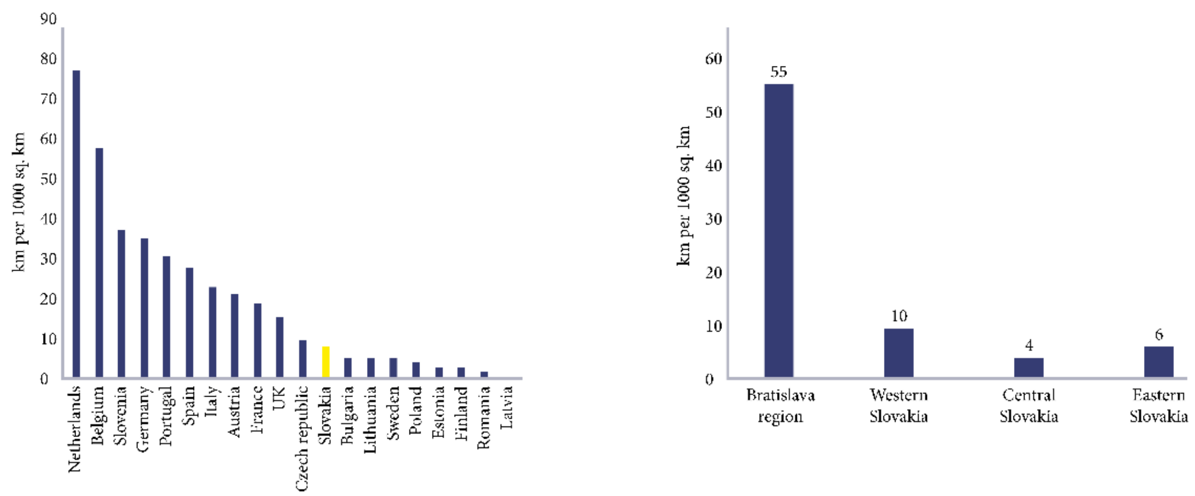


Fig. 1 Comparison of the density of the road network between member states and between Slovak regions [4]

Report on the state of the country from 2017 confirms that Slovakia evinces considerable shortcomings in the field of transport infrastructure, and nowadays is dedicating the necessary political attention to them. In comparison with the EU is the density of roads low, and congestion and average delay are considerable. Motorways and express roads are in good condition, but there is no continuous motorway link in the country. The ageing rail network limits the speed of trains and some routes appear to be unused, because there is driving a small number of trains on them [5]. In the report on the state of the country from 2018, transport infrastructure is mentioned only in one sentence, and that is one of the main reasons why foreign investors ignore the middle and to the east of the country, where is bedsides a low human capital the inadequate or absent transport infrastructure [6].

Removal of deficiencies in the road infrastructure is carried out unevenly, and slowly. In the years 2011 to 2014, the network of toll motorways was extended only negligible, but in 2015 there has been a sharp increase. The reason for the accelerated spending of EU funds was the completion of the programe, in the framework of which there were 56 km, and that caused that the highway network was extended by about 13 %. In the year 2016 has been set in the plan for the construction of a further 33 km with financed from the new program period (2014 – 2020).

The solution to the shortcomings of the network of the road infrastructure is in the short term period difficult due to the inefficient use of available funding, high unit costs of new projects, the lack of a proper planning and complicated complex of procedures relating to the planning and building permits.

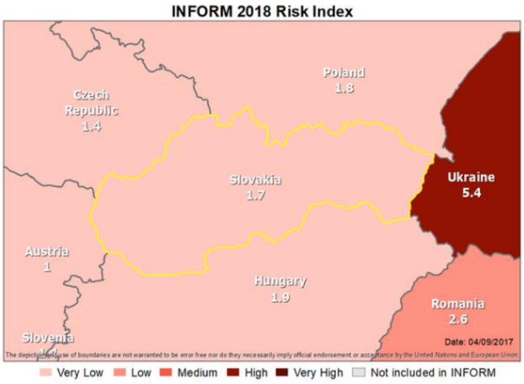
Investments in transport infrastructure have been, although in recent years, slightly above the EU average (0.9% of GDP in Slovakia compared with 0.8% in the EU), and in most cases were financed from the EU funds, however, in comparison with the past is invested in transport much less than is characteristic for convergent economy. Identified funding needs for the three corridors of the basic network represents approximately 11 billion euros [6].

Investment in infrastructure as such and its importance brings with it the need for security and protection. Since is the importance of infrastructure and its protection crucial for the functioning of the state, the following chapter will dissertate about the risks and possibilities of protection of the transport infrastructure.

3. Mapping the Risks of Infrastructure

The importance of mapping risks on a global scale proves the existence of the INFORM, which is a global transparent tool for understanding the risk of humanitarian crises. The INFORM is a collective project of the Standing committee among Inter – Agency Standing Committee (IASCA) and the European commission (EC). This project originated as a response to the recommendations of many organisations to improve the common evidence basis for risk analysis, as well as the actual requirements of the partner organizations for understanding the risk of humanitarian crises. The INFORM is based on the open-source, which means the shared risk assessment for all involved in the prevention of, preparedness for, and response to the crisis. The main aim of the shared risk assessment is that all stakeholders can work together to work more efficiently. The model INFORM is based on the concepts of risk published in the scientific literature and envisages three dimensions of risk: hazards and exposure, vulnerability and lack of capacity. The results in the form of a risk map and charts with the global index of risk are available on the website of the *Inform index for risk management* and consist of risk assessment for 191 countries at the national level. In addition to the other include also an index of risk of the infrastructure in the individual countries. The website is operated by the *Joint research center* and we can find there also the overall profile of the risks of the Slovak republic, which is shown in Fig. 2. The model INFORM can be characterized as a global assessment of the open source for humanitarian crises and disasters, of which the results can support decisions about prevention, preparedness and response (Fig. 3) [7].

On the basis of the information available from previous years, it is possible to see that the index of risk of the infrastructure has a decreasing tendency (Fig. 4). In 2015 was the index of risk 2,21 and nowadays from the year 2017 remain unchanged [7]. It can be stated that the decreasing tendency could be a reflection of the completion of certain parts of the infrastructures in Slovakia.



Eastern Europe
High income

	Value	Rank	Trend
INFORM Risk	1.7	165	–
Hazard & Exposure	1.8	152	–
Vulnerability	1.1	179	–
Lack of Coping Capacity	2.6	156	–

Fig. 2 The overall profile of the risks of the Slovak republic [7]

Fig. 3 Illustration of Model INFORM [5]

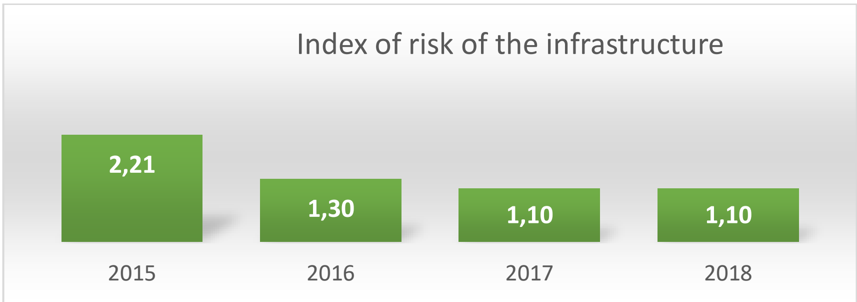


Fig. 4 Index of risk of the infrastructure

The importance of infrastructure and the preservation of its functionality is therefore becoming an essential effort of any state. The Slovak republic is an important transit node, and therefore is inadmissible for any of these important infrastructures to be compromised or failed. According to the outcomes from the *List of security threats* operating in the field of transport have been identified in these safety threats operating in the transport infrastructure:

- natural hazards and disasters (flood, snow calamity, the whirlwind, seismic activity, slope landslides and the like);
- dependence on a continuous supply of basic raw materials, energy, non-renewable resources and their transport – crude oil and petroleum products;
- dependence on a continuous supply of basic raw materials, energy, non-renewable resources and their transport – electricity, gas, heat;
- the vulnerability of information and communication systems;
- chemical accident;
- accident – explosion;
- accident – intrusion of dikes of water management structures;
- radiation accident;
- uncontrollable migration;
- terrorism;
- war conflict on the territory of the Slovak republic [8].

At the level of national and regional infrastructure, it is processed a number of projects, guidance material and studies in connection with the development and the protection of individual infrastructures. One of the possibilities how to prevent the crisis is to effectively monitor and map the risks. In addition to the classic methods of mapping the risk, it is possible to apply the law to the transport infrastructure process mapping of risk with the use of geographic information systems. The mapping of risks is a process by which are areas identified with varying levels of risk. The process of mapping risks is carried out on the basis of the technologies of the geographical information system (GIS) with the use of statistical and numerical analysis [9]. GIS-y are classified geospatial technology, whose importance in

the recent time is growing. It is the combination of software and geographic data that allows to search for the optimal route of movement, specific locations, or records the location of a place. Today, many mobile phones, tablets, or even cameras include the receivers of GNSS to determine the location. These technologies, however, are also in navigation systems of cars, tourist navigation devices and there are appearing more and more the practical applications in the field of public transport, or evidence of various phenomena in our surroundings. Geographic information have several important properties, and the most important of them is the position aspect. The spatially localized information then can be placed into the map. An essential prerequisite therefore is, that in the mapping of risks could be only included such kind of extraordinary events, whose manifestation on a specific area can be somehow expressed in cartographical view, on the map. For a specific type of emergency there must be a layer of a GIS-u, or there must be data from which can be a layer of the GIS generated (for example, overview of objects of a given type, such as an inventory of address locations, or as an inventory of coordinates).

The process of mapping risks using a GIS as a such consists of five, which are shown in the Table 2 or three phases depending on the available data.

Table 2

The process of mapping risks using a GIS [9], edith author

1 phase	the determination of the extent of the risk	⟹	creation of maps of danger
2 phase	establish the vulnerability	⟹	creation of maps of vulnerability
3 phase	determination of the cumulative risk	⟹	creation of maps of the cumulative risk
4 phase	determination of the readiness	⟹	creation of maps of preparedness
5 phase	setting of the adjusted risk	⟹	creation of maps of the adjusted risk

As an example cuold I mention the crash in road transport, where is the danger the road communication and the endangered areas are the areas around the road communications and the size of this area depends on the type of crash. The impact of the effects of the accident with leakage of dangerous toxic substance is possible to characterize by the coat zone around the ground communication, for example with the size of 400 meters. For example, during leakage of a petroleum substance may be the coat zone with the size of 200 meters (the size of the zones is based on the volume of tanks which are carrying dangerous substances). During crash in passenger transport without the massive leakage of dangerous substances it is possible to use coat zone of 100 meters. The density of traffic affects the probability of the occurrence of the crash in transport, and on the basis of the observed density of traffic it is possible to categorize road communications. The map layer of the coat zones of 100, 200 and 400 meters it is then possible to use for determination of the coefficient of the intensity of the hazard of K_i. While we proceed from the assumption that the intensity of the effect of the crash near the road of communication is higher than at bigger distance. For the determination of the coefficient of the source of danger it is possible to use the map layer of the GIS, in which are added the results of the sum of the motorway and road network. Those characterize the density of the traffic and classify the roads into ten categories according to the number of passed vehicles for the time of 24 hours.

To express the vulnerability of the roads it is possible to use the map layer of the GIS motorway and road network, while this categorization can be used to help to set the coefficient of the intensity of vulnerability (Table 3). Line layer of the motorway and road network it is necessary to convert to polyn layer using a buffer of 100 meters [9].

Table 3

Representation of the vulnerability of the roads [9], edith author

Type of danger	Level/Category	coefficient
Crash in road traffic	*Endangered territory*	K_i
	The territory of defined boundary coat-zone - 100 m	1
	The territory of defined boundary coat-zone - 100 a 200 m	0,75
	The territory of defined boundary coat-zone - 200 a 400 m	0,5
	Category of roads according to the density of the transport	K_{zdr}
	Roads with the highest density (category 10)	1
	Roads with the lowest density (category 9 - 1)	0,9 – 0,1
The element of vulnerability	The expression of vulnerability	coefficient
Roads	*Category of roads*	K_iZ
	Motorways and express roads	1
	1st class roads	0,75
	2nd class roads	0,5
	3rd class roads	0,25

Map of preparedness would be established by merging the maps of the individual elements of preparedness in the territory. Elements of preparedness are hospitals, warning, police, components of the integrated rescue system and

other. The integration of the maps of the hazard, the preparedness and vulnerability will be created a map of risks. The maps of risks which are the result of a process of mapping the risks using GIS, contain comprehensive information about the load of area by risks and they are an essential input into the processes of emergency and crisis planning and a data base for processing of the analysis of the threatened objects [9]. To make the process of mapping of the risks allows to get a comprehensive overview of the structure and the type of risk for on a specific territory, which is then possible to divide according to the level of risk and establish priorities for the application of anti-crisis measures.

4. Conclusion

Due to the constant development of industrial production and trade are the demands on the infrastructure constantly increasing. Infrastructure is essential to the functioning of modern society. Indeed, roads and other transport lines, gas pipeline network, as well as broadband networks are essential for the functioning of the economy and also for social and territorial cohesion. Especially in cities, we meet with the fact that the degree of autonomy of the existence of the citizen or the organization is very low and short-term downtime of any infrastructure or critical infrastructure can cause serious problems. Without a functioning infrastructure, it is not possible to have a functioning economy of any state. The functional infrastructure and its security is a major topic on a global scale. This fact is reflected also in the strategic plans of Europe and also plans of individual states. The european union recognises the importance of monitoring and mapping the risk of the infrastructure. The aim of this contribution was to show the importance of infrastructure and the need to conserve its functionality. Within the maintain of options and maintain of the functionality and safety of the infrastructure are opened the possibilities to use the process of mapping of risks of the infrastructure networks using the geographic information networks.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

The process of preparation and implementation of the Baltic Air Policing Task Force

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Abstract

Army of the Czech Republic implemented the Baltic Air Policing Task Force fighters from the Čáslav air base, which were complemented by selected national forces. The main task was to guard the Baltic nations' airspace, forming NATO's "eastern flank.
The first mission, conducted from 1 May to 31 August 2009, required a total of 9 live take offs against the intruders in the zone of responsibility, while the second mission, which took place between September 1 and October 31, 2012, required 15 live take offs when pilots flew over the Baltic a total of 326 flight hours in 298 flights. The NATINAMDS system, which allows countermeasures against the intruders into the zone of responsibility, is controlled through the Combined Air Operations Center (CAOC) deployed in Uedem, Germany, and then through the Center for Control and Reporting (CRC) deployed in Karmelava, Lithuania.
Taking into account the security situation at the eastern border of the North Atlantic Alliance, it can be assumed that if the disputed issues concerning the sphere of influence reflected in territorial claims remain unsettled, the occurrence of similar incidents will increase, even if the past experience shows the conflict will be a latent one, resulting however in a growing number of live take offs.
KEY WORDS: *Baltic States, air policy, airspace protection, logistics preparation, deployment, sustainment*

1. Introduction

On the basis of the 1949 North Atlantic Treaty commitments, the Baltic States also became part of the security system in their accession in 2004, and the Alliance has assumed responsibility for the security of the region, in particular those capacities and capabilities that are not available to the Baltic States.

Baltic States, which were collectively unable to defend their airspace from potential threats, became members of NATO in 2004. Changing security challenges is all the more important, as the military does not always have the capacity to realize all areas for security and will increasingly use capacity-sharing [1]. The Baltic States do not have the capacities needed to protect airspace, so NATO has been looking for adequate means since 2004 to find this apparent lack of bridging.

It can be assumed that the re-election of President Putin and the subsequent constitutional government will continue the previous orientation of policy towards NATO's eastern flank. Given the number of contacts in the airspace, the combined maritime exercise in the Baltic Sea shows that the threat from Russia is real, and the rhetoric from Moscow is only growing worse. Asymmetric threats are caused by their unpredictability and the low level of attitude of troops to this kind of activity [2]. It can be assumed that Moscow will shake interests on all fronts to secure its own stability [3].

Possible threat to NATO's "eastern flank requires ensuring a permanent presence of Alliance forces in the Baltic States to ensure fulfillment of contractual obligations. NATO officials are also aware of the need to increase the resilience of airports that are part of NATO's critical infrastructure and the European Union. Crisis management implemented in airspace protection is more complex, especially for reasons of decision-making speed [4].

Baltic States' airspace protection has been implemented since 2004, when Member States of the Alliance have, at agreed intervals, controlled the airspace of the States. The end of the Baltic States Airspace Protection Mission was scheduled to take place in 2014, but with the evolution of the situation, the views of the NATO interlocutors changed.

As follows, the Alliance decided to extend this mission provided that the Baltic member states will increase their contribution in order to compensate the costs supported by nations providing this protection.

The Baltic States, which belong to the size of the state and the population of small countries, are aware of the need to meet the 2% of GDP allocation for defensive spending and promised to meet the demand in 2018. The apparent dependence on NATO and EU allies against possible Russian aggression is one of reasons for an active approach of the states of the region to participation in NATO activities. Like the other countries, the two countries do not make a 2% of gross domestic product (GDP) allocation to the defence budget, only Estonia adheres to the agreed amount.

There are several challenges in territory of the Baltic states; Russian domination and foreign policy formulations and the region presents unique military and political difficulties that would need to be overcome. The Baltic States are geographically isolated from the Alliance surrounded on the south and east by Russia and Belarus. Lithuania shares a border with the Russian exclave of Kaliningrad on the west. Lithuania shares a land border with another non-Baltic

NATO member. The length of the border with Poland is almost 100 kilometres in the southwest between Kaliningrad and Belarus.

The Baltic States are geographically small in population and size but become geographically hot spot. The Russian Federation, in an effort to show its interests, is carrying out military exercises in the region. The presence of the Russian presence in the Baltic Sea can be documented by a brief list of maritime exercises. In 2015 almost 4000 soldiers took part in live exercises. In the Baltic Sea, an active phase of Russian-Chinese Maritime Collaboration 2017 was taking place on 24-27 July 2017 [5].

Overall, about ten ships of different classes and more than ten planes and helicopters of two countries participate in the exercise. The number of participants in the Russian-Belarusian exercise West 2017, which took place in September 2017, did not exceed 13,000 people [6].

The Russian Baltic Sea Fleet, anchored in the Baltic Sea Baltic outpost of Kaliningrad, conducted a three-day routine exercise in the Baltic Sea. The exercise took place on 3-5 April 2018. This is to include the firing of sharp missiles that would be aimed at aviation and naval targets in the event of a fight [7].

An important fact is also the demonstration of NATO air force when the Russian Air Force has been testing NATO's airspace in the Baltics. The number of take-off has risen, with 200 take-offs in 2013, 400 take-offs in 2015, 2016 and 2017. At the same time, there has been a continual increase in the number of NATO airspace disruptions.

The development of NATO airspace disruptions has led to the adoption of measures whereby the Alliance's Member States have tripled since the beginning of 2014 the number of aircraft designed to protect the Baltic air space.

Kaliningrad represents a Russian exclave along the Baltic Sea, Russia’s Western Military District, with approximately 25 000 members of the Russia armed forces. Kaliningrad is also a naval base for the Russian Baltic fleet, which consists of approximately 50 ships, including submarines. To reach the territory of Kaliningrad, Russia must obtain transit rights to overcome the littoral airspace. Geographical separation is the source of airspace disruption.

The change in the attitude of the Baltic States to the cancellation of air bases was triggered in 2008, when the tension on the border with Georgia changed. The following security level changes that were caused by the annexation of the Crimea and the war in eastern Ukraine in 2014 were a warning to NATO planners and showed the need to continue to protect the Baltic States' airspace. The Baltic States have re - examined their stance to leave the Ämari air base in Estonia as part of an expanded role for Baltic Air Policing. Baltic Air Policing strategy was started in March 2004.

The Nordic countries of the Baltic region play a key role in ensuring the stability and security of the Baltic Sea, particularly in the transport sector. At the same time, they play an indirect role in ensuring the security of the Baltic States.

In order to improve security of eastern wings of the Alliance NATO should establish a permanent military presence in the Baltic region, maintain a robust maritime presence in the Baltic Sea, and commit to a speedy and robust ballistic missile defence in Europe. Ballistic missile defence capable ships will likely operate in the Baltics someday as part of NATO’s missile defence system. The Baltic States view NATO’s ballistic missile defence system as a fundamental part of the Alliance’s defence.

2. Logistics Preparation for The Air Baltic Policy

The primary mission of a Czech Armed Forces in the Air Baltic Policy is to ensuring effective and efficient execution of theater-level logistics. Emerging concepts recently used contain following areas:

- Prepare estimates based on the Baltic Air Policing Task Force mission guidance for operations;
- Conduct logistics and sustainment analyses and transportation feasibility studies;
- Monitor and analyze the logistics situation and make adjustments within the parameters of the NATO and CAF intent and guidance;
- Manage logistics functional centers;
- Allocate logistics resources according to the NATO and ACR priorities;
- Advise the Chief of general staff of the ACR on logistics readiness, the current situation, and possible shortfalls;

The Logistics Center could be organized around a number of different functional areas that correspond to the functions and capabilities assigned by the sending nation. These functional areas could include following areas activities: petroleum, a materiel management, munitions, a distribution, and a repair and maintenance. Ensuring proper recognition of accountability is an important contribution to eliminating unnecessary purchases and allows the allocated assets to be used more appropriately [8]. The use of host country capacities and other participating entities is an important 3E principle, with the logistics center having its capacity structure for the liaison section.

2.1. Logistics Center in Contingency Employment Scenario

On receipt of a warning order for a small-scale contingency in "Baltic states," the Logistics Center (hereinafter LC) coordinates with the J-3 and J-4 staff to develop a deployment concept. The Logistics Center planners have capability and provide input to the time-phased force and deployment data. The LC coordinates with the national strategic partners and the Logistics Agency, to ensure understanding of the ACR requirements and directs the "fort to port" effort.

The ACR coordinates deployment process through Department of Transport. The LC develops the distribution and support plan and may direct a push of sustainment materiel before service logistics activities submit requisitions. The LC also establishes contracts in order to use the capacities that are in the place of dislocation.

The Logistic Center supports the reception, staging, and onward movement process, using a given capacity [9]. The LC receives requirements and then prioritizes and assigns lift assets based on the operational requirements. The LC ensures that all critical nodes are outfitted with radio frequency identification interrogators and maintains the logistics common operating picture. The LC synchronizes end-to-end inter- and intra- distribution operations and coordinates with local authorities.

Deployment of logistic support units into the operation area contains movement activity. Principles of the transfer and division of the logistics unit mean scheduling, loading of moving unit material, allocation of transport capacity, wagon transport, other types of transport, shipment and termination, moving from Port of debarkation to concentration).

This is mainly about the following activities method of planning transfers and shipment:

- Basic calculation standards and principles to ensure a smooth move, the budget for loading people and materials at the LC;
- The role of logistical units to ensure transfers;
- An order to move the unit;
- Transport of units by rail and calculation standards for wagon transport, passenger transport by rail;
- Transport of units by ship;
- Transport of units by air transport;
- Termination of shipments = extravagance, unloading from ships and aircraft, system of occupation of concentration area).

2.2. Use of Logistics Support Units in the International Environment

Identifying and limiting conditions resulting from international bilateral and multilateral conventions and acts (Technical Agreement, ROE, and Transfer of Authority).

The analysis of constraints and the requirements of the new environment are to clarify the constraints that are enshrined in the agreements and regulations applicable to the operation, including sanctions for breach or non-compliance with the provisions of the provisions [10]. Knowledge of local conditions will facilitate the implementation of logistics negotiation with local suppliers; operate in favour of deployed units.

Duties of 2nd level logistics units and the definition of responsibility and security conditions throughout the concept of support.

3. The Czech Republic Participations in The Baltics Air Policy

Task Forces made up primarily of the 211th Tactical Squadron guarded the airspace over Lithuania, Latvia and Estonia. Both missions were implemented on supersonic aircraft JAS JAS-39C Gripen. The air force formed part of the NATO QUICK REACTION ALERT (QRA) team and operated from a Lithuanian air base.

3.1. 1st ACR Contingent of Air Policing 2009 in Lithuania

The NATO operation in Latvia, Lithuania and Estonia was aimed at protection of air space of these three NATO countries. The first operational overseas deployment of the Czech Republic has been undertaken by air force since joining NATO in 1999.

Both chambers of the Czech Parliament approved the government proposal at its meeting on January 28 and February 4, 2009. The structure and equipment of the contingent were accepted. The structure of the approved governmental proposal for mission implementation on the territory of the three Baltic States in the framework NATO's Baltic Air Policing Mission was composed of four supersonic aircraft JAS 39 Gripen and 75 persons. The contingent operated from the Lithuanian air base Šiauliai [11].

The implementation of a mission to protect the airspace of the Baltic States was preceded by the adoption of a governmental proposal for the deployment of a Czech military contingent by both Chambers of the Parliament of the Czech Republic in January and February 2009. The Czech Army, on the basis of an agreed mandate, allocated four JAS 39 Gripen supersonic aircraft to operate at the Šiauliai Air Base.

The Contingent was formed by 75 soldiers from five military units - 21st Tactical Air Force Base at Čáslav, 26th Command, Control and Reconnaissance Brigade at Stará Boleslav, Joint Forces Command at Olomouc, Military Police Command at Stará Boleslav, and from MoD Operations Division in Prague. The core of the Contingent was composed of flying and ground personnel of 211th Tactical Air Flight from Čáslav [12.]

Implementation of the NATO Air-Police Mission in the Baltic Airspace was carried out by pilots from 211th tactical squadrons located in Čáslav on JAS 39 Gripen C. Two of the aircraft were held at readiness to take off within 15 min on a 24/7, with the commitment forming part of the wider NATO Integrated Air Defence System. The Gripen supersonic aircraft were equipped with two Raytheon AIM-9M Sidewinder short-range air-to-air missiles and

27mm Mauser BK 27 Aircraft Cannons for the Baltic mission.

The Czech air force had had completed 400 flight hours and 336 sorties during their rotation [13]. The first Czech aircraft arrived at the Lithuanian Siauliai on 30 April 2009, with the presence to continue until the German air force takes over responsibility for the QRA mission on 1st September 2009.

Czech Republic Army fighters launched a mission in Lithuanian Siauliai on April 30, 2009. In accordance with the rotation plan, the QRA mission was terminated on September 1, 2009. Responsibility for airspace security was taken over by the German Army Air Force. Altogether, 75 members of the Army of the Czech Republic were deployed. The total includes eight pilots and 36 maintenance and logistics personnel at Siauliai and some personnel assigned to a Lithuanian command and control facility at Karmelava.

The mission was planned to total around 290 flying hours and not more than 350 by September, with the latter limit having been established to avoid adversely affecting operations at Čáslav. A timetable for preparations for the Czech contingent deployment was launched in February 2007. The initial reconnaissance of the airport was carried out, exploring the possibilities of using local capacities and the preparation of the material security of the mission. The capabilities and needs identified were the basis for the planning of the logistics part of the planning, which started in October 2008. The final reconnaissance of the future destination of the Czech contingent was realized in February 2009.

The final stage of the training was the exercise realized on March 9 - 13, 2009 at the air base in Čáslav. It can be stated that the preparation of members of the contingent can be carried out in simulators in the preparatory phase [14]. Part of the exercise was the assessment of standard processes, procedures and techniques in an international environment where there is a permanent conflict with the Russian Federation fighters. Knowledge of the opponent's portions is a significant advantage in training [15]. The process included support from Czech air force Aero Vodochody.

Supersonic aircrafts JAS 39 Gripen lease agreement between the governments of the Czech Republic and the Kingdom of Sweden enabled the use of logistic support for flying only on the national territory of the Czech Republic. It was necessary to sign an addendum to the agreement, which would allow the support of flying support also during the NATO Air-Police Mission in the Baltic Airspace. The Ministry of Defense of the Czech Republic has signed an amendment to the contract for the lease of the Gripen, because the existing contract allowed the support of aircraft to be used by the territory of the Czech Republic [16]. By signing the treaty amendment, missions in the Baltic States were secured from the point of view of the JAS 39 Gripen supersonic.

Continuous logistic support was carried out by weekly flights by Antonov An-26 from the Czech Republic to the Siauliai base. Components and other material were transported in accordance with air traffic safety requirements. The transfer of almost 80% of the logistics material to the mission was carried out by land transport from home bases. Under security, sensitive commodities and ammunition were transported by air via An-26. Contingent members have used standard procedures to prepare aircraft for standard practice [17].

In accordance with the JAS 39 Gripen rental contract, only minor maintenance and repairs were carried out by the technical staff at the Siauliai base. Periodic technical inspections were carried out after 200 hours in accordance with the lease agreement on the territory of the Czech Republic. The scheduled maintenance time is planned from four to six weeks.

The agreement allowed the use of the Swedish support team's capacities to secure air traffic at the Šiauliai Air Base in the initial phase of the mission. But in a sign of the Squadron’s independence they soon returned to the Czech Republic. The addendum to the agreement allowed Gripen to be secured through middlemen of the Swedish company who were temporarily transferred to the Šiauliai base to secure eventual requirements in the first phase of the mission. The rotation of members of the contingent was carried out within three days between 28 June and July 2009.

3.2. 2nd ACR Contingent of Air Policing 2012 in Lithuania

The second mission to safeguard the airspace of the Baltic States was made up of 64 members of the Armed Forces Armed Forces of the Czech Republic on the basis of a mandate granted by the Parliament of the Czech Republic. The air transfer into the area of responsibility located over thousand kilometres away commenced on 21 August 2012. The advance team transferred from the Čáslav to Šiauliai airbase on a Czech Air Force CASA C-295M transport aircraft. Additional transfers took place on August 23 and 30, 2012.

A Lithuanian C-27J Spartan transport air - plane was also involved in besides the aircraft operated at the 24th Air Force Base Transportation Kbely. The necessary materiel and equipment, including twelve ISO containers, back-up power generator and airplane tug, were transferred in a ground convoy provided by the 14th Logistic Support Brigade headquartered in Pardubice from August 20-25, 2012. On the last but one day of August, four JAS-39C Gripen multirole supersonic fighters made a transfer flight. It did not take them more than sixty minutes to get there from their home station. Ahead of the departure of the Czech Armed Forces 2nd deployment for the Baltic Air Policing mission. Three years from the first deployment of the Czech contingent in the Baltic States is what we regard an optimal rotation cycle. Pre deployment prepping was a long term effort and was informed to maximum extent by the lessons the first Czech Armed Forces deployment learnt in 2009.

Representatives of the Army of the Czech Republic consider the three-year set-up to protect the airspace of the Baltic States during the ideal period that will allow the use of previous experience. Significant help is also an addition to the Gripen repair contract and knowledge of the Baltic States' aerodrome environment. The reality is that the four-month plus effort in the Baltic States means a double employment for the Čáslav airbase pilots in NATINADS.

The contingent also operated in Karmelava at Kaunas, Lithuania, where two Czech specialists served a tour at

the local Control and Reporting Center. To perform the operational assignment, the Czech Armed Forces contingent had four JAS-39 Gripen multirole supersonic aircraft. Over a four-month mission the Czech Air Force Quick Reaction Alert (QRA) pilots logged the total of 404 flight hours in 336 sorties, of which were eight alpha scramble flights to commercial as well as military airplanes in their area of responsibility, which had not been complying with civilian air traffic management rules.

Transport of the first group of the second ACR contingent into the area of responsibility in the Baltic republics was conducted on 21 August 2012 by CASA C-295M. Continuation of the contingent deployment, which consisted of 64 members of the contingent, including four JAS-30 Gripen, was held on 23 and 30 August [18]. The Department of Transport of the Logistics Agency has planned the air transport of other members of the 2nd Contingent in terms of 23 and 30 August. In these terms, four JAS-30 Gripen supersonic aircraft were also planned.

The majority of the detachment came from the 21st Tactical Air Base in Čáslav, which operates JAS-39 Gripen supersonic aircraft. The second contingent took responsibility for the NATO Air-Police Mission in the Baltic Airspace from 1 September 2012 to 4 January 2013 [19]. The 21st Tactical Air Base in Čáslav, operating the JAS-39 Gripen supersonic aircraft, was based on the personnel composition of the second Czech contingent.

The second contingent did not have a liaison officer for the CRC (Command and Report Center) in Karmelava. The second contingent of the Czech Armed Forces took over responsibility for the surveillance of the airspace on 1 September 2012. Subsequent to the expiration of the mission period, the Danish contingent assumed responsibility on 4 January 2013. The departure was scheduled for January 4, 2013.

4. Conclusion

NATO plays the role of a global actor of security, but it is not the goal of creating a defensive line on the territory of the Baltic States. In order to eliminate the efforts to disrupt the integrity of Alliance states and defend territory of Baltic States it can be said that the Baltic Air Policing Task Force is an appropriate measure that does not increase tensions in the region but clearly defines the sphere of influence of the Alliance.

The Air Baltic Policy is an important step in securing the eastern wing of the Alliance, and it also represents the expression of mutual assistance to countries with limited capacity, in this case defense of airspace. Although we are witnessing political debate and different views of Czech political subjects, the continuation of the mission and participation of ACR members is a necessary proof of active collective defense.

NATO Air Policing is the fulfillment of the Alliance's commitments to the Member States since 1949. The Alliance member states complement the capabilities of the Baltic States to protect the airspace by the continuous presence of fighter aircraft. The task is to respond quickly to the disruption of the airspace of the Alliance member states. The integrity of the airspace of the Alliance in terms of capabilities, particularly small Member States, must be realized by the presence of other Member States with the capacity to ensure the integrity of airspace in the NATO Integrated Air and Missile Defense System (NATO IAMD). Participation of States with aviation and missile defense capabilities should be an important element of pooling and sharing capacities of Member States to protect the territory and the population against airborne threat. [20]

Further developments in the region will depend on the development of the Ukrainian crisis and mutual contacts in the airspace of the Baltic States.

Implementation of the logistic support of the Air Force contingent in the Baltic states has demonstrated that the logistics management and logistics management system through the Logistics Agency is in the field of securing military transport outside the territory of the Czech Republic and subsequent logistic support of the contingent by a fully functional subject and cooperation across the Czech Army, the support is based on standard procedures that are used across the Alliance.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Theory of Complex Systems and the High Reliability Organization Concept in Transport Safety Modeling

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Abstract

The article presents several well-known technical safety concepts, which according to the author are suitable for use in modeling and transport safety analyzes. This is cognitively promising and relatively unknown research concepts, such as the interpretation of the transport system as a complex system, the conisection of "high reliability organization", J. Reason's concept of accidents and the concept of "safety space" by R. Amalberti.
KEY WORDS*: transport, modeling safety, complex systems, High Reliability Organizations (HRO), Normal Accidents Theory (NAT), Swiss Cheese Model (SChM), safe space of activities* (*SSA*).

1. Introduction

Safety is a systemic feature of considered technical objects, technological processes and decision situations and expresses their ability to avoid losses. The term loss refers to a variety of adverse events such as: disruption, incident, accident, disaster. Terms associated with the concept of loss, but in terms of technical reliability, are: disability, malfunction, failure, damage. With risk are associated terms of danger and sense of danger that are associated with the perception of risk [1].

Differences of safety interpretation of any object result mainly from the kind of concerned losses. For many researchers, the concept of safety concerns the loss of each of the elements of the system "Man-Technology-Environment" (M-T-E). According to others, in the definition of the object safety should be taken into account only the loss of life and health of the human factor in the task implementation process. Economic, ecological and other losses may be taken into account in safety analyzes when they affect the reduction of the duration of human life.

Out of the many interpretation of safety in technology perhaps the most general system definition is given in the work [2]: „Safety is an emergent feature of the system, understood as its ability to: a) preserve important systemic properties, such as: integrity, stability, self-sufficiency, competitiveness; b) providing important systemic behaviors, such as adaptation, homeostasis, growth, learning, equality, purposefulness".

In modeling and safety studies of transport you can use analogy and similarity to the concept of researchers, which were created in different areas of technology. This article briefly describes several theories which have been or may be used in modeling and research transport safety [2].

2. Four Levels of Safety Problems. Geysen's Thesis.

W. Geysen said following the thesis: „(...) safety problems in the various areas are very often the same nature and can be formalized in the same way. This gave the start to what now is called the science of safety" [3]. This simple, but profound observation allows the use of reasonable analogies, theories and safety models to study problems of transport safety.

Looking for a reasonable analogy, researchers must keep in mind the characteristics of the transport and road transport in particular. Looking for a new approach to transport safety studies, consideration should be given to the potential source of inspiration, or the results of the developing Science of Safety (SoS), which is probably one of the best examples of a multidisciplinary synergies in science [4].

The safety of any object can be considered on 4 levels [3]:

1. „Safety philosophy ": determination of the safety and loss criteria;
2. Ways and methods that may be useful for improving safety;
3. "Safety technology: technology to improve safety;
4. " Safety policy": build knowledge and practice levels 1, 2, 3.Polityka bezpieczeństwa": compilation of knowledge and practice levels 1, 2, 3.

3. Transport Systems as Complex Systems

If you deal with any type of transport in a large area, and in the longer term, it can be interpreted as a complex system [1]. The definition of such systems is justifiable here [5]: comples "system is a system which development is very sensitive to initial conditions or small distortions, in which the number of independent elements interact is large, or

one in which there are many possible paths for the development of this system."

In large transport systems, there are two known forms of complexity: 1) chaotic complexity; 2) organized complexity.

The first is derived from a very large number of elements (infrastructure elements, means of transport, human factors involved in the implementation of and participation in transport). The second is derived from the "matter" of the system – in this case, the worker processes on transport; mainly traffic processes. Safety depends on the strength of functional bindings that occur in such systems. There are always tight and loose couplings. The first are characteristic of decentralized, and the second for centralized (hierarchical) structure of management. This leads to the paradoxical situation that C. Perrow characterized in such way: system (organization) should have in the same time characteristics of centralization and decentralization [6].

Big transport systems are complex systems which have the following features [1]:

1. They are difficult to determine boundaries; finally fixed it because of the purpose and scope of the research (such as may be determined by the ability to observe the operation of the system);

2. They are open systems, in accordance with the cybernetics approach;

3. They are systems with memory; they are dynamic;

4. They are "embedded" systems, that is, their subsystems are complex systems themselves; we're talking about traffic subsystems, control systems, initial-final (load) processes;

5. They can "produce" the phenomena of emergence (the emergence of new features);

6. The interactions between elements of these systems are non-linear, which means that initially small transport incidents can have large effects;

7. The interactions between the elements are feedback loops, which means that there are both negative and positive (reinforcing) couplings.

Transport systems also meet other criteria of complex systems:

8. They are intrinsically hazardous systems;

9. They contain mixtures of "hidden failures" (hidden failures, eg incorrect design conditions, are prerequisites for accidents in the system);

10. Human experience in these types of systems is constantly changing;

11. The introduced changes generate new forms of damage (failures);

12. Security is a system characteristic, not individual elements.

In transport systems comes to huge numbers of interactions between elements of transport infrastructure, means of transport and the activities of the human factor. The products of these interactions are sometimes hard to predictable behaviors, systems, in particular, human behavior in the areas of decision-making and action. The ultimate product are transport accidents and congestion - the main negative effects of transport NET [7].

4. Transport Systems and High Reliability Organizations

In 1984, the University of California at Berkeley researchers launched a study of complex systems, which was given the name High Reliability Organizations, HRO. The point is that there are systems which an integral part are highly dangerous technologies, and yet serious accidents almost do not happen. These are systems in which mistakes and failures can have disastrous consequences for people and the environment. It applies to nuclear energy, chemical industry, management systems in passenger aviation, maritime industry. So the HRO systems are systems where disasters are avoided and where are expected so-called "normal accidents" (a concept introduced by C. Perrow) because of the many risk factors and complexity of such a system.

How you can simply define HRO? According to K. Roberts you can do this by answering the following question: how many times could the organization fail without causing disastrous consequences? If the answer is: tens of thousands of times, this means that we have to deal with HRO [8]; quote for: [9]. The key term "fail" refers to errors and inefficiencies that may happen in such a system, and yet, there will be no major consequences.

You might ask: did big transport systems – which are, after all, complex systems – are also systems HRO? Or to the management of safety in road transport systems can be made using the philosophy and methodology used in High Reliability Organizations? Large transport systems can sometimes be exemplifications of HRO systems; It is all about the functioning of transport in terms of crisis management, as well as the transport of dangerous goods. In general, however, it would not be possible to include road transport to HRO systems for two main reasons:

1. The potential consequences of individual road accidents in road transport are almost never catastrophic; Of course, the size of losses is devastating when road accidents are considered for longer periods of time.

2. Traffic accidents are statistically frequent events.

5. The Theory of Perrow's "Normal Accidents"

The main thesis of "Normal Accident Theory" (Normal Accident Theory, NAT) of Charles Perrow is (Perrow, 1984): "Accidents in complex organizations (...) are inevitable". Exactly this is also the case for road accidents on a global scale: they are inevitable. That is why there is only one rational strategy for improving road safety - eliminating fatal and serious accidents. This is obviously known for 16 years (Swedish Vision Zero), but almost 30 years ago it was stated by the creator of NAT, but in a more general perspective.

What Perrow referred to as normal accidents or ordinary accidents, he also called, and later others: system accidents or organizational accidents. According to [10] these are: unexpected interactions with many failures in a complex system. Perrow's rather pessimistic thesis about the inevitable accidents in complex systems has its own alternative; proponents of the "high reliability point of view" argue that good design and effective management in such systems can significantly reduce the likelihood of accidents [8, 11].

Perrow also discusses the concept of risk which results from possible interactions between factors and elements of complex social and technical systems. He divides systems into simple and complex ones, depending on the type of interaction in these systems. Simple systems are those in which simple interactions - predictable ones - dominate, as in the domino set. Systems are complex if complex interactions - that is, unpredictable, from accumulation of factors or aspects that are considered separately - appear to be free from risk. The complex interaction emergence initiates unpredictable system behaviors that develop so quickly that the system operator no longer understands the resulting situation, making it irreversible and leading to a systemic accident. This aspect of security is emphasized by Perrow saying that "accidents in the complex system are inevitable". System accidents are the effects of accumulation of so-called group-mode errors (common-mode failures) that form in the system due to unknown feedback loops between system components.

A comprehensive definition of a system accident is given in the paper [12]: “(…)This is no longer just the result of an unhappy combination of passive and hidden negligence with active and direct defects, and not just the result of a specific combination of human errors and material defects. An accident is (...) rooted in the organization's history: a series of decisions or lack of decisions; the development of an organizational, institutional and cultural context that in the future interferes with the system; progressive deterioration of conditions or factors that are within the organization; some special events that have a huge impact on the life and operation of the socio-technical system, creating a disadvantageous situation: the area in which the accident (or incident) can break in and develop. (...) the accident goes through the incubation process. The incubation period can be long”.

The frequency of occurrence of system accidents depends on many aspects of the functioning of the complex system, but above all depends on:

– degree of „interactive complexity”;
– degree of "strong links" between the interactions in the system.

This second feature makes the system highly interdependent, that is, changing one of its parts can quickly affect the condition of other parts and the entire system.

It should be mentioned that Perrow's theory has contributed to the change of philosophy in the design and operation of complex systems, as well as in the study of the safety and reliability of such systems. Attention was drawn to the risk aspects of accidents resulting from the complexity and presence of strong interactions in such systems.

It is necessary to put forward a research postulate to verify the working hypothesis regarding the frequency of system accidents in road transport, i.e. to determine whether it depends on interactive complexity and strong links in large road transport systems, as well as in integrated transport systems. The "transport interpretations" of system accidents known from other areas of technology would be of great importance [13].

For a large road transport system to meet the criterion of strong links it would have to have the following characteristics [12]:

– most work processes are time-dependent, i.e. you can not stop the system by waiting for corrective interactions to appear;
– specific and invariable sequences prevail, in such a way that Event A always leads to Event B;
– the system is not very flexible, so it is planned so that there is only one way to achieve the final goal;
– the system has little leeway. the size of the processed must be in quantities scheduled, the system resources may not be replaced by other, no quick (temporary, temporary) changes of system tools are possible

It seems that only the first criterion can be met by any road transport system. However, the system of dangerous goods transport would mostly meet these criteria.

Perrow’s paradox. The risk in many modern systems of technology depends on the strength of functional connections occurring in such systems. There are always tight and loose. The first are characteristic of decentralized, and the second - for a centralized (hierarchical) management structure. This leads to a paradox - because a well-functioning system (organization) should have both the characteristics of centralization and decentralization [6]. It turns out that centralized control is essential during normal operation, while the ability to improvise is essential in critical situations. It is therefore necessary for such systems to be able to shift from a strict hierarchy to a decentralized, fast structure needed in critical situations - which can be used in the construction of a transport safety management system.

6. System Management Dilemma: Productivity Versus Safety

Using the results of research by J. Rassmussen [14], R. Amalberti introduced the concept of “safe space of activities” (SSA) which he defined by risk analysis at the design stage of a specific real system.Bezpieczna przestrzeń działania jest zawarta pomiędzy trzema liniami granicznymi:

– administrative, social and other regulations;
– market rules;
– safety rules.

In practice, each system aims to achieve greater efficiency and increase the benefits of individual people working

in such a system. As a result of such pursuit - the new security space goes beyond the boundaries defined in the initial (design) space. This new safety space is characterized by lower margins for the risk of incidents and accidents as well as increased violations of regulations and standards.

A security trap is created, in that the continued simple strategies of combating infringements by establishing an increasing number of provisions cause an increase of aversion and ambiguity in reporting incidents in the system, which reduces the quality of risk monitoring and, consequently, increases the risk of an accident. Amalbertii calls this effect a "paradox of an almost completely safe system" and refers it primarily to the general transport system. The SSA concept may be useful for the analysis of safety boundaries in road transport.

An issue from the same subject area is one of the important management dilemmas, i.e. the "two P dilemma", as described in the English-language literature [15]. It is about maintaining a balance between P production and security understood as "protection" P. The resource allocation policy has a decisive influence on the balance in management (Fig. 1).

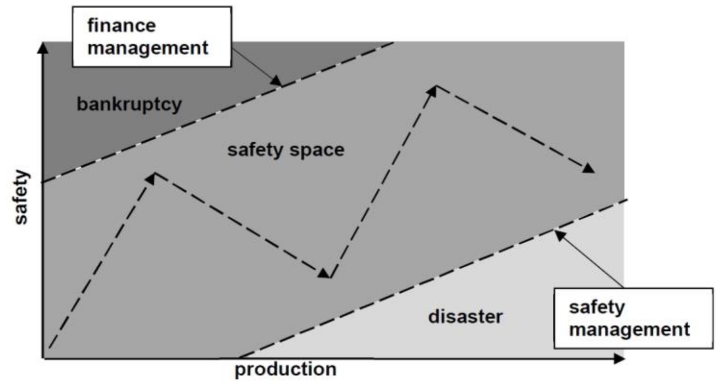

Fig. 1 Interpretation of the two-P dilemma and security space, [15]

Slightly simplifying: when too much attention and resources are devoted to the implementation of the production sphere - the risk of accidents in the system increases; the reverse - by shifting the emphasis of management towards the security of the system - you can bankrupt in an economic sense. Between these extremes is the area called the "security space". It defines a "balance area" that must be known and respected in the management of the system (organization). The main way to solve the above dilemma is risk management, which is sometimes referred to as the synonym "risk balancing". It is a management that has two risks in mind: the risk of bankruptcy and the risk of a disaster.

"Production" can be interpreted differently, hence the "two-P dilemma" model can be implemented in various real systems. This aspect can also be found in transport systems in general and in road transport in particular. Each transport system can be described as a summary due to two "products", which gives: a product of danger (accidents, collisions) and a product of transport efficiency. Managing such "products" in transport systems is difficult because it requires making compromise decisions. Hence the dilemma: what is more important in road traffic? Is the efficiency of road networks and the flow of traffic flows resulting in lower losses of time and the resulting lower transport costs? Or are absolutely preferred safety of road users? Road safety can be a limitation for the efficiency of the traffic system when considering short-term (operational) traffic management horizons. However, it can be one of the goals of management in a strategic vision of management [16].

7. Reason’s Theory. Latent and Active Failures as Necessary and Sufficient Conditions of Creating Accidents

In the process of transport management there are specific "gaps" and "excess" of management, which are symptoms of the counter-effectiveness of this process. Improving the efficiency of transport management, and in particular transport risk management, requires the development of methodologies for identifying such gaps and management excess. In particular, management gaps can be interpreted as hidden conditions for the emergence of accidents in complex systems; also in transport. The criteria for identifying management gaps can be found in J. Reason's theory, which is a significant extension of the theory of signal detection [17, 18].

The basic tool for studying management gaps would be the well-known model of "Swiss Cheese Model" (SChM) by J. Reason, which is part of the wider concept of risk management modeling so called "organizational accidents" arising in complex systems [18]. One of the SChM’s thesis can be formulated as follows: accidents are the effects of gaps in the management of a given system. In this model, the so-called layers of protection ("cheese slices") with various "holes", i.e. hatches of two kinds: 1). Active errors; 2). Latent conditions (so-called “resident pathogens”). Reason believed that these gaps were the main causes of accidents.

Active failures - these are incorrect behaviors and actions of the human factor in the system, as well as errors: omissions, executions, procedural and offenses. However, latent threats are errors from the system design stage or errors in the implementation of management procedures. The main idea of SChM is this: when a hidden threat overlaps with an active error - a gap is created, which is a prerequisite for an accident.

In every real system, including transport, security layers are created, which have a material form (control sytems,

security zones, etc.) or intangible (regulations, standards, procedures). In order for a transport accident to occur on each security layer, gaps must always appear and create an abstract time-space sequence through which the trajectory of the accident will pass (Fig. 2) [19].

Applying the Reason model to the interpretation of road accidents, one can give the following statement: a traffic accident is a result of the imposition of dangerous driver activities, road management problems, erroneous traffic supervision and the so-called traffic accidents at the time and point of the road network. hidden conditions (holes in "Swiss cheese"), (Fig. 2).

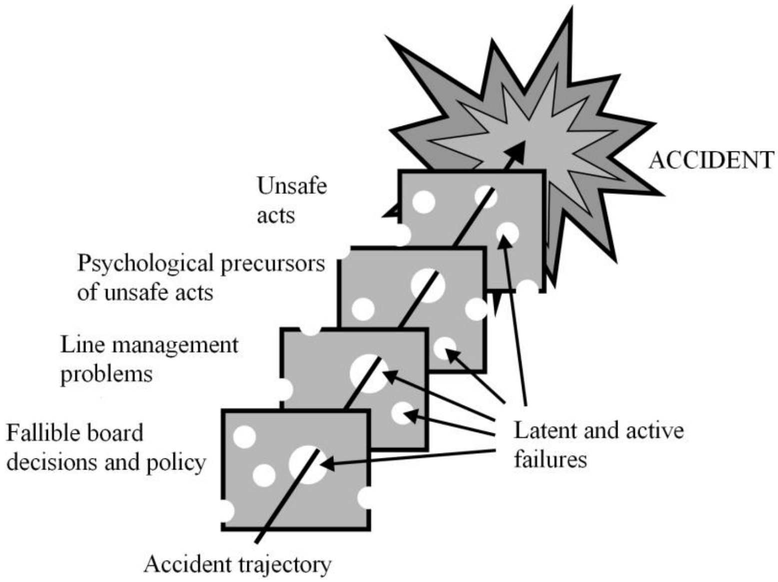

Fig. 2 Swiss cheese model illustrating the abstract trajectory of an accident [19]

In a complex system, active errors are consequences, not causes, because they are forced by various combinations of hidden conditions. Hence the conclusion that security prevention in such a system should minimize the hidden conditions there. And hence the seemingly paradoxical conclusion that the reduction of potential human errors in the transport system is not the most important in the prevention of safety. More important are the activities improving these characteristics of the complex (transport) system, which increase the probabilities of active errors. The thing is, resident pathogens should be removed from the system as early as possible. This forces the application of proactive system management methods, which requires minimization of errors at the level of system design. In the case of transport systems - it is, among other things, about detecting and eliminating errors that appear already at the stage of creating legislation for transport managers (administrations) [20].

8. Conclusions

The article recalls several safety concepts that have been used in safety research in various technical fields (nuclear energy, air transport) and according to the author, they are more widely used in the field of transport. This is in particular a systemic approach to developing a methodology for minimizing all risks associated with the functioning of transport systems - that is the risk of transport accidents, the risk of increased congestion and environmental risk.

These risks accompany any actions aimed at increasing the efficiency of transport, which depends to a large extent on the effective management of activities aimed at the implementation of three basic transport objectives:

1. ensuring high functional efficiency;
2. ensuring a minimum nuisance to the natural environment;
3. ensuring the maximum level of safety.

Effective transport safety management is possible when it is managed by objectives, i.e. the type of system management. The known rule of such management says: safety management referring directly to the size of acceptable risk is usually referred to as risk management. As previously stated, this principle should be extended and specified as follows: transport safety management, referring to the total accepted volume: transport accident risk, environmental risk and transport congestion risk - is defined as the overall (system) transport risk management [1].

There are many major challenges before transport safety research. One of them is the need to research and strengthen the synergy between entities responsible for the level of transport safety. This involves the need to balance active transport policy and spatial planning due to the existence of strong relationships in this area, for example the relationship between mobility and space planning investments.

A very important problem is the integration of risk management methods in all types of transport, as well as on their "contact". Today, the basic challenge for scientists, engineers and transport policy makers is to create a methodological framework and develop a universal standard for integrated transport safety management. However, it must be remembered that from the point of view of safety management, there are significant differences between particular

modes of transport. They mainly concern large differences of road transport from other modes of transport. Therefore, the "1 + 3" concept of an integrated transport safety system will need to be rethought [21].

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Modeling the Impact of the Control Command Systems on the Train Traffic Control Process

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Abstract

In the process of traffic control required the use of systems that guarantee detection and location of trains on the railway line. Currently used CCS systems allows to railway traffic control on the "fix block distance" which allows to ensure the safe distance between trains on the railway line and the information's for driver are provided by signal lights. In this paper the authors deal with functionality problem of railway lines equipped with various CCS systems (line block system and three levels of ERTMS/ETCS). For such analysis the stochastic processes are used to build appropriate models giving the possibility of estimation both probabilistic and time parameters related to efficient application of such solutions. For this purpose, was used mathematical model based on homogeneous, stationary and ergodic Markov processes.

KEY WORDS: *ERTMS/ETCS, stochastic processes, Markov models, ATP/ATC systems, train control command processes*

1. Introduction

The process of safe train traffic control requires use the systems guaranteeing detection and locating of trains on the railway line. Among them you can include track circuits, sensors, cable loops, axle counters and systems ensuring safe sequence consequences (distances) between individual vehicles moving along the routes and stations, i.e. interstate blocks, automatic and semi-linear blocks, or station interlocking systems. In practice, commonly used standard rail traffic control systems (TCS) allow to carry out rail traffic at "distance", ensuring adequate distance between vehicles, thus excluding the possibility of two vehicles (trains) appearing at the same time on the same railway section, and the information is passed on to the driver in the form of appropriate light on the signals. The method of providing information to the driver in the form of light signals, however, has many drawbacks related to the possibility of driver correctly assessing received information. It depends on, among others from weather conditions (day, night, haze, rain, direct sunlight on the signaling device's lenses, or driver's cab), maintenance status of trackside devices (overgrowing of trackside, failure to observe the signals visibility distances, or acts of vandalism), psychophysical state (fatigue, lack of sleep, ...), or even use of sunglasses by the driver. Experience shows that many railway events were the result of a misinterpretation of provided light signal by a human being, which led to incorrect assessment of the situation and mistaken actions by the driver. In addition, according to the requirements and railway regulations, signals can be used on lines on which trains move at a maximum speed equal to $V = 160$ km/h.

In order to eliminate the ambiguity of interpretation of light signals and the limitations of this method of informing the driver, on the railways the cabin signaling system has been used to enable provided information the driver directly to the control desk in the train. These systems commonly referred to as CC (control command) systems allow to meet the requirements of safe train running, limiting the same the possibility of human error. In more advanced CC systems up to control human activities and correct its errors (eg. checking the correctness of driving the train by the driver regarding to the current safe speed profile). The next step in the standardization and unification of CC systems was the introduction of a single system platform - ERTMS / ETCS system [2].

Because regardless of the technical means used, the implementation of specified functionalities (information transfer and driver's activity control) requires the use of more and more complicated and hardware-enhanced systems on vehicles. The question arises what impact the vehicle's technical equipment may have (on specified reliability features, availability ...) on the efficiency and steady flow of railway traffic [4, 5].

In particular, it is the search for an answer, what is the probability of a disturbing event the railway traffic, consisting in stopping the train on the route as a result of an event disturbing the control system, e.g. lack of communication between the center and the vehicle, fault of the on-board system or safe reaction of the on-board system to mistakes made by the driver.

In order to estimate the value of the probability of disturbing event on railway traffic, mathematical modeling based on Markov processes was used [1, 4, 5].

2. The use of Markov Stochastic Processes to Modeling of Events in Railway Traffic

In global terms, railway traffic is a deterministic process based on defined train schedule, which means that such a move takes place according to a predetermined plan with possible deviations. In the macro, this is understood as arrivals and departures to particular route points (stations), time plays a significant role in this process, because at specific moments of time on the appearance of train at the station can be treated as a certain event.

In train traffic control process based on information exchange between the train and the control center, it was assumed that this communication is not determined by time and event (discrete), i.e. for example, the train request for permission to authorized ride (movement authority – MA), the arrival of train at the semaphore. With this approach it is not possible to precisely determine the time of occurrence of an event in the system means that the moments of notifications in the control system understood as time moments t_1, t_2, ... t_n will occur irregularly randomly.[1] Thus, they can be treated as stochastic declarations that are a set of random variables {ξt; t T} [1, 4, 5], defined in particular moments of time t, belonging to the set of determinacy T, in the case of control system, which is the system with real signals, the set T is a countable set and in terms of the control process is time.

By referring above directly to the process of control system, it can be stated that the registration of trains (signals) to the control center can be carried out at any time intervals. If we denote the number of notification as N (s, t) registered in the time interval of duration t beginning at the moment $s \geq 0$, (s, $s + t$) then there is a relation (1).

$$N(s,t) = N(s+t) - N(s), \tag{1}$$

where $N(s,t)$ – number of notifications registered in the system at time t; $N(s+t)$ – number of all notifications registered in the system; $N(s)$ – number of notifications registered in the system until the moment of s.

In this case, the random variable described by the function N (s, t) for each set s and t, means the number of events registered in the system in the interval (s, t), with probability (2) for which the condition (3) is met, that the variable random N (s, t) only accepts non-negative integers for all $t \geq 0$ and $s \geq 0$.

$$r_n(s,t) = P\big(N(s,t) = n\big), \tag{2}$$

where r_n – the probability of a random event N (s, t); n – number of notifications registered in the system in the time interval t, n = 0,1,2,3.

$$\sum_{n=0}^{\infty} r_n(s,t) = 1\,. \tag{3}$$

Because the notification (staying in a certain state) in the case of the control process does not depend on the moment of observation start, specifying the starting point s, and only from the appropriate time interval t, we can assume that in this case we are dealing with a homogeneous process [1, 3, 4]. In order to conduct a mathematical description of events occurring in the railway control process, modeling was based on stochastic Markov processes [1, 3]. Therefore, it has been assumed that the railway control process has a random nature of notifications to operating along with the following assumptions:

– notification is a stochastic, homogeneous process (the point of the beginning of the observation s is not specified);

– in a wider sense of stationary (in the control process we have real signals);

– globally ergodic (in relation to a single implementation of the process step, in this process the average value is constant for the entire process);

– the correlation function depends only on the time interval t.

Such assumptions allow determining the stochastic features of the process based on one implementation [1, 4].

3. Mathematical Model of the Railway Traffic Control Process

The mathematical model is intended to represent the real or theoretical characteristics of the tested system, its structure or selected events, i.e. the occurrence of an event stopping the train on the route as a result of the safety systems implemented on the train, which in turn results in disruption steady flow of railway traffic and can make delays.

Trains ride from the point of view of railway control devices can be presented by the stochastic process. In many works [1,4,5], a homogeneous, stationary and ergodic Markov process is indicated to describe transitions between states responsible for typical train behavior. This train protection process is presented in the figure 1 [4,5], the states correspond to the following situations:

state 0 - the state of correct driving according to the last information received, the driver driving the vehicle according to the last-received MA until the next information about the new MA is received,

state 1 - the state of correct implementation of the control procedure (in accordance with the signal display presented on the signaling device or according to the on-board computer instructions),

state 2 - state of emergency stop or decrease of speed due to safe reaction of the on-board system (emergency

braking enforced by the ATP system - on Polish Railways - SHP system of AWP category).

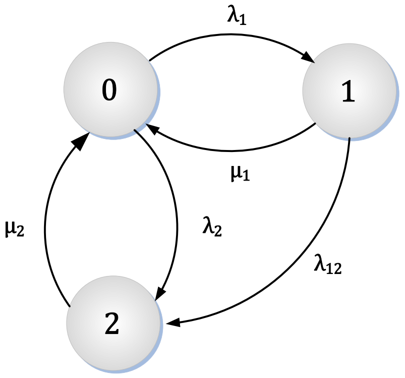

Fig. 1 Basic model of train control [own:4, 5]

The differential equations used to describe transitions between states are based on:

the distance and speed parameters presented above,

λ_1 - the intensity of events related to the train's departure on the permission signal or the received authorized ride and received information about the next ride procedure;

λ_{12} - the intensity of event related to an incorrect train driver reaction or incorrect ATP system operation;

λ_2 - the intensity of the incident related to the implementation by emergency signal a braking (without the participation of the driver) until the train is completely stopped;

μ_1^{-1}- the time necessary to display to the driver information about the next operation - train ride procedure taking into account safety conditions;

μ_2^{-1} - the time necessary for the driver to start ride after automatically stopped the train.

$$\begin{cases} \dfrac{dP_0(t)}{dt} = -\lambda_1 P_0(t) + \mu P_1(t) - \lambda P_0(t) + \mu_2 P_2(t) \\ \dfrac{dP_1(t)}{dt} = \lambda_1 P_0(t) - \lambda_{12} P_1(t) - \mu_1 P_1(t) \\ \dfrac{dP_2(t)}{dt} = \lambda_{12} P_1(t) - \mu_2 P_2(t) + \lambda_2 P_0(t) \end{cases} \tag{4}$$

taking into account the initial condition $P_0(t)+P_1(t)+P_2(t)=1$, (estimate the boundary values of probabilities of occurrence in defined earlier states. $P_i(t)\big|_{t\to\infty}$) (5).

$$\left.\begin{aligned} P_0 &= P_0(t)\big|_{t\to\infty} = \frac{\mu_2\cdot(\lambda_{12}+\mu_1)}{(\lambda_{12}+\mu_1)(\lambda_2+\mu_2)+\lambda_1\cdot(\lambda_{12}+\mu_2)}; \\ P_1 &= P_1(t)\big|_{t\to\infty} = \frac{\lambda_1\mu_2}{(\lambda_{12}+\mu_1)(\lambda_2+\mu_2)+\lambda_1\cdot(\lambda_{12}+\mu_2)}; \\ P_2 &= P_2(t)\big|_{t\to\infty} = \frac{\lambda_1\cdot\lambda_{12}+\lambda_2\cdot(\lambda_{12}+\mu_1)}{(\lambda_{12}+\mu_1)\cdot(\lambda_2+\mu_2)+\lambda_1\cdot(\lambda_{12}+\mu_2)}. \end{aligned}\right\} \tag{5}$$

The single step of the control process is understood as the event consisting in the exit from the state 0 to any other state of the process (receiving information by the driver about the mode of proceeding 1,2) and returning to the initial state 0. The use of the proposed mathematical models is presented on the example of a train system equipped with national B-class systems and traffic in the mode of "fixed block distance - ride to the signal of signal device, and a train equipped with ERTMS / ETCS system of different levels.

3.1. Class B National System

This model describes currently the most often implemented process of train traffic control. From the point of view of the control process for this case, it is situation where there are 3 states of this process 0, 1, 2 and a situation is possible that causes the train to stop without driver interference as a result of receiving a STOP signal or as a result of a wrong driver reaction (excluded from consideration are cases of stoppage due to damage to the vehicle). For this case, a model of a single step of the control process was obtained as in Fig. 1.

In existing railway control devices, which are used to ride a train based on a fixed block distance (occupancy of

subsequent sections), occupancy of subsequent track sections takes place based on the display of signal authorized ride and information about the occupancy of the track sections from vehicle moving along the railway line.

Therefore, the state $P2$ can be treated as the operational coefficient (functional), which is responsible for the effectiveness of the railway control. This means that the train control method is related to the capacity of the railway line resulting from the possibility of occupying subsequent track sections.

Assuming a maximum length of block section 1500 m and a maximum speed of 160 km/h, as well as the parameters for the Markov model shown in Fig. 1, which are:

– λ_1 - intensity of required rides for properly authorized ride permits amounting of 106.67h-1 (corresponding to the time of preparation for displaying to vehicle a permit signal 33.75s);

– μ_1 - intensity of typical service amounting to 300 h^{-1} (request service time 12 s);

– λ_2 – intensity for incorrect interpretations in relation to the requirements (failure rate) equal to 0.000227687 h^{-1} (associated with the occurrence of 2 ride ended by an emergency stop in a year);

– λ_{12} – intensity of erroneous interpretations in relation to requirements (failure rate) 0.005952381 h^{-1} (related to the time occurring during emergency ride, 1 per week);

– μ_2 - intensity of emergency service of 72 h^{-1} (inverse emergency service time of 50 s) after substituting for the above equations and calculations, we get the value for a fixed block distance of: $P2_{FBD}$ = 2.401 * 10-5.

3.2. ETCS Level 1

Level 1 of ETCS is an overlay for railway control devices used at stations and on railway line and is treated as a distributed control system. Assuming the maximum length of block section of 1500 m and in this case for the maximum speed of 250 km/h and the parameters for the Markov model shown in Figure 1 which are [2]:

– λ_1 – intensity of connection before a balise (signal) equal to λ_1 = 166.67h^{-1} (in relation to 21.6s);

– μ_1 – estimated intensity of services of 360000 h-1 (related to max. 10 ms) is associated with the assumption of, synchronization time when passing over 1 m;

– λ_{12} – intensity of failure telegrams from balise leading to train stop of 0.33 * 10^{-9}/h;

– λ_2 - intensity of on-board equipment failures in accordance with THR for on-board equipment 1x10^{-9};

– μ_2 - intensity of switching on-board devices to the dedicated mode for non-equipped trains amounting to 0.03333 h (associated with 120 s, time to implement the train in the non-equipped train mode),

after substituting the above equations and calculations we get the value for ERTMS / ETCS level 1 of: $P2_{ETCS\,L1}$ = 3,003 * 10^{-8}.

3.3. ERTMS/ETCS Level 2

Level 2 of the ERTMS / ETCS system uses continuous control of the vehicle by using a digital two-channel data transmission. Track-side equipment (except eurobalises) are additionally equipped with the RBC radio control center. This is related to the possibility of eliminating trackside signaling devices and the use of non-switchable eurobalises in control areas.

Using the assumptions as for level 1 and the parameters of the Markov model presented in Fig. 1, they are[2]:

– λ_1 – equal to 14,173h^{-1} (in relation to the maximum ERTMS / ETCS request time related to RBC 254 s);

– μ_1 – estimated intensity of telegram services in the RBC amounting to 3,600 h^{-1} (related to the service time of 1s);

– λ_{12} – intensity of stopping the vehicle by RBC, THR for the radio control center 0.67 * 10^{-9} /h;

– λ_2 – intensity of on-board equipment failures in accordance with THR for on-board equipment 1x10^{-9};

– μ_2 – estimated intensity implementation of emergency mode 30h^{-1},

after substitution to the above equations and calculations we get the value for ERTMS / ETCS level 2 of: $P2_{ETCS\,L2}$ = 3,407 * 10^{-11}.

3.4. ERTMS/ETCS Level 3

Level 3 of the ERTMS / ETCS system is a development of level 2 resulting from the transfer monitoring of track section occupancy by railway control equipment from the level of trackside devices to the level of vehicle equipment. This allows controlling the consequences of vehicles with the use of a changeable block section that does not use traditional track circuits and track axle counters.

Using the assumptions as for the level 2 parameters of the Markov model presented in Fig. 1, including exceptions:

– λ_1 – intensity of the authorized ride is above 70 h^{-1} (related to the maximum request time of 2 s);

– μ_1 – estimated intensity of telegram service in the RBC amounting to 3,600 h^{-1} (related to the service time of 1s);

– λ_{12} – intensity of stopping the vehicle by RBC, THR for the radio control center 0.67 * 10^{-9} /h;

– λ_2 – intensity of on-board equipment failures in accordance with THR for on-board equipment 1x10^{-9};

– μ_2 – estimated intensities for the implementation of emergency mode 30h^{-1},

after substituting for the above equations and calculations we obtain the value for ERTMS / ETCS level 3 of: $P2_{ETCS\,L3} = 3{,}695 * 10^{-11}$.

Table 1

The probability of appearance of failure state in analyzed model of a fixed block distance in relation to three levels of the ERTMS / ETCS system

PROBABILITY	FIXED BLOCK DISTANCE	ERTMS/ETCS LEVEL 1	ERTMS/ETCS LEVEL 2	ERTMS/ETCS LEVEL 3
P_2	$2{,}401 \cdot 10^{-5}$	$3{,}003 \cdot 10^{-8}$	$3{,}407 \cdot 10^{-11}$	$3{,}695 \cdot 10^{-11}$

The probability of appearance of failure state in analyzed model of a fixed block distance in relation to three levels of the ERTMS / ETCS system presented in Table 1.

4. Summary

The calculations allow the performance of a statement describing the efficiency which is possible to achieve with the use of classical railway control devices during the control of the occupancy by train of subsequences fixed block distances with respect to the three levels of the ERTMS / ETCS system.

All presented parameters refer to the official data on railway control devices and the ERTMS / ETCS system [2]. In each model presented (fixed block section, level 1, level 2, level 3) the probability of state 2 is significant from the point of view of unavailability of the system (state 2 corresponds to the uncontrolled emergency stopping of the vehicle caused by malfunctioning signaling devices or automatic vehicle control devices).

It can be notice that each subsequent level of vehicle control reduces the probability of occurrence of state 2, so the availability of the entire system is improved. The presented model is quite simple, however, it gives the opportunity to model and verify the assumed parameters using computer simulation methods.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Safety Performance Analysis of the Movement and Operation of Locomotives

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Abstract

To estimate the state of the locomotive facility and work, performed by the locomotives, a system of planned and calculated indicators is used. The state of traffic safety in a locomotive facility is estimated in most cases by comparing the absolute number of traffic incidents with previous periods. Accordingly to the existing system of traffic safety analysis, the volume of work performed in the locomotive facility is not taken into account. **The purpose** of the research is to determine the methodology for forming a certain dimensionless indicator (or group of indicators) that will reflect the overall level of safety in the locomotive facility, taking into account the volumes of work performed by locomotives. The authors suggest the usage of the relative indicators to estimate the state of traffic safety, factoring in the volumes of transportation. As a **method of research**, we chose the method of the main components as the appropriate mathematical apparatus, which allows analysing the proposed indicators, characterizing the performed work and the traffic safety state with the necessary degree of informativeness. **As a result**, the most informative indicators and the degree of their correlation with the general index of traffic safety state were determined. **Originality** of the study lies in the fact that the system of indicators for the traffic safety analysis was improved; the concept of the traffic safety state index and the method of its determination using the method of the main components were improved. **The practical value** of the work is that we propose to use the relative indicators for estimating the traffic safety, taking into account the volumes of transportation; the ranking of the proposed indicators accordingly to the degree of their impact on the overall level of traffic safety is performed.
KEY WORDS: *railway transport; traffic safety; locomotive; indicators of locomotives operation; method of main components; traffic safety index*

1. Introduction

Compliance with the safety in operation of vehicles is a prerequisite for the passengers and cargo transportation. Operation of all railway systems must comply with the conditions for safe transportations. On the railway transport, much attention is paid to the traffic safety state. This is explained by significance of railway transport for the economy of any country and its social function concerning passenger transportation.

Transport companies constantly conduct an analysis of train traffic safety to obtain data about the level of actual or predicted train traffic safety. The results of the analysis of traffic safety state are used to estimate the effectiveness of measures aimed at ensuring a given level of safety, for the rational destribution of resources allocated for the tasks solution of safe trains traffic, for certification of transport services and technical means of railway transport, to justify priorities in the destribution of resources and suchlike.

The analysis of the traffic safety state is performed continuously and is based on the analysis of statistical data, expert assessments, and the use of probabilistic methods. Undoubtedly, to achieve absolute safety of traffic - at which the probability and actual occurrence of incidents (accidents, catastrophes, injuries, destruction of rolling stock and objects of infrastructure) will be zero is impossible. The highest level of the traffic safety state, theoretically, can be achieved if transportation is stopped. There will be no operation of the railway, as a result the probability of occurrence of incidents is minimal. This approach is contrary to the target of railway transport, but reflects the imperfection of the system of indicators used for the analysis of the traffic safety state.

2. Analysis of the Traffic Safety State

Transport companies [1-4, 6, 18], when performing the analysis of the traffic safety state, use a comparative method of estimating the absolute values of indicators for certain calendar periods of time. Using this approach, the change in absolute indicators such as: the number of transport events, the number of victims and injured persons, the number of passes of prohibited signals and others are estimated. The application of such an approach does not take into account the volume of work performed, intensity of movement, etc., which leads to an incorrect comparison of the periods being analyzed.

The system of planned and calculated indicators is used to evaluate locomotive facility and work performed by locomotives. The well-known one is the distribution of indicators in the work of locomotive facility on quantitative (volumetric) and qualitative indicators. With the help of these indicators and a number of calculations, comparison and analysis in the efficiency of locomotive operation and the general state of the locomotive facility is carried out. [5].

Operational work on railway transport should be organized in accordance with the requirements of the Rules of Technical Operation of Ukrainian Railways (RTO). In addition to analyzing the quantitative and qualitative indicators in the railway network, constant monitoring and analysis of traffic safety state is conducted. The aim of the analysis is to determine ways to improve the operation of locomotives and ensure transportation safety.

Locomotive facility is a part of the complex organizational and technical system of the railway. Tasks of the locomotive facility include: operational work, repair of rolling stock, ensuring traffic safety, planning technical and organizational support, and others. Obviously, estimating the work of a locomotive park using an existing system of indicators is a difficult task. Carrying out the analysis of indicators requires the use of a systematic approach that will lead to a more complete and deep analysis.

With the existing system of analysis of the locomotive facility operation, statistical information is a huge amount of information that is difficult to analyze. The conducted analysis [7] allows confirming that the existing system of traffic safety indicators periodically changes from year to year, which also complicates the analysis. It must be understood that attempts to improve the process of analyzing the performance of a locomotive through the introduction of new additional indicators will lead to the creation of even larger amount of data that will be difficult to analyze by conventional methods.

Specialists in the field of locomotive facility are working to improve the existing system for predicting and analysis of the traffic safety state.

Researches [8-13] are devoted to studies on the reliability of the rolling stock, as well as the analysis of the traffic safety state. In papers [8] a technique for estimating the quality of locomotive repairs based on the energy efficiency indicator is proposed.

The paper highlights the technique of determining the statistical parameters of the train traffic safety during the operation [10]. The authors propose a probabilistic approach to defining the traffic safety indicators. This allows estimating the overall level of traffic safety in a particular locomotive depot compared with other locomotive ones in railway network. The authors take into account only statistical deviation of the indicators from the mean value, while the volumes of performed work not count. A more perfect approach can be given based on volumes of work performed by locomotives.

Papers [11, 12] are devoted to the definition of the level of risks in the performance of passenger and cargo transportation. The necessity of increasing the informativeness of the indicators system applied for the analysis of traffic safety state in the locomotive facility is emphasized. In paper [12] the necessity of formation of a single indicator for functioning of separate structural subdivisions or railways as a whole is indicated. When determining the risk of losses in passenger and cargo transportation, it is proposed to take into account the ton-kilometers of the work performed or the total value of losses for the reporting period for all types of transport events. From our point of view, the ratio record of work performed to the number of involved locomotives can be more informative in the assessment of risks.

Principles of assessing the cost-effectiveness of measures to improve the traffic safety were considered in paper [13]. The risk assessment is performed using the ALARM technique and the expert judgment method. The authors propose the approach of determining the priorities for implementing measures to improve the traffic safety state using quantitative risk analysis. It based on statistical data and fuzzy logic apparatus.

The assessing the level of risks and possible economic losses is also necessary in the development of locomotive diagnostic systems, selection and improvement of rolling stock maintenance systems, which is reported in papers [14, 15]. The practicability of using methods of expert research, methods of fuzzy sets theory in the development of locomotive diagnosis systems, as well as with the aim of analyzing the level of losses and risks are presented in papers [16, 17].

Thus, the current trends in the direction of reliability and traffic safety are in gradual transition from absolute values of indicators to more precise and objective assessments.

In paper [7], the definition of a single integral indicator of the traffic safety state I_{ts} was proposed, calculations were made using the hierarchy analysis method [17] characterizing the work performed and the traffic safety state.

3. Calculation Results

In this paper, we offer the further improvement of the proposed index I_{ts}. For this aim, it is proposed to use the bonded locomotive fleet, the number of workers in the locomotive facility and others for the analysing the specific values of the index, taking into account the work performed by locomotives. As input data, information from statistical sources of Ukrzaliznytsia (UZ) is taken.

When carrying out calculations the expediency of using new and refining existing indicators for assessing the traffic safety state of the locomotive facility was considered. Proposed indicators x_i ($x1 \div x11$), that are relative ones and take into account the scope of work performed and traffic safety state. Each of the proposed indicators is defined as safety ratio of the component (SR) to the quantitative and qualitative indicators of locomotives usage (LU):

$$x_i = \frac{SR_i}{LU_i}\,. \tag{1}$$

Characteristics of the proposed indicators are given in Table 1.

The indicators x_i are formed on the basis of logical analysis of the mutual connection in components of safety

and operation of locomotives. In order to verify the degree and nature of the mutual connection in the components, the coefficients of mutual linear correlation are calculated.

The calculation results are given in Table 2.

Table 1

Characteristics of the proposed indicators for the analysing the locomotive traffic safety state

Indicator	Unit measure	Definition
*x*1	event/locomotive section	(the total number of transport events) / (fleet of locomotives in operation)
*x*2	event / tkm.gross	(the total number of transport events) / (average annual productivity of the locomotive)
*x*3	event /thousand ton	(the total number of transport events) / (cargo transportation)
*x*4	event / thousand ton	(the total number of transport events)/ (the number of employees engaged in the operation of locomotives)
*x*5	event /(locomotive section/ per diem)	(the number of transport events resulting from the unsatisfactory depot repair) / (daily average operating fleet of locomotives)
*x*6	event / thousand people	(the number of transport events resulting from unsatisfactory depot repair) / (the number of employees engaged in maintenance work in the locomotive facility)
*x*7	event / thousand people	(the number of transport events resulting from improper actions of locomotive crews) / (the number of employees engaged in maintenance work in the locomotive facility)
*x*8	event / thousand people	(the number of transport events resulting from the passage of the prohibited signal) / (the number of employees engaged in maintenance work in the locomotive facility)
*x*9	event /thousand ton	(the number of transport events resulting from the passage of the prohibited signal)/ cargo transportation)
*x*10	event /(locomotive section/ per diem)	the number of transport events caused by the failure of locomotives / daily average operating fleet of locomotives)
*x*11	event / (thousand people / per diem)	(the number of transport events resulting from improper actions of locomotive crews) / the average number of employees engaged in maintenance work in the locomotive facility.

Table 2

Coefficients of components correlation of the proposed indicators

Index	Components of the proposed indicator		Value of the linear correlation coefficient between components
	traffic safety state (SS)	Locomotive usage (LP)	
*x*1	the total number of transport events	fleet of locomotives in operation	**0.87**
*x*2	the total number of transport events	average annual productivity of the locomotive	**-0.92**
*x*3	the total number of transport events	cargo transportation per year	0.43
*x*4	the total number of transport events	the number of locomotive employees engaged in the operation of locomotives	**0.95**
*x*5	the number of transport events resulting from unsatisfactory depot repairs	average daily fleet of locomotives	**0.87**
*x*6	the number of transport events that resulting from unsatisfactory depot repairs	the number of employees engaged in the operational work in the locomotive facility	**0.92**
*x*7	the number of transport events resulting from improper actions of locomotive crews	the number of employees engaged in the operational work in the locomotive facility	**0.75**
*x*8	the number of transport events resulting from the passage of the prohibited signal	the number of employees engaged in the operational work in the locomotive facility	-0.34
*x*9	the number of transport events resulting from the passage of the prohibited signal	cargo transportation per year	0.16
*x*10	the number of transport events caused by the failure of locomotives	daily average operating fleet of locomotives)	**0.86**
*x*11	the number of transport events resulting from improper actions of locomotive crews	the average number of employees engaged in maintenance work in a locomotive facility per diem	-0.53

As we see from the calculation results, components of indicators $x1$, $x2$, $x4$, $x5$, $x6$, $x7$, $x10$ have a linear relationship. The presence of a link indicates the expediency of using these indicators for further analysis, since their components are interrelated. When one of the components changes, another component must also change by a certain amount, and this value of mutual change in the components is constant. In the events of violations in the organization of the locomotive safety management system, the nature of deviation between the components will change. Thus, analysing the changes of these indicators over a certain time interval will allow determining the traffic safety state.

Actual is the increase in the informativeness of existing indicators or the creation of an integral indicator for the analysis of traffic safety state. The authors performed calculations using the hierarchy analysis method [19]. They were aimed at the determining the degree of impact of each of the proposed indicators x_i on the total integral specific index of operational traffic safety I'_{ts}. Since indicators x_i take into account the number of transport incidents per unit of work or the number of personnel, then the integral index of operational traffic safety I'_{ts}. in its content is a specific indicator.

Output data for calculation are given in the Table 3.

Table 3

Output data for calculation

Indicator	Value by year							
	2008	2009	2010	2011	2012	2013	2014	2015
$x1$	0.00029	0.00034	0.00032	0.00028	0.00028	0.00027	0.00028	0.00030
$x2$	0.00074	0.00070	0.00065	0.00058	0.00051	0.00045	0.00040	0.00042
$x3$	0.00081	0.00100	0.00086	0.00073	0.00068	0.00062	0.00065	0.00072
$x4$	6.32813	6.71548	6.63793	6.17068	5.73661	5.45667	5.27228	5.54688
$x5$	0.00015	0.00019	0.00018	0.00016	0.00016	0.00015	0.00015	0.00016
$x6$	3.28125	3.66109	3.66379	3.43545	3.25893	3.06792	2.87129	2.94271
$x7$	1.69922	1.61088	1.68103	1.37856	1.60714	1.68618	1,68317	1.74479
$x8$	0.00099	0.00039	0.00000	0.00256	0.00117	0.00168	0.00143	0.00260
$x9$	0.00001	0.00000	0.00000	0.00002	0.00001	0.00001	0.00001	0.00002
$x10$	0.00021	0.00022	0.00019	0.00020	0.00021	0.00021	0.00020	0.00025
$x11$	0.62500	0.62762	1.09914	0.98468	1.09375	1.10070	1.38614	1.04167

When the calculation is made the required percentage of saving the original information is not less α = 87%. As a result of the calculation, 4 main components were identified $g_1 \dots g_4$, which in total contain 92% of the source information. Each from components g_i contains a certain amount of information concerning traffic safety and performance factors. The block diagram for the index of operational traffic safety I_{ts} is shown in Fig. 1.

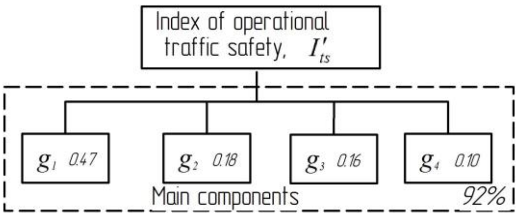

Fig. 1 Structure of the index of operational traffic safety

Index I'_{ts} contains 92% of the source information and consists of 4 main components with dispersions: g_1 = 0.468, g_2 = 0.185, g_3 = 0.158, g_4 = 0.102.

Time history I'_{ts}. by years is presented in Fig. 2.

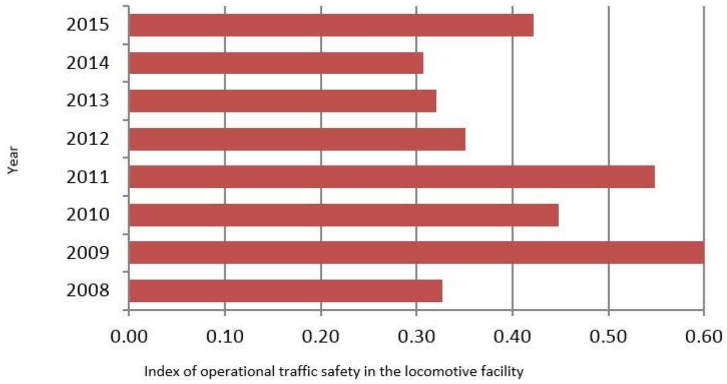

Fig. 2 Index of operational traffic safety in the locomotive facility

The obtained values attest about deterioration of the relative safety state in the locomotor facility in 2009, 2011

and 2015.

The composition of each component includes the values of the quantities $x_1 \div x_{11}$ to some extent. Indicators $x3$, $x4$, $x6$ have the greatest impact on the values of the first main component. Indicators $x9$, $x11$, $x2$ has impact on the formation of the second component. Indicators $x1$, $x6$, $x8$ has impact on the third; the fourth is impacted by $x9$, $x6$, $x11$ ones.

4. Conclusion

Based on the calculations it was established that the index of operational traffic safety in the locomotive facility is most impacted by the following indicators:

– the ratio of the number of transport events resulting from the passage of the prohibited signal to the number of transported goods ($x9$ - 18% of impact);

– the ratio of the number of transport events resulting from improper actions of locomotive crews to the average number of employees engaged in the operational work in the locomotive facility, ($x11$ - 14,5% of impact),

– the ratio of the total number of transport events to the fleet of locomotives in operation ($x1$ - 14.5% of impact)

– the ratio of the number of transport events that resulting from unsatisfactory depot repair to the number of employees engaged in maintenance work in the locomotive facility ($x6$ - 13.5% of impact).

Thus from the point of view of the indicators informativeness is expedient to carry out the analysis of the traffic safety state using relative indicators and taking into account volumes of transportations.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Repeatability of the Road Surface Temperature Indications Using a Mobile Sensor in the Context of a Road Weather Information System

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Abstract

The paper presents the tests results of pavement temperature measurement using a mobile road weather information sensor, installed on the vehicle, especially in the context of repeatability assessment. This type of sensors may be a part of the measurement layer of the early warning system which will be informing users about deteriorating road surface conditions. First part of the tests was the repeatability assessment of the road surface temperature in static conditions, i.e. when the vehicle was stopped. In the next phase of research, at the shortest possible time intervals, three runs were made along a designated route of about 2.5 km. During test the temperature of the surface and the position of the vehicle on which the sensor was installed were simultaneously recorded. This allowed the analysis of recorded temperature waveforms as a function of the road and the average temperatures on particular road sections. The authors have demonstrated qualitative compatibility of the temperature changes between the individual sections identified in the subsequent runs. Nevertheless, probably due to the air temperature rising during the tests, the measurements carried out in the morning hours did not allow the quantitative assessment of temperature changes. Therefore, the tests were repeated in night conditions, providing a more stable air temperature. The analysis of the repeatability of the road temperature readings was carried out again. The test results and analysis presented in the work indicate a satisfactory repeatability of the road surface temperature indication determined by the mobile weather information sensor. Therefore, the suitability of such a sensor as a part of the measurement layer of road weather information system should be positively assessed.
KEY WORDS: *mobile sensor, pavement temperature, road weather information system*

1. Introduction

The surface condition is one of the basic determinants of the road safety level. Information on the current condition of the surface is important for drivers and maintenance services, especially in winter conditions, when the air temperature fluctuates around 0°C. Paper [1] presents the initial concept of a road information system in the city's transportation network, which would also enable short-term weather prediction and, therefore, early warning system about the adverse road weather conditions. The system consist of the three layer: measurement, calculation and information. The basic element of the measurement layer may be a system of mobile registration of road weather conditions [2]. The system is used to gather data recorded using the Lufft MARWIS mobile road weather information sensor, GPS receiver, accelerometer and current vehicle speed from the CAN bus. Its task is also to process the information obtained into a standardized form and transfer it to an external database.

In the context of using the MARWIS sensor for the construction of a road weather conditions mobile registration system, the issue of repeatability of its indications becomes highly important. Mobile sensors are a relatively new solution, which are rather rarely discussed in literature. Sample results of measurements made with the use of mobile sensors from other manufacturers (Vaisala DCT111 – measurement of surface temperature and DCS 111 – determination of surface condition) are presented in publication [3]. Sensors of this type are mounted on the vehicle and enable continuous measurement of selected parameters of the surface condition while driving. In combination with the GPS transmitter, the measurements of the sensor are correlated with the geographical position. From the point of view of the utility of the aforementioned systems, the most important indication of the mobile sensor is the road surface temperature measurement. Therefore, the authors of the article attempted to assess the repeatability of indications of this measured parameter.

2. MARWIS Sensor

The MARWIS mobile road and weather sensor, which is the subject of this study, is shown in Fig. 1. It is used to detect road condition by providing information about:

- road surface temperature;
- dew point temperature;
- relative humidity of the air above the road surface;
- water film height;
- ice percentage (percentage of the frozen part of the aqueous solution on the roadway);

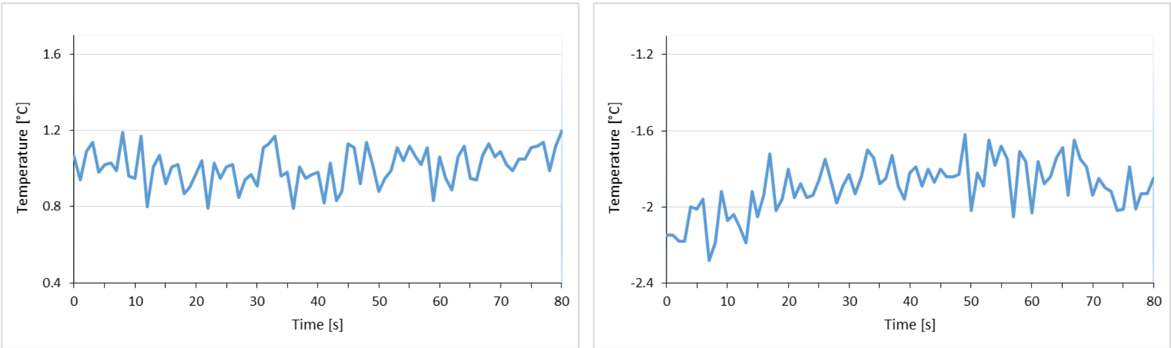
- friction;
- surface condition (dry, damp, wet, snow-/ice-covered, chemical wet, critically wet).

Road surface temperature measurement is carried out in the range from -40 to 70°C with a resolution of 0.1°C, accuracy of ± 0.8°C and frequency of less than 1 s.

Fig. 1 MARWIS sensor

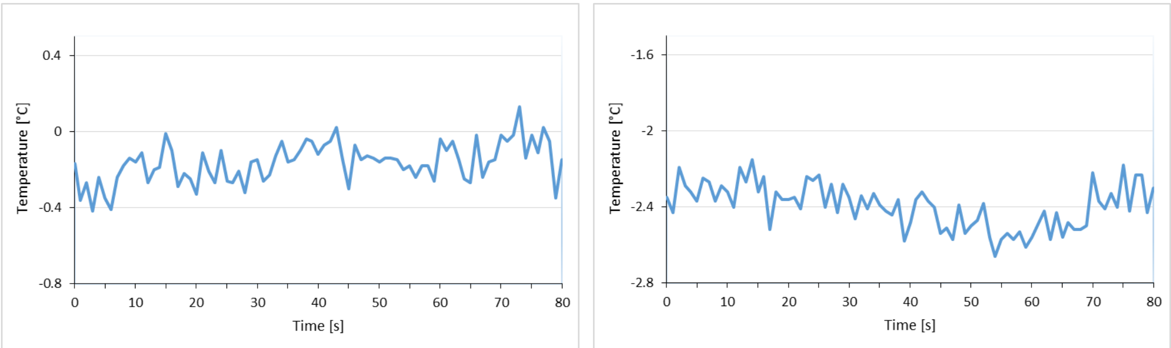
3. Stationary Tests

The first stationary tests were carried out with the parked vehicle. They were supposed to give the answer what is the stability of indications of surface temperature measurements using the MARWIS sensor in stationary conditions. Tests were performed under daylight and after dark. Each time the measurement was carried out twice - once for the dry surface and once for the snow-covered road. Figs. 2 and 3 shows respectively obtained results for day and night conditions. Additionally in Table 1 presented the standard deviation of the measurements.



a b

Fig. 2 Road surface temperature obtained in stationary test conducted during the day: a - dry road; b - snow-covered road



a b

Fig. 3 Road surface temperature obtained in stationary test conducted during the night: a - dry road; b - snow-covered road

Table 1

Standard deviation of road temperature measurement in stationary conditions

Measurement condition	Standard deviation [°C]
day, dry road	0.098
day, snow-covered road	0.141
night, dry road	0.105
night, snow-covered road	0.117

The following conclusions can be drawn from the results of stationary test:

1. in stationary measurements road temperature shows good stability, as evidenced by small values of standard deviation;
2. stability of indications in stationary measurements for dry road is better than for snow-covered road regardless of lighting conditions (day, night);
3. the amplitude of the indication changes is less than 0.5°C, and therefore does not exceed the accuracy of the measurement declared by the manufacturer;
4. stability of indications in the conducted stationary measurements is slightly better in night conditions.

4. Test Drives

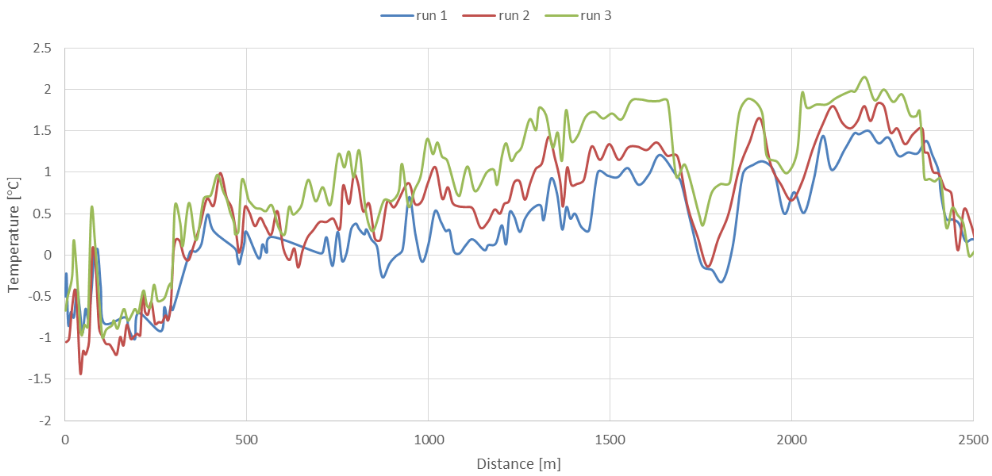
The basic road tests were carried out in mid-February 2018 in typically winter weather conditions. Since the studies concerned the determination of repeatability of surface measurements and the authors do not have access to a professional test road section with regulated surface conditions, it was decided to choose a relatively short route of about 2.5 km. Thanks to this, subsequent drives were carried out in small time intervals to minimize the impact of road state changes related to both the state of the atmosphere and the traffic. At the same time, chosen route is characterised by varying traffic and level of maintenance services in the winter season, so that different road conditions could be observe. The route is located in the foothill area in Bielsko-Biała.

Day runs

First, a series of three drives in daylight conditions were made. The tests took place at possibly short intervals. The entire research process was carried out between 8:20 and 9:10. In this period registered varied road conditions, but no precipitation occurred. The maximum travel speed during the tests did not exceed 50 km/h. In test the road surface temperature, speed and position of the vehicle on which the sensor was installed were recorded. This allowed analysis of the recorded waveforms of temperature as a function of the road and the mean temperature values for 100 m sections. In Figs. 4, a and b showed the registered value of the surface temperatures for particular sections, while in Fig. 4, d presented a list of the registered parameters as a function of roads for all three drives. Fig. 5 shows the averaged results for each 100 m sections.

a

b



c

Fig. 4 Road surface temperature along the test drives for daytime passes: a - run I; b - run III; c - distribution of road surface temperature as a function of the distance

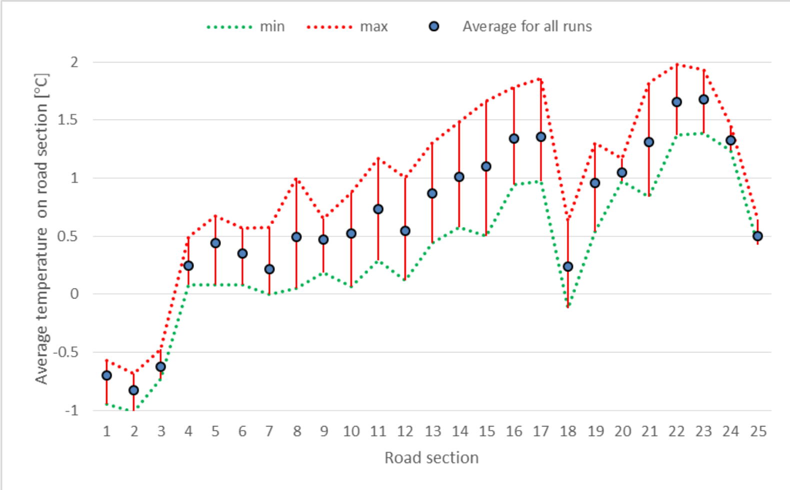
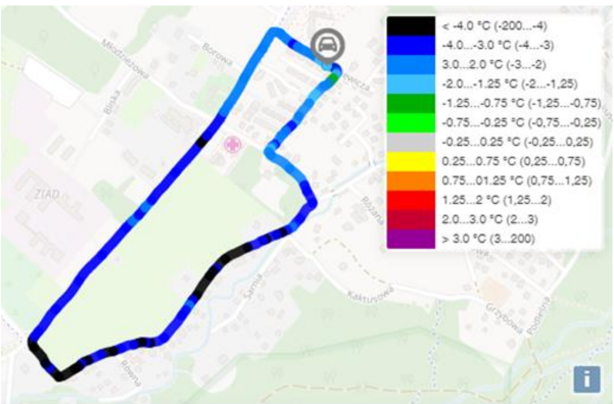


Fig. 5 Averaged results for daily drives for 100 m sections

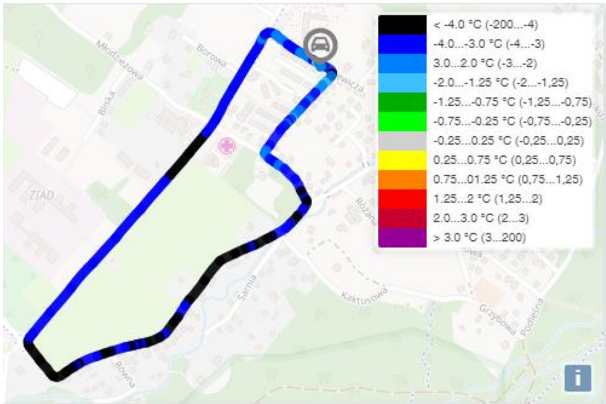
Analysing the obtained results, in particular the charts presented in Fig. 4, c and Fig. 5, it can be noticed that the character of the road surface temperature as a function of the road is similar for individual test runs. It demonstrates the qualitative conformity of the temperature changes identified in subsequent runs, between the individual sections. However in Fig. 4, a and b, there is a noticeable increase in temperature for subsequent runs. This is understandable due to the fact that in morning hours the ambient temperature increased slightly, consequently increasing the road surface temperature. All in all, this noticeable temperature rise trend seems to be a positive sign of the MARWIS sensor's measurement properties.

Night runs

To ensure a more stable air temperature, and therefore more stable measurement conditions, the tests were repeated on the same day, but in the evening hours (20:15 - 21:15). The obtained results are shown in Figs. 6 and 7, similarly to day runs.



a



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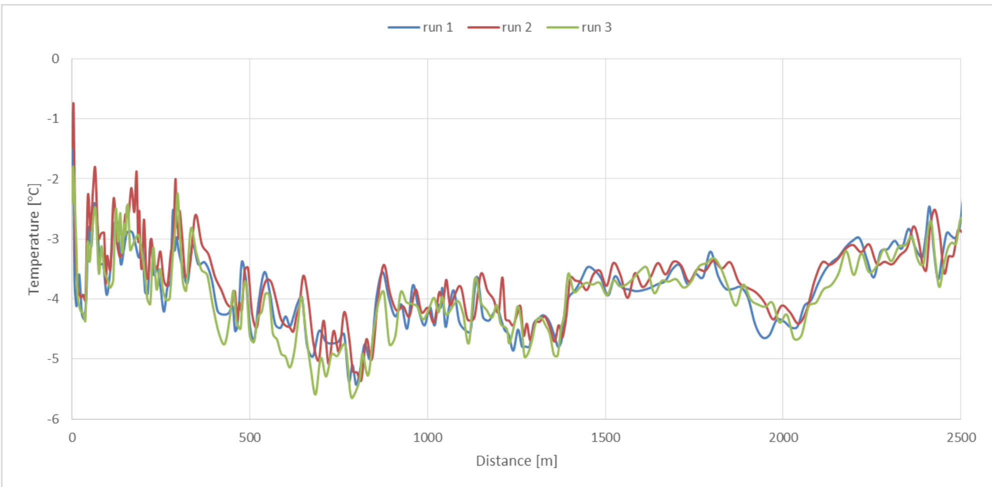

c

Fig. 6 Road surface temperature along the test drives for night passes: a - run I; b - run III; c - distribution of road surface temperature as a function of the distance

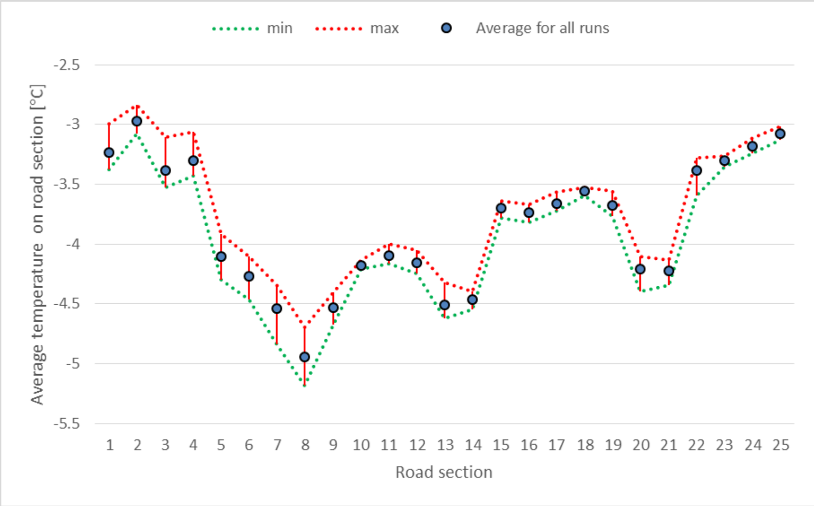

Fig. 7 Averaged results for night drives for 100 m sections

The results and analyses of the night tests indicate a high repeatability of the road temperature registered by the MARWIS sensor. The recorded differences in averaged indications for individual sections do not exceed 0.5 °C, i.e. the nominal measurement accuracy declared by the manufacturer.

5. Conclusions

The results of carried out MARWIS sensor tests including repeatability of road surface temperature measurements were positive. The stationary tests were characterized by a considerable stability of indications regardless of lighting (day and night) for both dry and snow-covered road sections. What is particularly important, the amplitude of indications did not exceed the accuracy of the measurement declared by the sensor manufacturer. Road tests also confirmed satisfactory repeatability of road surface temperature readings, both for single measurement points and for averaged values for 100 meter sections. In addition, the measurements performed during the daytime at a slightly rising ambient temperature indicated that the tested sensor correctly responds to even small changes in temperature. Summing up the results of the tests, it can be concluded that the MARWIS sensor will fulfil its role well in the road information system in the city's transportation network [1] and in the mobile registration system of road weather conditions [2]. The authors intend to use this sensor also for research related to the development of assumptions for the local meteorological shield system of the Bielsko-Biała ring-road.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Analysis of Movements of TEU Intermodal Transshipment Terminal in the Area of Polish

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Abstract

Favourable premises of intensive development of intermodal transport, due to situation of Poland at the intersection of main European transport corridors, were analysed in this article. Proper functioning of the whole chain of intermodal transport depends mainly on proper functioning of trans-shipment terminals. The authors analysed the processes taking place in trans-shipment land terminals and mathematical analysis was conducted for a road part. A non-parametric method was used for this purpose.
KEY WORDS: *trans-shipment land terminals, intermodal transport*

1. Introduction

The integration of transport processes requires development of international systems combined into one network. Intermodal transport combines rail transport with road and maritime transport, while maintaining one form of cargo. Supporting of development of terminals of intermodal transport will enable to limit transport of goods by road transport, which leads not only to destruction of road infrastructure, but also increases exhaust emission, which leads to degradation of the environment. Therefore, there is a strong need to stop the tendency of growing use of road transport and replacing it with intermodal transport, which may also contribute to safety in a road traffic.

European Union, European Confederation of the Ministers of Transport and European Economic Commission UN, claimed that intermodal transport, as an alternative to traditional road transport, may play a significant role in achieving goals of all-European policy of sustainable development of transport, because promotion of such form of cargo flow may contribute to solving current and future transport problems in Europe. European Union emphasized that it is necessary to change European transport system into the one better for environment and human life [1, 16, 5, 6]. It is fundamental to the future of transport of European Union.

2. Intermodal Transport in Poland

Due to accession of Poland to the European Union in 2004, supporting the development of intermodal transport should be one of main elements of Polish transport policy [2]. A stimulus to the development of intermodal transport in Poland is foreign contractors, who require to use standardized loading units. The majority of intermodal transports in Poland is transport by containers (94,2%), and also swap bodies (5,4%) and car trailers (0,4%). The major participants of the market of intermodal transport in Poland are PKP CARGO, Spedcont, Polcont, Polzug, Trade Trans, Cargosped and seaports, including, above all, Baltic Container Terminal in Gdańsk port. The activity of PKP CARGO is focused forwarding companies and operators of intermodal transport of containers, trailers and swap bodies in Poland and abroad. Intermodal transport network in Poland is the part of Trans-European transport network and includes linear and nodal infrastructure allowing transport and trans-shipment of intermodal transport units (TEU). In Poland, there are favourable premises for intensive development of intermodal transport, due to situation of Poland at the intersection of main European transport corridors (Fig. 1) [10].

Nodal infrastructure of intermodal transport networks consists of, above all, land and sea terminals (mainly container) and logistic centres (Fig. 2) [9, 7, 11]. The network of railway lines of intermodal transport in Poland is 4 278 km, and basic terminals, important for international intermodal transport, are situated in Gdańsk, Gdynia, Gliwice, Cracow, Łódź, Małaszewicze, Poznań, Pruszków, Sosnowiec, Szczecin, Świnoujście and Warsaw. Poland, in terms of number of terminals - 31 does not differ considerably from European countries, except for Czech Republic - 65, France - 83, Germany - 119 and Italy – 104.

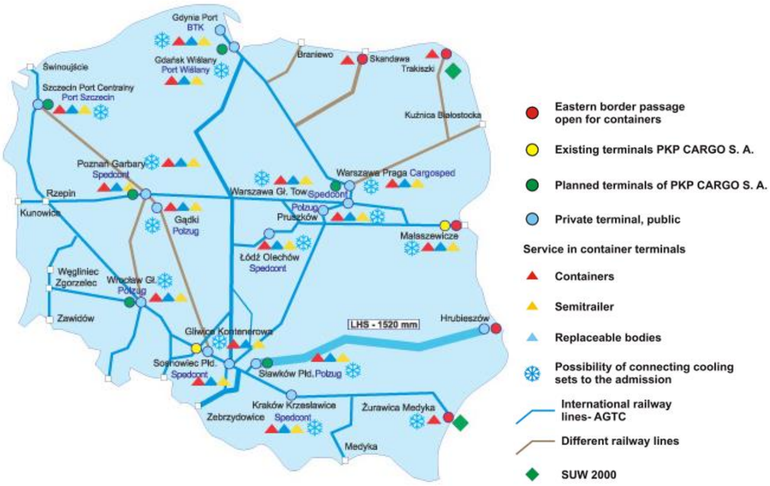

Fig. 1 Main transport corridors in Poland and Europe in intermodal transport [10]

Fig. 2 Loading terminals in Poland [17]

3. Land Trans-Shipment Terminals in Chains of Intermodal Transport

Land terminals in transport chains provide space, equipment and environment for the transfer of intermodal transport units (TEU). Therefore, it can be presented as a box (Fig. 3), where TEU comes to by road vehicle, a

nd after trans-shipment, they leave a terminal in carriages formed in a train or units come to a terminal by train and leave terminal in road vehicles.

Fig. 3 Units entring and leaving land terminal [10]

3.1. Infrastructure of Trans-Shipment Land Terminal

Typical trans-shipment land terminal consists of (Fig. 4.):

- railway system;
- road system,

loading front: railway strip, manipulation strip, storage strip, road strip.

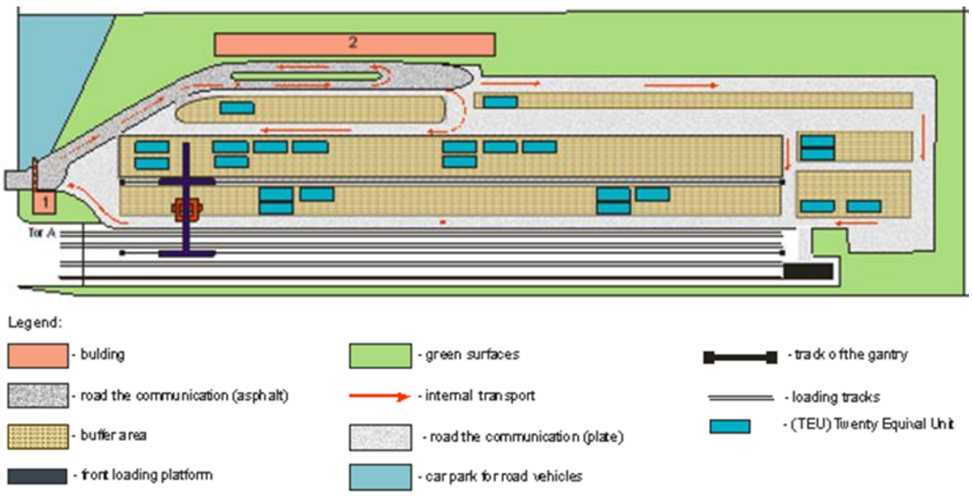

Fig. 4 The plan of the distribution of base stations and their radio ranges in the trans-shipping terminal A

Railway strip - it includes railway tracks (loading tracks) and tracks or railway track connecting front of cargo with a railway network [12].

Road system - it includes access roads, which connect terminals with network of public roads, as well as roadway and manipulation strips for road vehicles within loading front, and parking lots for motor vehicles.

Loading front– it connects railway system with a road system.

Railway ***loading front*** consists of:

- **railway strip –** it includes a loading track where carriages are placed for the purpose of trans-shipment works;

- manipulation strip – an area of work of loading devices;

- storage strip - (zone, storage area) for storage of TEU interoperational during indirect trans-shipment, as well as for long-term storage of TEU;

- road strip – an area for road vehicles within loading front.

In practice, manipulation strips and road strips may be, above all, of functional meaning. Manipulation, road and storage strips should allow cars to move freely, as well as devices operating within land terminal, which requires appropriate strength of surface and dewatering.

In order to increase efficiency of functioning of a terminal of intermodal transport, it should be equipped with such elements as: equipment (*weighing machines*), trans-shipment machines, technically efficient means of transport, lighting devices, plumbing systems, communication system, data procession centre, peaks, administrative buildings, technical back, fire-fighting equipment, electrical connector, fence [13, 3, 15, 14, 18].

Communication devices – telephone lines of postal network, (communication of a terminal with a customer), railway network (communication with railroad service), Internet. Moreover, land terminal should be equipped with a network of radio communications and IT network.

JTI weighing machines – they are used to check the mass of TEU. Properly equipped land terminal should provide 24-hour work (the illumination of the whole area of a terminal).

4. Identification of a Model Service System of Road Part of Land Trans-Shipment Terminal

In order to assess a system, which is trans-shipment land terminal in terms of temporal relations in such systems, there is a need to develop a mathematical model of such terminal (Fig. 5). The use of models with a theory of mass service, presenting trans-shipment land terminal in a form of network of service posts is justified, because using such mathematical device enables to determine the parameters such as: mean lengths of queues, mean waiting times TEU, the number of service posts, mean time of complete task accomplishment etc. [4, 8].

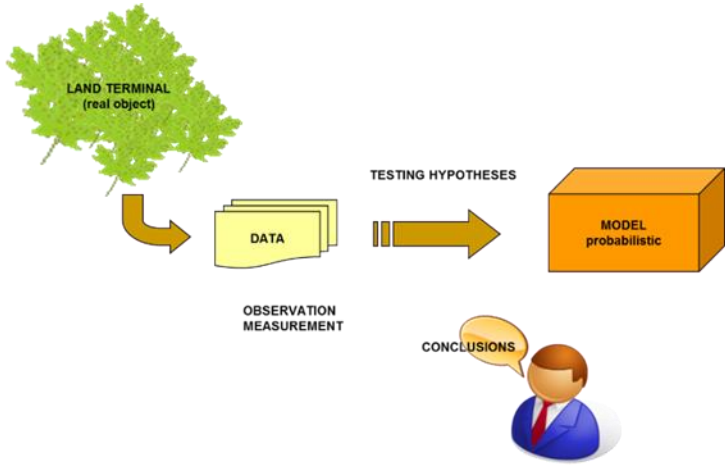

Fig. 5 Model identification (own study)

The authors analyzed the parameters, processes occurring in the transshipment terminal by land A (Table 1).

Table 1

Technical capabilities of Terminal A (own study)

Technical features	**Terminal A**
trans-shipping capabilities	41 tons
number and the length of railway tracks	$2 \times 700 = 1400$
surface of the terminal	76 000 m^2
area of storing	53 800 m^2
possibility of storing	6000 TEU, 3 coset
kind of TEU reloaded	containers, swap, bodies, semi-trailers

4.1. Identification of Distribution of an Input Stream of Notifications in Land Terminal A

In order to get information about the possibility of applying a mathematical device of theory of mass service do

further research on complex system, which is trans-shipment land terminal, conformity of input stream of notifications with Poisson stream in land terminal A was tested.

If we deal with Poisson stream, then time slices between subsequent notifications must have exponential distribution with a distribution function (1):

$$F_o(t) = 1 - e^{-\mu t}\,. \tag{1}$$

The following hypotheses for terminals A and B were formulated (2):

H_0: time slices between notifications have an exponential distribution with a distribution function

$$F(t) = 1 - e^{-\mu t}\,; \tag{2}$$

H_1: time slices between notifications do not have an exponential distribution.

Null hypothesis was checked with the use of λ-Kolmogorov compatibility test.

Statistics in a form of (3) is used for conformity assessment:

$$D = \sup_x |F(x) - F_o(x)| \tag{3}$$

and (4):

$$\lambda = D\sqrt{n}\,. \tag{4}$$

Statistics, with the assumption that hypothesis H_0 is true, has an asymptotic distribution λ-Kolmogorov.

The measurements of notification moments on 2017-08-10 (terminal A) were taken based on statistical data from Table 2.

Table 2

Notification moments and calculations

Service time		Empirical cumulative distribution	Cumulative distribution theoretical		
		0			
1	1	0,02564103	0,081119041	0,055478016	0,081119041
2	3	0,1025641	0,155657784	0,053093681	0,130016758
3	1	0,12820513	0,224150015	0,095944887	0,121585912
4	2	0,17948718	0,287086222	0,107599042	0,158881093
5	2	0,23076923	0,344917104	0,114147873	0,165429924
6	3	0,30769231	0,3980568	0,090364493	0,16728757
7	3	0,38461538	0,446885856	0,062270471	0,139193548
9	2	0,43589744	0,532982377	0,097084942	0,148366993
10	2	0,48717949	0,570866399	0,083686912	0,134968963
11	3	0,56410256	0,605677305	0,041574741	0,118497818
12		0,58974359	0,637664384	0,047920795	0,07356182
13	3	0,66666667	0,667056702	0,000390035	0,077313112
14	2	0,71794872	0,694064743	0,023883975	0,027398077
15	3	0,79487179	0,718881918	0,075989877	0,0009332
17	2	0,84615385	0,762640136	0,083513711	0,032231659
19	2	0,8974359	0,799587046	0,097848851	0,0465668
21	1	0,92307692	0,830782882	0,092294041	0,066653015
19	1	0,94871795	0,799587046	0,149130903	0,123489877
35	1	0,97435897	0,948230518	0,026128457	0,000487431
42	1	1	0,971365567	0,028634433	0,002993407
	Number of observations 39				0,16728757 D – maximal difference

Avarge value 11,82051282

Intensity 0,084598698

Deviation standard 8,77158029

Value of the Kolmogorov 1,044710537

Value of the cumulative distribution Decomposition border Kolmogorov 0,77

Significance level 0,23

Conclusion: With determined significance level α = 0,23 there are no grounds for rejection of hypothesis H_0.

4.2. Identification of Distribution of Time Service in Land Terminal A

A hypothesis for terminal A:

H_0: Time of service of a notification has an exponential distribution with a distribution function (5):

$$F_0(t) = 1 - e^{-\mu t};\tag{5}$$

H_1: Time of service of a notification is not subject to exponential distribution.

Null hypothesis was checked with the use of λ-Kolmogorov compatibility test. The following statistics are applied for conformity assessment:

$$D = \sup_x |F(x) - F_o(x)|\tag{6}$$

and (7):

$$\lambda = D\sqrt{n}.\tag{7}$$

Statistics, with the assumption that hypothesis H_0 is true has an asymptotic distribution λ-Kolmogorov.

The measurements of duration of service of notifications on 2017-08-10 in a land terminal A were taken on the basis of statistics from Table 3.

Table 3

Service time and calculations

Service time		Empirical cumulative distribution	Cumulative distribution theoretical		
		0			
1	1	0,025641026	0,081119041	0,055478016	0,081119041
3	4	0,128205128	0,224150015	0,095944887	0,198508989
3	2	0,179487179	0,287086222	0,107599042	0,158881093
3	2	0,230769231	0,344917104	0,114147873	0,165429924
3	3	0,307692308	0,3980568	0,090364493	0,16728757
4	4	0,41025641	0,446885856	0,036629445	0,139193548
4	4	0,512820513	0,491753945	0.021066568	0,081497534
5	2	0,564102564	0,605677305	0,041574741	0,092856793
5	2	0,615384615	0,637664384	0,022279769	0,07356182
6	2	0,666666667	0,667056702	0,000390035	0,051672087
6	1	0,692307692	0,694064743	0,001757051	0,027398077
6	1	0,717948718	0,718881918	0,0009332	0,026574226
7	3	0,794871795	0,741685947	0,053185848	0,023737229
7	1	0,820512821	0,762640136	0,057872685	0,032231659
7	2	0,871794872	0,799587046	0,072207826	0,020925775
7	1	0,897435897	0,815844353	0,081591545	0,055950519
8	1	0,923076923	0,879362785	0,043714138	0,018073112
8	1	0,948717949	0,906403619	0,04231433	0,016673304
8	1	0,974358974	0,938686611	0,035672363	0,010031337
8	1	1	0,971365567	0,028634433	0,002993407
11	Number of observations 39				0,198508989

D – maximal difference

Avarge value 11,820

Intensity 0,0845

Deviation standard 8,825

Value of the Kolmogorov 1,239

Value of the cumulative distribution Decomposition border Kolmogorov 0,902

Significance level 0,098

Conclusion: With determined significance level α = 0,098 there are no grounds for rejection of hypothesis H_0.

5. Conclusion

Movement towards and within the land terminals A and B was analysed. The research conducted by the authors has shown that service system of a road part of trans-shipment land terminal is a typical M/M/n system in accordance with D. G. Kendall's symbolism. An analysis of TEU service time has shown that it is in conformity with exponential distribution. As a result of identification of the streams of notifications (road part of trans-shipment land terminal) for terminals A parameters such as: mean coefficient of the post use, stoppage rate, mean length of a queue, mean number of notifications in a service system of a road part, mean waiting time in TEU queue, mean time of staying in a service system, mean TEU service time in the post.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Non-destructive Testing of Critical Infrastructure Objects

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Abstract

The article deals with the possibilities of using non-destructive methods for diagnostics and evaluation of building materials and structure elements suitable for critical infrastructure. It focuses on diagnostics before and after blast explosions and penetrations. It describes the use of ultrasound pulse method for diagnostics of materials and elements, resonance method and hardness method for evaluation of materials.
KEY WORDS: *non-destructive testing, materials evaluation, materials diagnostics, ultrasound, resonance method*

1. Introduction

In the Czech Republic, there are several institutions and companies focused on the development of new building materials, that could be used for critical infrastructure protection, for example the University of Defence (Department of Engineering Technology and Department of Mechanical Engineering), the Military Research Institute in Brno, the Research Institute of Building Materials in Brno, the Czech Technical University in Prague, the University of Technology in Brno and other private companies. There is also the Technical University of Ostrava, where many interesting articles on critical infrastructure have been written [1-4]. In the Slovak Republic, it is the Žilina University in Žilina where several articles dealing with testing and protection of critical infrastructure have been written at the Faculty of Special Engineering [5-10]. In cooperation of the University of Defence (Department of Engineer Technology) and the Czech Technical University in Prague (Department of Concrete and Masonry Structures), a new building material on a cementitious base was developed and tested, both in a laboratory and also in situ. This building material is called ultra-high performance fibre reinforced concrete (UHPFRC) and it is characterized by high compressive strength (higher than 150 MPa) and by a relatively low modulus of elasticity. It is a building material which, by its parameters, is very suitable for the fortification of military bases, but also for improving the protection of critical infrastructure objects, for example power plants, substations or road bridges. The basic research of UHPFRC took place at the Department of Concrete and Masonry Structures at the Czech Technical University in Prague, where the basic properties were determined [11-14].

The slabs and panels of different shapes and sizes, made from UHPFRC, were exposed to the loading of an explosion and after that they were tested using non-destructive methods, for example ultrasound methods. This field testing is carried out by the Department of Engineer Technology at the University of Defence for more than ten years [15-20] and it has started with the dissertation thesis "Use of reinforced concrete for protective structures" [6]. The development and testing of the material and elements continue in two projects: "Technology Development in the Field of Arms, Ammunition, Arms Equipment, Materials Engineering and Military Infrastructure" funded by Ministry of Defence and "Research, Development, Testing and Evaluation of Critical Infrastructure Elements" funded by Ministry of Interior of the Czech Republic.

2. Non-Destructive Testing

The non-destructive testing (NDT) is currently used in civil engineering mainly for the diagnostics of reinforced concrete structures. The methods of NDT are used to determine strength characteristics of structural elements of constructions built from reinforced concrete and to localize the reinforcement and its quantity and shape. The NDT methods are sometimes also used for detection of defects or homogeneity in structural elements.

There is a number of the NDT methods that are used in civil engineering, mainly for their non-destructive nature and thus the possibility to repeat the tests, even several times, on the same point of the structural element, as it is shown on the example of a bridge structure [21]:

- hardness methods – reflection, imprinting;
- dynamic methods – ultrasound, resonance, impact-echo, acoustic emission, phase velocity, shock absorbing;
- electromagnetic methods – probes, resistance and capacitive methods, semiconductor methods;
- radiation – radiometric methods, radiographic methods, radon measurements;
- methods of local breach – core boreholes, tear tests, hardness penetration;
- chemical methods.

3. Ultrasound Method

In the civil engineering practice, several types of ultrasound methods are used to determine properties of building materials and to localize defects in structural elements [22]. The ultrasound waves with frequencies ranging from 20 kHz to 150 kHz (exceptionally up to 500 kHz) are used most often in the civil engineering. The main advantage of ultrasound waves is that they can penetrate through relatively thick layers of building material. The ultrasound pulse methods are based on the fact that any defect in the structural element decreases the pulse velocity but also increases the wave attenuation. Another important fact that might highly negatively influence the results of the measurement is a position of measuring points, see Fig. 1, which has to be spread over the tested element away from steel rod reinforcement or handling points.

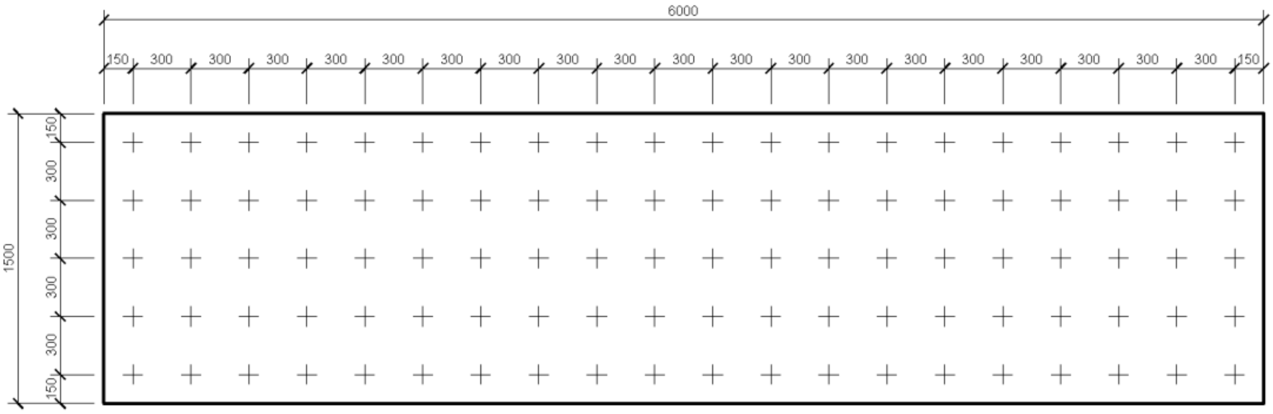

Fig. 1 Measurement grid on full-scale slab loaded with a distant blast

The ultrasound method is used directly on the construction site to check the homogeneity, strength characteristics and flaw detection in building structures made from reinforced concrete. Air humidity, air temperature, measurement base and measurement procedure are crucial factors that could significantly influence the propagation velocity of ultrasound waves. Based on the evaluation of the longitudinal wave velocity, the building element is tested with ultrasound to find out some of its properties:

- Propagation velocity of ultrasound waves;
- Dynamic modulus of elasticity;
- Compressive strength;
- Tensile strength;
- Other properties (weight, waterproofness, frost resistance, gas tightness).

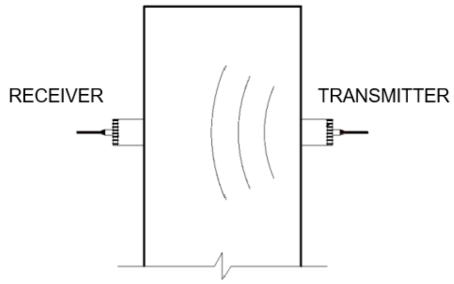

Fig. 2 Principle of measurement by ultraasound pulse method

Any crack or inhomogeneity inside the structural element prolongs the path of the pulse between the probes, see Fig. 2, and it also behaves as a phase boundary showing significantly lower passage velocity and higher attenuation than the building material itself. The crack or the inhomogeneity is more correctly detectable if it is oriented in the perpendicular direction to a pulse propagation direction [23].

For this reason, it is necessary, besides to the direct method, to employ also the indirect method to detect the crack or inhomogeneity that is parallel to the pulse propagation direction, as shown in Fig. 3 and Fig. 4. The indirect method does not give the correct pulse velocity values but it can show the approximate position of any flaws inside the structural element that are not visible on the surface of the tested element and thus it enables to assess in a more reliable way the level of damage of the element caused by the effects of the loading of an explosion.

The direct method together with the indirect method was several times effectively used by the authors of the article within in situ experiments in a military training area [15, 16, 23, 24]. During many NDT measurements of the full-scale slabs before and after the explosive load, see Fig. 5, around 5500 points of measurement grids were examined. Using both methods has revealed the true extent of damage of the tested elements after an explosion load, even inside the 300 mm thick UHPFRC slab, as shown in Fig. 6.

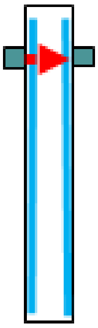

Fig. 3 Direct Method

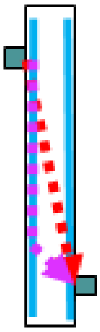

Fig. 4 Indirect Method

Fig. 5 NDT measurement of the full-scale slab before the 25 kg explosive load

For the in situ experiments in a military training area, a portable ultrasound device "Pundit Lab Plus", which consists of the main unit with a display and two attached ultrasound probes, a transmitter and a receiver, was repeatedly used. The device is equipped with several functions: an estimate of compression strength, an integrated wave measurement, a real time stamp and an extended probe ranges. The main purpose of these experimental field measurements with the ultrasound device was to assess the condition of building structural elements that were exposed to an extraordinary load of both close and distant explosions of several kilograms of plastic explosive. The NDT measurement was carried out before and after the explosions to acquire data about pulse passage velocity. The evaluation of the effects of this type of an extraordinary load is useful for both civil engineering area, for example, in assessing the condition of a bridge after a terrorist attack, and also in military constructions, especially in the evaluation of fortifications in military bases hit by a rocket or a mortar.

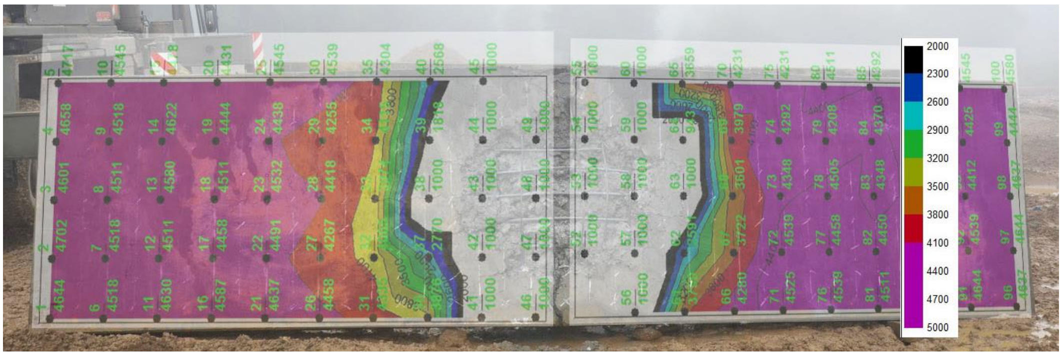

Fig. 6 Sample No. 1 after the loading of 25 kg of an explosive

4. Resonance Method

The resonance method is a dynamic non-destructive testing method which is used to detect dynamic properties of the material such as the dynamic tensile modulus, the dynamic shear modulus and the dynamic Poisson coefficient values [25, 26]. The principle of the pulse excitation method consists of detecting the natural frequency of the tested element. There are two main categories of the resonance method:

1. Method of continuous excitation – the device, providing the excitation range from 30 Hz to 30 kHz, where an electric signal is transformed into mechanical oscillation, consists of two probes, an exciter and a receiver, and the oscilloscope shows the amplitude of forced oscillation in the tested element.

2. Method of impact excitation – the device has just one probe, a receiver, while the impact is caused by a steel ball or by a hammer, and the oscilloscope shows the amplitude of forced oscillation in the tested element placed on a special pad, as shown in Fig. 7, and the relation between the amplitude and the frequency and between the amplitude and the time, see Fig. 8.

Fig. 7 Rubber pad under the tested element

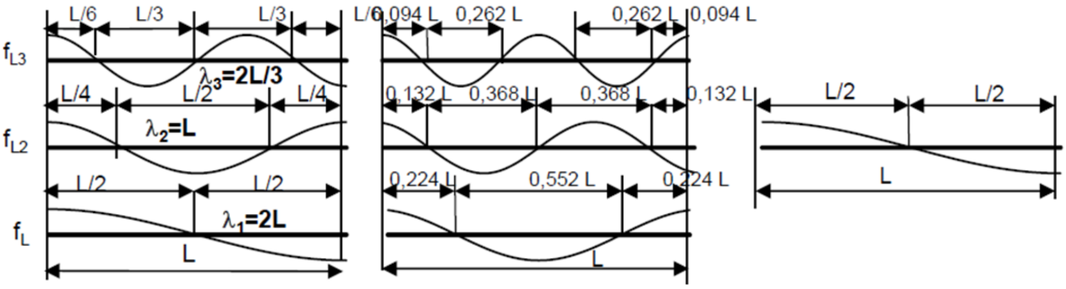

Fig. 8 Oscillation flow diagram

5. Conclusion

The detection of the flaws in the UHPFRC structural elements caused by an explosion loading is a complex problem and it is not possible to rely only on just one detection method. Based on the field tests carried out during past years it was found that the direct measurement method must be used together with the indirect measurement method. The disadvantage of this method is a low sensitivity to small cracks but a smaller number of measurements are necessary in comparison with the direct method. While using the ultrasound method, it is also necessary to take into account the position of the steel rod reinforcement in the structural element because the propagation velocity of ultrasound waves in steel is 1.2 - 1.9 times higher than in plain concrete, which could seriously distort the measured values and thus the whole measurement.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

The Influence of the Piston Surface Shapes on Biodiesel Combustion in Compression Ignition Engine

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Abstract

At present, the internal combustion engine is the most advantageous and convenient source of power for all large-scale plants and large-scale transportation vehicles. But on this question, it is mainly caused by the efficiency of these engines. In order to improve the efficiency, the researchers made a lot of investigations, like how to make air and fuel full mixing is done in the engine cylinders. By properly designing the intake manifold and exhaust manifold [10], combustion chamber shape, pistons, etc., can improve the characteristics of diesel engines (IC engine) [11]. In the combustion chamber, how to mix air with fuel, air movement, fuel injection time, internal pressure and bowl size at the bottom of the piston and geometry are some important evaluation parameters for controlling engine properties and exhaust emissions. The intake manifold includes a throttle body and a combustion chamber, wherein the piston is an important component. Usually the researchers conduct single study on the throttle or piston effects to improve performance for engine. In this paper, author will combine the throttle valve with differently shaped pistons to find the best combination to improve engine performance, air-fuel mixture formation and combustion completeness for reducing the exhaust emissions.
KEY WORDS: *intake system, complete combustion, piston geometry, engine efficiency, swirl*

1. Introduction

In the engine, we can use various methods to control the exhaust emission. Usually there are two methods used to improve engine performance: one is change the engine structure, another is change the fuel used. Thus, instead of traditional fuels, biofuel could combust in the engine combustion cylinder. Then design of combustion cylinder could be improved for changing the air and fuel mixture ratio in the combustion chamber, and in the exhaust system the EGR used to control exhaust gas emissions. Optimal location of the injectors (injector's installation angle) could improve the quality of the air–fuel mixture [5]. In addition to change engine structure, the change in fuel type for improving the engine performance could be implemented. These are biofuel, life refuse oil, plant seed oil modified through addition of aromatic agents, etc. In this paper, the influence of piston surface shape on the degree of mixing air with the fuel will be considered. In general, the mixing ratio of the air and fuel mixture is important to the engine. So in this paper the research is focused on the effect of the different shapes of the piston on improvement of the air-fuel mixture coefficient. Find the better one by the geometry of the surface of the piston. the target of the current research is to make the air-fuel to mix better in the premix process (induction stroke) and pave the way for the combustion after.

2. Research Background

It is meaningful to study the application of biodiesel in diesel engines to improve operational efficiency and reduce pollutant emissions. And engine performance and exhaust emissions characteristics of a CI (compression ignition) engine are primarily determined by the combustion process. The combustion ratio of fuel in the cylinder is controlled by various factors such as fuel injection time [12], pressure at fuel injection, engine design, such as combustion chamber geometry and injector installation position [6], fuel properties, the number of boreholes and the size of the injector, the spray pattern of the fuel, the vortex ratio generated by the air entering, the amount of fuel entering during the injection, etc. [13]. The geometry of the combustion chamber and the nature of the fluid in the combustion chamber are important in diesel combustion [14]. As the piston moves up, the gas is pushed into the piston bowl. The geometry of the piston bowl can be designed to create a squeezing and rotating action by which air can be vortexed, which can improve the steering of the air/fuel mixture to form a complete mixture prior to ignition, thereby increasing the rate of combustion and reducing Emission of harmful substances in the exhaust gas. The background above the diesel engine combustion and emissions formation process is closely related to the geometry of the piston bowl, which it is possible that strong eddy currents can affect the mixing of air and fuel before the start of premixed combustion. [9]. Recently, the effects of diesel fuel and biodiesel in different bowl geometries have been experimentally studied. Jaichandar and Annamalai studied the effect of the geometry of the bowl at the bottom of the piston on engine

performance when burning biodiesel in diesel engine combustion. In their study, the geometry of the four types of piston bottoms was studied, namely hemispherical piston combustion chambers, planar piston combustion chambers, double hemispherical piston combustion chambers and inclined bottom piston combustion chambers [1-4]. Dolak and Reitz began researching fuel injections and studied variables such as the number of injections and eddy current ratios to optimize engine performance and combustion ratio. [2]. Raj et al. A research of energy-saving piston configurations for useful air movement was conducted, in which four configurations of flat, tilted, center bowl and tilt-biased bowl pistons were studied [3]. Therefore, this paper is mainly to study the engine piston chamber geometry required for the design. The main goal of this paper is to optimize the fuel-air mixture ratio during ignition and before ignition to achieve full combustion and complete combustion. Afterwards, the emission of exhaust components is improved. Then in this paper, the geometry of the engine piston is set to Fig. 1.

3. Structural Models

Before analyzing engine properties and emissions components, the model was created using ANSYS software. In this research, we performed CFD analysis and research using a four-stroke engine with dual-valve direct intake and exhaust manifolds. However, this article gives a schematic diagram of the basic flat piston engine, as shown in Fig. 1. The engine setting table is shown in Table [7]. In this research process, the CAD model refers to setting a uniform crank angle. Analyze at a specific crank angle. The model of the engine was created in Ansys program and meshing of it is done by the mentioned software. So, Fig. 2 shows the fluid calculation grid for the basic engine flat piston. For more accurate simulation results, the mesh set included element size as 2 mm and the part of valve was set 1mm as element size because this part due to the air flow through valve cause some eddies and the valve can stop air and fuel to go through so the boundary mesh was set to 1 mm in order to reveal effect during simulation.

And the engine description is shown below.

Table

Engine specification

Style	dual-valve, 4 cylinder inline
Diameter	83 mm
Stroke	92 mm
Compression ratio	17.5:1
Torque	28.6kg.m/2000rpm
Power	121PS/3800rpm

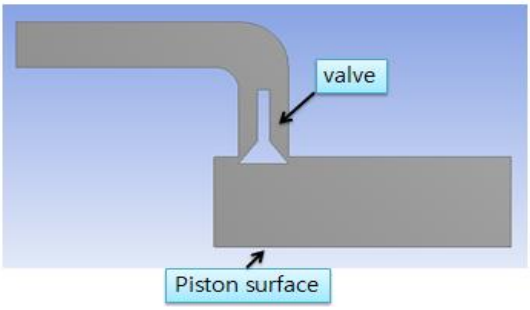

Fig. 1 Engine flat piston display

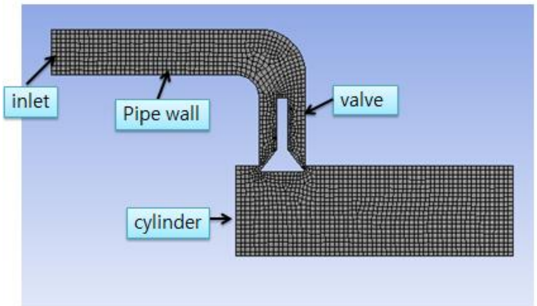

Fig. 2 The meshing of flat piston

4. CFD Analysis

In this study, the different shapes of the piston were set, when the air and fuel flow into the chamber in this process (induction stroke) on engine with constant engine speed, compare the displaying different shapes through particle image velocimetry [8], and at the last, set the simulation process with constant value and through the simulation for comparing the different conditions with different shapes of the engine piston. Through this simulation, we can observe that air and fuel can produce different levels of TR (rolling ratio) and TKE (vortex flow energy) through different piston shapes to show the degree of mixing of air and fuel in the cylinder [7].

The eddy viscosity in different piston shapes shown in Fig. 3. Four variations of pistons shapes can be found in these simulations. Eddy viscosity means when the boundary of vortex collide with another boundary of vortex, the two boundaries can generate viscosity that called eddy viscosity, in other words, many vortexes generated can cause the eddy viscosity to bigger, so in this simulation if produce many swirls then the eddy viscosity have to be obvious. To get complete combustion the swirl is needed in cylinder, that makes the air and fuel to mix better. Because the simulation is done with start of the induction stroke, assuming the time pass and the piston moves down, it could be found that the Double Hemispherical Combustion Chamber can generate the swirl with three bearing like large circle bottom, small

circle bottom and horizontal. Analysis of the Figure above shows that the Double Hemispherical Combustion Chamber is better than others. Just before the combustion stroke, it is needed the air and fuel to be completely mixed, and thus combustion process can get the complete combustion and produce less exhaust emissions. Simulation shows that the Double Hemispherical Combustion Chamber is useful for engine because this piston shape can make more eddies within cylinder cause the air-fuel complete mixing.

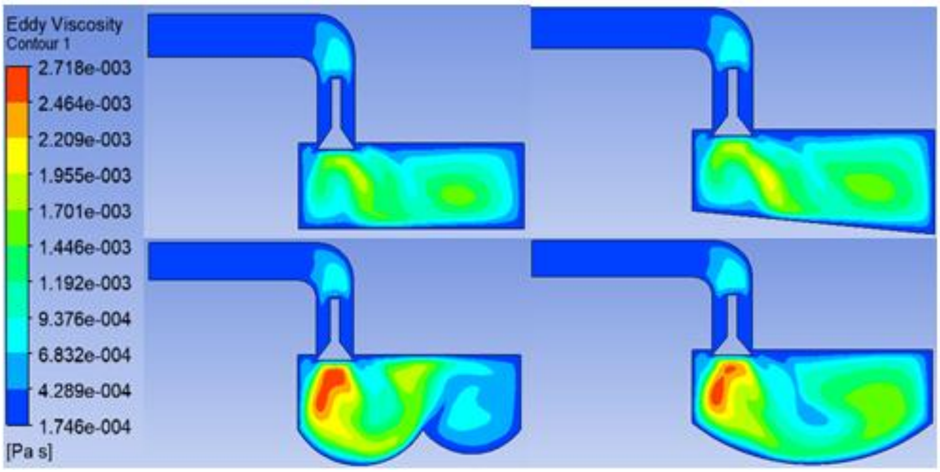

Fig. 3 The eddy viscosity for the different shape of pistons

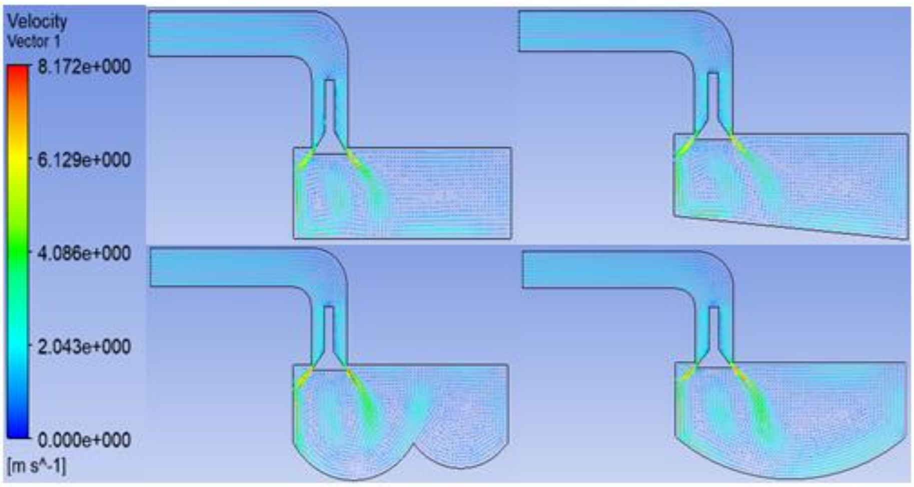

Fig. 4 Fluid velocities comparison for different pistons shapes

In the same engine speed, the speed in the cylinder at the beginning of the intake stroke was also analyzed through the simulations. Fluid velocities at same angle values for different piston shapes are shown in Fig. 4. The variation of fluid velocities and. On comparing the inlet velocity, it could be observed a significant increase in turbulence rate for the different pistons shapes and this process is continued till combustion stroke end. During the research it was established that A significant addition in speed takes place at the top dead center position of the double hemispherical combustion chamber piston. This maybe it's because the squeezing movement of the air and fuel blend within the combustion chamber. Squish is a radially inward or lateral and axial mixing of air/fuel motion near the top dead center position. This squeezing effect can result in better vortex preparation, as well as increased air to fuel mixing ratio, as well as increased burn rate and heat release rate. Due to the velocity increase, the turbulence is generated, and thus the combustion and emission characteristics can be improved as result

5. Conclusions

In the present simulation investigations, the effect of using improved piston bowl shape cylinder parameters on air and fuel mixing and combustion ratio was investigated. However, these studies have examined four types of piston bottoms, namely the common flat-bottom piston geometry, the single-round bowl bottom geometry piston, the double-round bowl bottom geometry piston, and the beveled bottom geometry piston. By analyzing these types of pistons, a shape that is advantageous for engine and exhaust emissions can be obtained. Some essential conclusions could be drawn:

1. The Double Hemispherical Combustion Chamber gives higher in-cylinder air velocities and high TR and TKE for good combustion characteristics as compare with other shapes. The significant increase in turbulence occurs in the

Double Hemispherical Combustion Chamber shape pistons as well.

2. The large eddy viscosity could be generated when Double Hemispherical Combustion Chamber is used. Thus, the turbulence occurs, and the combustion and emission characteristics can be improved as result.

Acknowledgment

This work was supported under the framework of international cooperation program managed by the National Research Foundation of Korea (NRF-2017K2A9A1A01092911).

This research was supported by The Leading Human Resource Training Program of Regional Neo Industry through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT and Future Planning (NRF-2016H1D5A1909917).

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Digital Interfaces for Diagnostics of Railway Traffic Control System

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Abstract

Operation of railway traffic control systems requires continuous provision of information on the status of devices. The expert system designed as part of the conducted research is constantly analyzing the state of the systems. To ensure the operation of the system in real time, it is necessary to use automatic data acquisition from devices installed on the PKP. This requires connection of diagnostic interfaces, which can reduce the safety of operated railway traffic control systems. For this reason, it is not possible to run and test diagnostic interfaces directly on the operated systems. Devices and systems installed in the laboratories of the Faculty of Transport and Electrical allow verification of the and can be the basis for the development of the safety case, which will allow for their practical use. Standard digital links between subsystems were used to diagnose systems. Interface systems have been developed to the following standards: RS232, RS485, CAN and Ethernet.
KEY WORDS: *railway transport, safety, railway traffic control, computer systems, digital interfaces*

1. Introduction

The Control Systems in Transport Department has been developing the laboratory base for many years related to railway traffic control systems. Thanks to cooperation agreements signed with the main producers of railway automation devices, the lab base of the plant is constantly developed and modernized. Having a laboratory base allows you to run and test devices that work with ATC systems [11-13].

At the University of Technology and Humanities, a project is being carried out as part of the Applied Research Program (PBS): A system for collecting operational data and analysis of reliability and safety of railway automation systems. The aim of the project is to optimize the activities and costs related to the process of maintaining and diagnosing railway traffic control systems and improving safety. This objective will be achieved by developing methods for analyzing diagnostic data of rail automation devices The assumed goal of the project is implemented through:

- construction of a new research laboratory of traffic control devices (including integration with existing laboratories at the Faculty);
- design of safety interfaces between railway traffic control systems and automatic data collection system;
- design of an automatic device data collection system;
- building a reliability model of rail automation devices;
- collection and preparation of data regarding rail automation systems;
- preparation of means for simulating typical and emergency operating conditions of systems;
- preparation of a database for gathering information about devices;
- preparation of procedures for determining statistical and reliability characteristics;
- development of an expert system for diagnostics of railway automation systems.

The expert system developed by SADEK (in polish: System Automatycznej Diagnostyki Elementów Kolejowych) as part of the project will contain basic data on the processes of railway traffic control systems use and their reliability and renewal for six main modules (railway traffic control subsystems):

- general description of technical, operational and economic characteristics;
- line block devices;
- adjustment devices;
- level crossings signaling;
- rail-vehicle interaction devices;
- remote control devices.

The use of own laboratory base enables creation (on a micro scale) of a complete system for automatic data collection on the state of equipment. Knowledge of protocols used in exchanging data between systems enables the development of simulators of equipment for which operational data from actual systems will be entered [4, 5].

2. Systems Installed in UTH Laboratories

2.1. Laboratory of Scheidt&Bachmann Systems

Systems laboratory with research equipment from "Scheidt & Bachmann Polska Sp. z o.o" contains models of modern German railway automation systems adapted to the requirements of traffic control in the Polish railway system. The laboratory of this company is equipped with:

– railway crossing protection device category A, B, C type BUES 2000;
– Interlocking system ZSB 2000;
– BUES / ZSB control panel for controlling BUES 2000 level crossing signal devices for the traffic controller (Remote Control Unit);
– LED traffic light type SYG / RYB / SBP / 01 by Scheidt & Bachmann GmbH.

Scheidt & Bachmann systems are characterized by open and modular architecture (Figs. 1 and 2). Adding similar components to devices allows you to expand the configurations of these systems accordingly. The use of appropriate modular processor software (basic system components) increases the security provided by the system. during the operation of the systems, they are also self-tested.

Fig. 1 BUES2000 control module

Fig. 2 Laboratory stands for testing railway automation systems by Scheidt & Bachmann

2.2. Bombardier Traffic Control Systems

Bombardier Transportation (ZWUS) Polska Sp. z o.o. Katowice is a leading manufacturer of modern railway traffic control systems and equipment in Poland and in Europe. It has a long-standing, rich tradition and extensive experience in the design, production and installation of systems and equipment for rail transport. It manufactures traffic control systems on railway, tram and subway lines as well as electromechanical devices. The subject of production is also crossing signaling systems, track circuits, axle counters for railway vehicles and many important elements of electronics used in railway and industrial automation systems. The Laboratory of Railway Automation Systems at UTH is equipped with devices designed for technical and functional tests of systems and components (currently produced and used on modernized railway lines), such as (Fig. 3):

– computer system of station equipment type Ebilock 950 with object controllers STC;
– station of the traffic dispatcher with the EbiScreen 2 computer system;
– computer two-way linear block type SHL-12;
– computer automatic crossing signal type SPA-5;
– counter-axis system type SOL-21;
– EAA-5 switch type drive;
– 5-chamber type EHA-22 signaling device;
– traffic signal type EHZ-7;
– warning signal for driver type EHZ-5;
– UOZ-1 animal protection devices manufactured by "Przedsiębiorstwo Wdrożeniowo-Produkcyjne NEEL Sp. z o.o." from Warsaw.

2.3. Systems and Devices of KOMBUD S.A.

The Control Systems Department in Transport cooperates with Kombud S.A. in the field of design and implementation of new devices. The employees of the plant (also authors) participated in the ESTER project, part of which is the SZP-1 crossing protection system [6]. In addition to the systems installed in the laboratory (Fig. 4), the authors have a SZP-1 crossing signal simulator.

Fig. 3 Laboratory stands for testing traffic control systems of Bombardier Transportation (ZWUS) Polska S.A.: a - system of station equipment type EbiLock 950 with object controllers STC; b - SOL-21 type unofficial monitoring system; c - automatic crossing signaling type SPA-5; d - automatic linear lock SHL-12 type [1]

Fig. 4 Laboratory of Railway Automation Components and Devices: a - general view of the laboratory; b - SPR-2 crossing signaling system (Cat. A); c - SKZR type unoccupied SKZ meter control system; d - automatic RASP-4Ft crossing signaling

This is the result of cooperation between the authors and the Kombud company. The SZP-1 level crossing protection system serves to secure journeys of categories A, B and C on single and double lines. For communication wired and wireless transmission was used. The control subsystem analyzes the information coming from the subsystem of impact devices and controls and controls the executive devices:

– traffic lights;
– drives;
– crossing warning shields.

The Laboratory of Railway Automation Components and Devices, equipped and moderated by the Automation Plant KOMBUD from Radom contains components made in relay technology and new computer traffic control systems:

– relays used in control of railway traffic;
– point interaction devices (SHP);
– tracker and switch-over drive;
– electronic overlay circuit (EON);
– track circuit type SOT;
– electromechanical, electronic and thyristor converters;
– OSA-H computer control panel;

– automatic crossing signal type RASP-4Ft;
– Counter-type SKZR type unoccupied control system.

3. Diagnostic Interfaces

In computer control systems of railway traffic, data interfaces between modules (in internal networks) are used:
– Ethernet;
– RS232;
– RS485;
– CAN;
– SPI.

All additional devices attached to SRK systems, including diagnostic interfaces, must not degrade the level of their safety. As part of the research, the ETHERNET, RS232 and RS-485 interfaces were developed. A CAN interface is currently being designed. Unfortunately, it is not possible to connect to the SPI interface without disturbing its operation. [2, 3, 7]

3.1. Ethernet

Ethernet was developed in 1976 by Xerox then developed by a DIX consortium (Dec, Intel, Xerox). The idea of the network is based on the idea of nodes connected to a common medium. Individual modules send and receive special messages (frames) using it - table. 1. This method of communication is called CSMA / CD (Carrier Sense Multiple Access with Collision Detection).

Currently, the following standards are used in Ethernet networks:
– 10Base-T - uses two pairs of wires. One pair transmits data and the other receives;
– 100Base-TX - similar to 10BASE-T, but with a speed of 100Mb / s.;
– 1000BASE-T - 1 Gbps on twisted pair cat. 5 or higher. Since the category 6 cable can carry up to 125 Mbit per second without losses, reaching 1000 Mb / s requires the use of four pairs of wires and modification of transmission systems that gives the possibility of transmitting approx. 250Mb / s to one pair of twisted pair cables CAN.

In railway automation systems, 10Base-T and 100Base-TX networks are used. In the developed prototype of the operational data processing module, the following functions have been implemented: reading data from systems (UTP protocol), preliminary analysis of data correctness, data encryption and sending processed data (TCP / IP protocol). Security of the system to which the interface provided by the physical (hardware) cut-off of the transmission line (TR + and TR-). This solution guarantees that the connected diagnostic module will not send data to the system. hanks to the hardware ensuring of transmission security, changing the software of the diagnostic module will not require any security analysis after changing the software.

Table 1

Parameters of the Ethernet frame [8]

The name of the field	Length (byte)
interframe gap (9.6 μs)	12
Preamble + SFD	8
MAC address of the target	6
source MAC address	6
Frame type	2
Data field	46 - 1500
CRC	4
Min. Physical frame size:	20 + (64 – 1518)

3.2. RS-485

The RS-485 standard was introduced in 1983 as a development of the RS-422A standard. The RS-485 link is symmetrical and balanced (i.e., the symmetrical and diverse circuit is a two-wire circuit, in which the wires and attached circuits have the same impedance to the ground as to other conductors). Transmitters must be three-state, because in a given time period it can transmit only one of them, and the others must be turned off. When no data transmission takes place all transmitters are switched off. The standard allows connection of up to 32 transmitters / receivers to the line, it is possible to connect more devices to the line by using appropriate repeaters. Fig. 5 shows how to connect the diagnostic device to the RS-485 bus. The SN (UCY) 75107 system was used to diagnose devices connected to the RS-485 interface. It is a standard receiver of a symmetrical line. System parameters, in particular propagation times and input currents, are more advantageous than the parameters of dedicated circuits for this interface. The connection of the receiver's inputs by resistors of several kilo-ohms guarantees the safety and correct operation of railway automation systems even in the case of damage to the receiver (the applied resistors provide "isolation" of the interface from the bus).

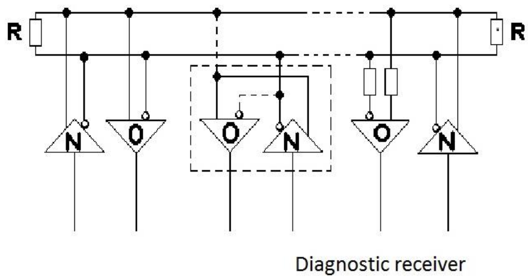

Fig. 5 Connection of the diagnostic interface

4. Conclusions

For remote diagnostics of railway traffic control systems, it is possible to use digital interfaces connecting individual subsystems [9, 10, 14, 15]. Connecting the diagnostic interface cannot decrease the safety of the system being operated. The solutions presented in this article allow you to connect to traffic control systems while ensuring the required level of security. This operation does not require proof of safety for the devices being diagnosed.

Devices developed and launched by the authors allow automatic reading, analysis and saving of device status information. The data collected in the system are used in the automatic analysis and forecasting of the state of the devices.

Acknowledgment

This material is based upon work supported by Polish National Center for Research and Development under Grant No. PBS3/A6/29/2015.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Influence of Using Ozonized Diesel Fuel on Exhaust Gases Toxic Emissions in a Compression Ignition Engine

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Abstract

This article presents the analysis of toxic substances emissions from Perkins 1104C-E44TA engine used in non-road vehicles. An experimental research was carried out at the test bench with electric braking device. Tests were conducted in compliance with C1 test and according to ISO 8178. The research was concerned exhaust gases toxic components emissions when the engine was fuelled by alternative fuel and traditional diesel oil. Ozonized diesel oil was used as an alternative fuel. During the experiments the standard toxic components were measured: CO, HC, NO_X, and PM.

KEY WORDS: *compression ignition engine, ozonized diesel oil, toxic components*

1. Introduction

The reduction of fuel consumption and the emission of toxic substances is currently the most important criterion determining the development trend in internal combustion engines development. Current research is aimed not only at improving the classical drive, but also at searching for alternative drives. Based on analyzes, we can conclude that combustion engines will continue to dominate [1]. The end of the era of cheap oil has alerted humanity to the need to reduce energy consumption. The limited resources of fossil fuels, with the current state of exploitation, will suffice for approximately: crude oil for 40 years, natural gas for 70 years, coal for 250 years. Despite forecasts that conventional fuels will satisfy the world's energy needs for years, it is important to search for alternative fuels, which could replace them completely [2].

Ozone, (O_3 trioxide) is a gas consisting of triatomic oxygen molecules. In natural conditions it is a pale blue gas with an acrid odor, well dissolving in water (about 50% better than oxygen). Cooled down to 161.3 K under the pressure 101325 Pa the gas would condensate into a dark blue liquid. In solid as well as liquid form, it tends to explode due to the spontaneous tendency of O_3 to disintegrates to O_2. In the gas form it is very unstable, because the third oxygen atom (in high concentration) reacts with the substance on which it operates. Ozone can react with organic substances in two ways: directly or through radicals [3, 7].

Ozone used in the combustion process behaves like a catalyst, accelerating the oxidation occurring at a lower temperature. During the catalytic action, it breaks down, and atomic oxygen radicals are formed as result. This initiates a chain oxidation reaction that affects combustion products and reduces fuel consumption. The ozone molecule consists of three oxygen atoms bonded at 116.8° in the gaseous state and 117.9° in the solid state. Fig. 1 shows the structure of the ozone molecule [7].

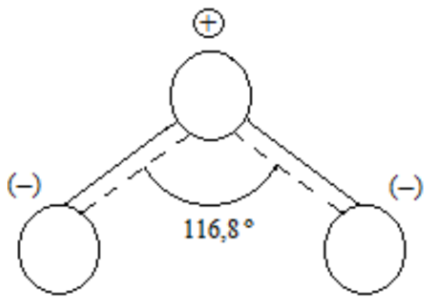

Fig. 1 Structure of the ozone molecule [3]

2. The Test Stand

The test stand was based on the Perkins 1104C-E44T engine. It is a four-cylinder turbocharged diesel engine with direct fuel injection into the combustion chamber and liquid-cooling. This engine is electronically controlled by two combined ECU. It is designed for working machines, agricultural tractors and power generators [4, 5, 6]. The tests measuring system consists of four measurement channels: (i) the pressure in the combustion chamber, (ii) the angle of rotation of the crankshaft, (iii) the toxic exhaust emissions, and (iv) the particulate emissions. Fig. 2 presents test stand diagram.

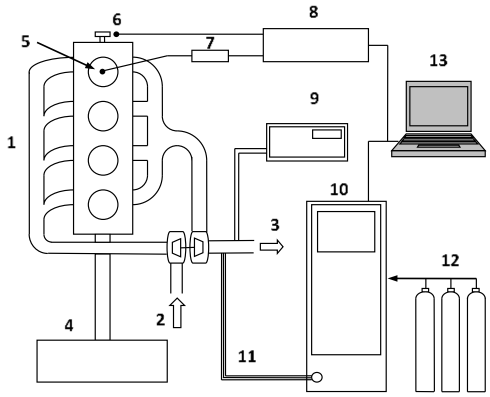

Fig. 2. Diagram of the test bench: *1* - engine PERKINS 1104C-E44T; *2* - air inlet; *3* - exhaust; *4* - brake; *5* - piezoelectric pressure sensor; *6* - crankshaft angle sensor; *7* - amplifier; *8* - indicating device; *9* - Horiba MEXA 1230 unit; *10* - AVL CEB II gas analyzer; *11* - heated route; *12* - reference gases; *13* - PC computer

The Perkins 1104C - E44T engine meets EU Stage II emission standards for Nonroad Diesel Engines in the F version, which applies to engines with effective power (so-called net power) in the range of 75 ≤ Ne 130 kW. The maximum torque is 390 N · m and is achieved at a speed of 1400 rpm, and the maximum power is 85 kW at 2200 rpm.

To obtain ozonated diesel fuel, a special setup was built. The setup had three ozone generators. Depending on the duration and flow rate of the ozonized air, a different degree of fuel ozonation can be achieved.

The diesel fuel used in the tests was saturated with ozone to the value of 1 kg per cubic meter at the ambient temperature T = 298 K and the pressure p = 0.101325 MPa.

3. The Results

Fig. 3 shows the comparison of the torque values of a diesel engine fueled by two fuels - diesel oil and ozonized diesel fuel.

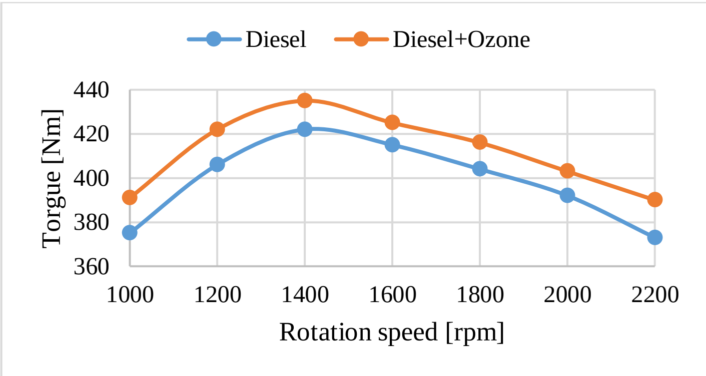

Fig. 3 Comparison of the torque value of the diesel engine fuelled with diesel oil and ozonized diesel fuel

Figs. 4-7 show the change in concentration values of selected toxic components in exhaust gas of diesel engine fuelled by two fuels - diesel oil and ozonized diesel fuel.

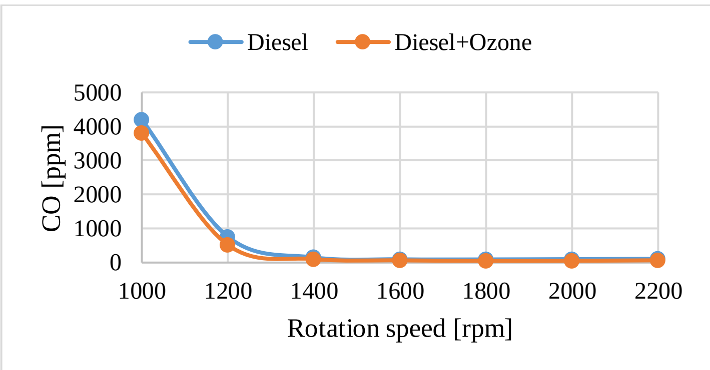

Fig. 4 Comparison of the CO concentration values in the exhaust gas of the diesel engine fueled with diesel oil and ozonized diesel fuel

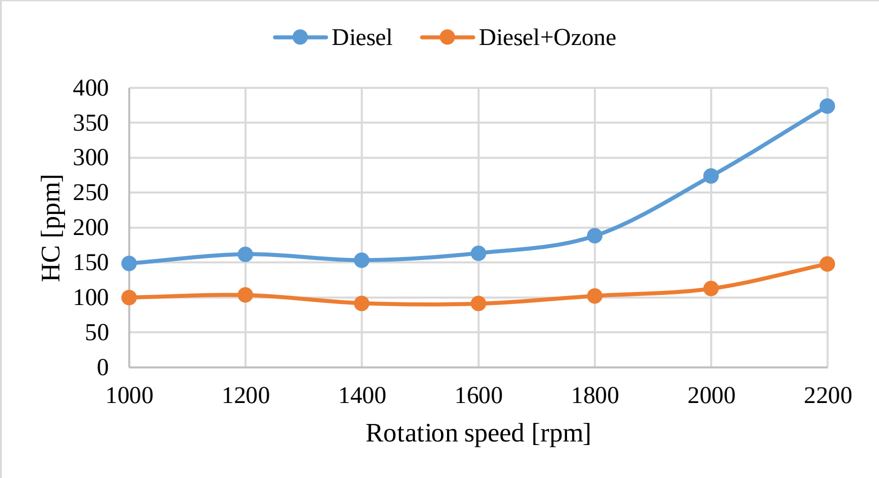

Fig. 5 Comparison of the CH concentration values in the exhaust gas of the diesel engine fueled with diesel oil and ozonized diesel fuel

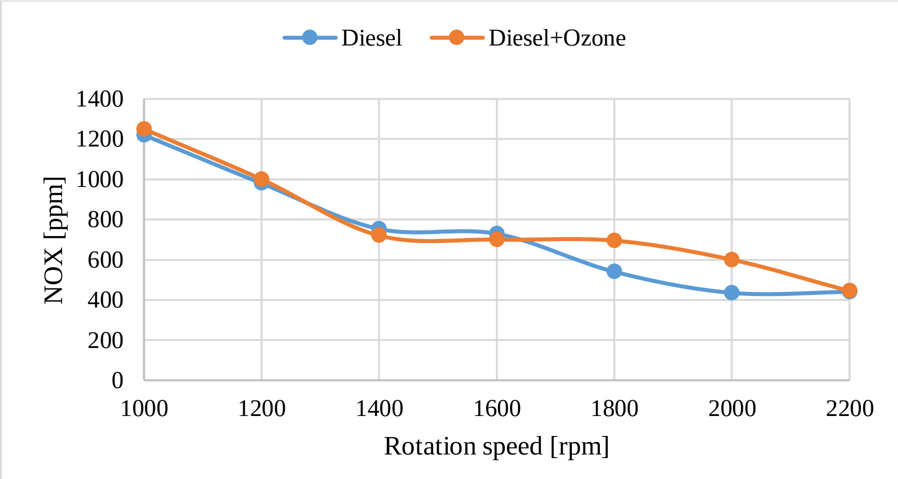

Fig. 6 Comparison of the NO_X concentration values in the exhaust gas of the diesel engine fueled with diesel oil and ozonized diesel fuel

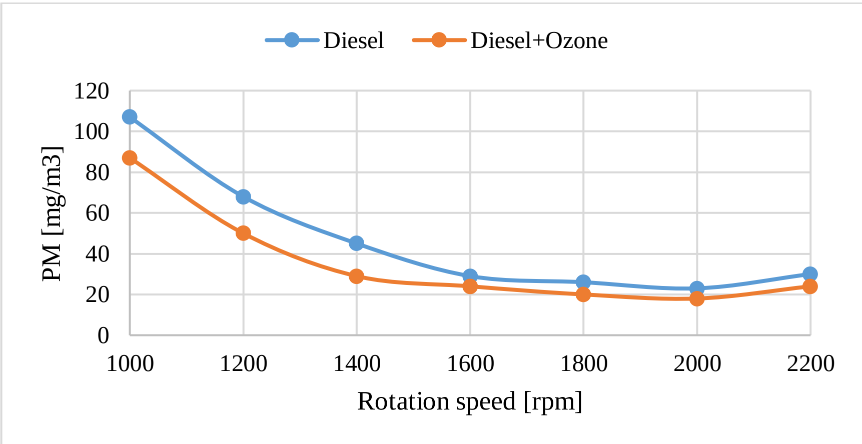

Fig. 7 Comparison of the PM emissions in the exhaust gas of the diesel engine fueled with diesel oil and ozonized diesel fuel

Fig. 8 shows the specific emissions of toxic components in exhaust gas for diesel oil and ozonized diesel fuel as well as the maximum allowed values according to the NRSC test, type C1 for engines in category F ($75 \leq P < 130$ kW).

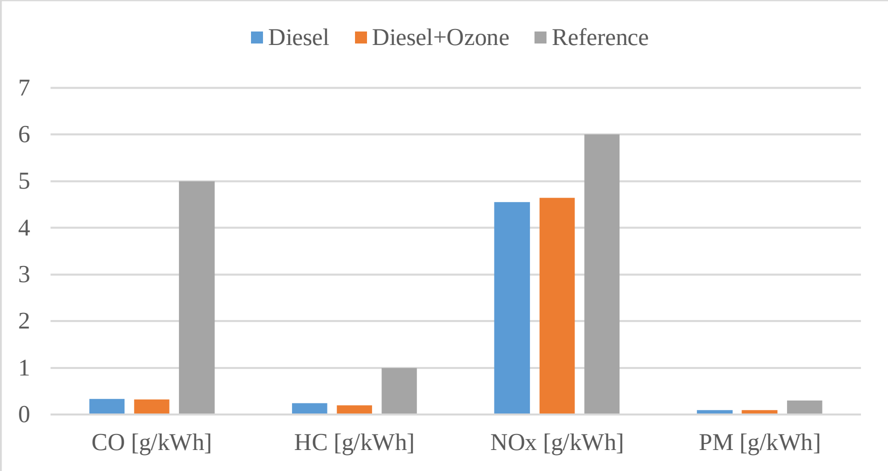

Fig. 8 Specific emissions of toxic components in exhaust gas for diesel oil and ozonized diesel fuel as well as the maximum allowed values according to the NRSC test, type C1 for engines in category F (75 ≤ P < 130 kW).

4. Conclusions

Based on the results and obtained characteristics, the following conclusions can be made:

- when the engine was fuelled with diesel oil, a slight improvement of effective indices was observed (around) 2…3%;
- utilization of ozonized fuel leads to reduction in concentrations of CO, HC and PM;
- thanks to the fuelling the diesel engine with ozonized diesel oil, smaller specific emissions were obtained for substances such as: CO, HC and PM, and in the case of NO_X there was a slight increase in the specific emission.

Utilization of ozonized diesel fuel in the ISO 8178 C1 test cycle in relation to commercial diesel oil allowed to obtain a reduction in CO emission of about 5%, HC hydrocarbons by about 19% and PM particles by about 3%. The reduction of these toxic exhaust gases occurred at the expense of increasing the specific emission of NO_X by about 2%. The reason for this phenomenon may be a higher oxygen content in ozonized diesel fuel than in standard diesel oil.

Due to the oxidation of atmospheric nitrogen in the combustion chamber, the concentration of NO_X increases. Due to the increased oxygen content in ozonized diesel fuel, the emission of compounds such as CO and HC are limited (it is known that formation of these compounds is affected by local and global oxygen deficiency). The reduction of PM particulate matter when fed with ozonated diesel fuel may be influenced by an increase in the combustion temperature.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Influence of New Panama Canal on Cargo Volumes, Capital Investments and Ship Sizes in the Americas Region

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Abstract

In today's global seaborne trade Panama Canal plays important role as infrastructure contributor to the shipping lines. With one of the largest single maritime investment in last decade having built new locks Panama Canal Authority has made remarkable asset which has snowball effect on the further large scale investments in the port infrastructures and other related assets from the both sides of canal. New locks were launched in 2016 and they have significantly higher capacity thus allowing larger ships to transit from Atlantic to Pacific and vice versa. New locks also allowed to enter ships with cargo not sent in transit before due to size restrictions. The transit volume growth through Panama Canal was larger as forecasted and several mail stones reached faster as expected. There are winners and losers due to opportunities created. Countries having direct influence due to the Panama Canal new locks are USA, Trinidad and Tobago, Bahamas, Dominican Republic, Mexico, Columbia and others from the Americas region.
KEY WORDS: *canal transit, port investments, market segment, long tons, seaborne trade*

1. Introduction

Operations in Panama Canal started in 1914, more than 100 years ago and through the sanctuary has long and also complicated history and development. Panama Government has started the work on expansion of Panama Canal in 2007 and accomplished 3rd traffic line with new locks in the summer of 2016. The total costs of the new line are estimated in amount of 5,2 billion USD. Once the work was finished the total capacity of Panama Canal has increased two times. The moves of the first vessels after new locks also had issues with tug boats and delays in terms of transit time. However, with the huge efforts from the canal operators side this giant and very important World's infrastructure project is in operations for almost 2 years bringing new possibilities to the global shipping industry and allowing new Neo Panama size ships to cross the canal. This has changed the map of port terminal infrastructure around canal and had large influence to both Atlantic and Pacific side. The transformation process of the related port and hinterland infrastructure within Americas is still ongoing.

Today Panama Canal is servicing 146 maritime routes and connects 160 countries. Of course those numbers are constantly changing together with the global trade. Even though the transit capacity has doubled as per valuations of the economists from Maersk Line the total transit volume growth through the Canal will be more moderate due to the global situation in the World's economy [10]. Once the World's economy has showed positive increase in 2017 so did Panama Canal transit volumes.

2. Impact to Cargo Volumes and Ship Sizes

Increased benefits from the transit through Panama Canal the country started to gain when the global trade has grown and the situation in Latin American countries and China has improved in 2017. The positive growth in previously mentioned areas is still continuing in 1Q of 2018. After the increase of the capacity of the Canal it was planned that the biggest contributor will be container segment ensuring 50% of total revenues until 2020. Already in Panama Fiscal Year 2017 containerized cargo has 52% of market share (by Market Segment) from all Neopanamax vessels and 15% from all Panamax vessels. From total cargo move via Panama Canal in FY 2017 container segment reached 23%. This is based on the fact that before new Panama Canal the maximum capacity of container vessel was 4400 TEU but after the new locks – 14000 TEU. It means that container vessel maximum capacity increased more than 3 times.

Of course it does not mean that all shipping lines will automatically start to use the maximum vessel's size because we have to consider also terminal capacities in the region as well as need for the bigger capacity. [2, 3] However, the total trend is that the vessel sizes will continue to grow almost in all trade routes and it has and will have to put pressure on terminal investments in infrastructure, equipment and as technologies.

Regions around Panama Canal like Latin America, Central America, Caribbean and US are directly impacted by the new Panama Canal and already 2 years after opening of new locks we can see winners and losers among port terminals. Terminals having the biggest challenge are those just partly involved in transshipment and located in Caribbean area. The capital investments have been made already before Panama Canal new locks were planned and as explained the bigger vessels doesn't mean more gateway cargo because it depends on the state of the art of economy (import/export volumes) and not on the size of the ships. We can see the trend that with larger mother vessel's also the

feeder vessel's average size is increasing and those terminals who are not ready for bigger ships are canceled from the map of transshipment hubs. It means that those port terminals will remain only as local gateway terminals. Also existing Caribbean transshipment hubs are facing challenging investment decisions because they have to invest just to maintain existing flow and accommodate larger vessel's but not in the way to increase the cargo flow. As per statistic data Caribbean region together with Latin-American region is stagnating for the last decade and for the first time only in 2017 the positive growth was reviewed. It is important to understand the World's Seaborne Trade [1] and the share of major cargo segments and its impact on Panama Canal transit.

Table 1

World's Seaborne Trade and split by cargo types 2015 in Million tons [4, 6]

Cargo Type	volume	CAGR[1] (2011-2015)	Impact on Panama Canal transit
Seaborne trade	10.959	+ 3,8%	USWC strike gave positive impact
Container trade	1.744	+5,6%	Important part in total volume
Dry Bulk	4.668	+5,0 %	Grain export from Brazil to Asia
Oil Trade	2.843	+0,7%	Trade from Ecuador to Mexico
LNG	259	+1,2%	Trade from Gulf of Mexico to Asia

As it's represented in the Table 1 above the main cargo contributor to the World's seaborne trade is dry bulk followed by oil and containers. In terms of CAGR the most sustainable growth from 2011-2015 have containers and dry bulk where the smallest growth has oil trade what is related to low oil prices in last 5 years. From the Panama Canal authority point of view, the biggest focus after new locks is stressed on container transit. Panama Canal Authority is forecasting that container cargo share in total Panama Canal transit will grow from current 34% to 50% until 2020. It is forecasted by UN that in 2016 the World's seaborn trade have increased by 3-4%.

Table 2

Panama Canal Traffic 2015 – 2017 in USD, Long Tons[2] and PC/UMS[3] [7]

Fiscal year[4]	transits	17/16 (%)	Tolls (USD) millions	17/16	Long tons	17/16	PC/UMS	17/16
2015	13874	--	1.994	--	229.147.960	--	340.747.128	--
2016	13114	--	1.933	--	204.706.283	--	330.433.312	--
2017	13548	+ 3%	2.238	+ 16%	241.008.112	+ 18%	403.831.295	+ 22%

Considered that new locks are opened in the middle of 2016 (FY 2016) from the Table 2 above we can see following trends comparing 2017 with 2016:

- Increase in transits through the canal by 3%;
- Increase in PC tolls by 16%;
- Increase in cargo transited in Long tons by 18%;
- Increase in cargo transited in PC/UVS by 22%.

The increase of transits slower than increase of cargo transited in long tons is representing the increase of average vessel's size passing Panama Canal. Analyzing the statistic of cargo transit, we have to use the long tons but the PC/UMS are representing the vessel's size and displacement factor. In this case containers and cars (ro-ro) are also converted in long tons to get the overall statistic data and to obtain comparable measurements. As we can see from the table No.2 the increase of volume in 2017 versus 2016 for both PC/UMS and Long tons is different where higher increase was related to PC/UMS. Once the tolls are calculated from PC/UMS we can consider the Panama strategy and also the fact that vessel size increase together with displacement tonnage is the main factor for the Panama canal operator.

Table 3

Average vessels size transiting Panama Canal in PC/UMS [5]

Year	Average vessel size (PC/UMS)	Increase in %
1955	4.832	--
1975	9.931	205%
1995	18.940	190%
2016	28.236	149%
2017	29.807	6%

[1] CAGR - The compound annual growth rate (CAGR) is a useful measure of growth over multiple time periods. It can be thought of as the growth rate that gets you from the initial investment value to the ending investment value if you assume that the investment has been compounding over the time period.

[2] Long Tons - also known as the imperial ton or displacement ton is the name for the unit called the "ton" in the avoirdupois or Imperial system of measurements standardized in the thirteenth century that is used in the United Kingdom and few other countries. A long ton is defined as exactly 2,240 pounds.

[3] PC/UMS – The tonnage measurement system for Panama Canal tolls assessment, the Panama Canal Universal Measurement System. Also includes containerships and passenger vessels.

[4] Fiscal year in Panama is from October, 1st until September, 30th. All data in the publication reflects to Panama fiscal and not calendar year.

As we can see from the Table 3 above the average vessels size transiting Panama Canal has increased by almost 2 times in every decade except the last one. This represents the dramatic growth of the World's shipping industry. The average growth of vessels size passing Panama Canal in last decade was more moderate because the maximum size possible to transit the previous canal was reached. As from 2017 we can see another growth by 6% what is impressive increase of average vessels size transiting Panama Canal in one year after new locks are operational. However, we can also see decrease in total tolls and cargo handled via Canal in 2016 versus 2015 what reflects to the slowdown of global economy in last few years and then increase in 2017 versus 2016 by 16%. This shows the high potential ROI for new locks what Panama Canal Authority is facing with current cargo volume increase.

In September 2017 the 2,000th transit of Neopanamax vessel marks another step forward for the Expanded Canal, which has served a number of vessel segments since its opening in June 2016, including containerships, liquefied petroleum gas (LPG) carriers and liquefied natural gas (LNG) carries-a new segment for the waterway.

As in September 2017 at 54 percent, the container segment accounts for more than half of the transits through the Expanded Canal, while LPG and LNG vessels represent 29.2 and 8.6 percent, respectively. Bulk carriers, tankers, car carriers and cruise ships have also transited the Expanded Canal. Similar proportion by market segment for Neopanamax vessels can be monitored in the March of 2018.

If so we can conclude in short term about vise and necessary decision for those ultra large infrastructure investments and also, we can predict even more significant influence on transit cargo growth in the mid and long term.

Table 4

Panama Canal Traffic by market segment (cargo type) in 2017 [7]

Market segment	Number of Transits	Share in total (%)	PC/UMS Net tonnage (000)	Share in total (%)	Long tons of cargo (000)	Share in total (%)
Container	2.493	21	142.614	35	53.656	22
Dry Bulk	2.915	24	79.135	20	96.241	40
Vehicle Carriers/ ro-ro	801	7	46.806	12	4.791	2
Chemical tankers	1.959	16	42.473	11	39.464	16
Crude product tankers	627	5	17.342	4	14.780	6
Liquefied Petroleum Gas	876	7	28.498	7	15.319	6
Refrigerated	868	7	8.450	2	3.274	1
General cargo	654	5	7.808	2	5.038	2
Other cargo	799	8	29.644	7	8.443	5
Total	**11.992**	**100**	**402.770**	**100**	**241.007**	**100**

Table 4 above represents Panama Canal transit by market segments in other words by type of the cargo. As we can observe containers are representing more than 21% from all transits, more than 35% from PC/UMS net tonnage and around 22% from total cargo transited via Panama Canal in 2017. This is the cargo segment with highest growth potential after new locks are operational and the first 18 months after inauguration are confirming those assumptions.

In terms of total transits, the most important cargo segment is dry bulk followed by chemical tankers representing 24% and 16% accordingly. In terms of PC/UMS net tonnage containerships are followed by dry bulk and vehicle carrier's/ro-ro vessels representing accordingly 35%, 20% and 12% of total annual volume in 2017.

Once observing transited long tons, we can conclude that leading segment is dry bulk with 40% followed by container carriers and chemical tankers having 22% and 16% of market share from the total volume in 2017. After new locks are in operations we can see that there are new market segments opening in Panama Canal transit like Liquefied Natural Gas due to the increase of vessel's size and reaching 163 transits in 2017 versus 17 transits in 2016.

Table 5

Cargo movement through Panama Canal (origin-destination) Pacific-Atlantic (long tons) 2017 [7]

From	ECUS[5]	Europe	Others	Total
Asia	**24.653.758**	279.664	8.639.302	33.572.724
WCUS[6]	**655.830**	1.433.439	1.458.053	**3.547.322**
Others	10.743.150	14.098.2017	10.238.596	41.970.025
Total	**36.052.738**	**15.811.310**	**20.335.951**	**72.199.999**

As we can see from the Table 5 above the largest contributor to the Panama Canal transit from Pacific to Atlantic is Asia region (46% from total) followed by West Coast of South America, then West Coast of Central America and then by WC of Canada. We can observe that after new locks are operational the Asia-ECUS in 2017 increased by 10% what can be explained by larger ships calling ECUS ports directly versus calling WCUS also with ECUS cargo than delivered by railway or smaller ships from WC to ECUS. This is proven also by fact that in 2017 the total cargo volume from WCUS to ECUS has dropped almost 4 times compared with 2016.

[5] East Coast of the United States
[6] West Coast of the United States

If we review the same statistic from the final destination's perspective than without doubt ECUS is far the largest receiver of the cargo. So in the year 2017 EC of the US received almost 36 million of tons of cargo via Panama Canal counting 50% from the total volume as destination. As explained in the publication there is high chance that the volume in the ECUS ports will grow in the future with the new locks in Panama Canal being opened and large-scale infrastructure investments in ECUS (mainly Florida) made. This mainly will to containerized cargo. But in 2017 the total cargo volume (Pacific-Atlantic) has dropped by 10% versus 2016 and also ECUS volume has dropped by 8% what is mainly caused by the import drop from other destinations than Asia and reflects to the US global trade policy and trends.

Table 6

Cargo movement through Panama Canal (origin-destination) Atlantic-Pacific (long tons) 2017 [7]

From	Asia	WCUS	Others	Total
ECUS	**44.153.394**	**10.107.803**	32.628.106	**86.889.303**
Europe	352.228	1.139.264	11.321.486	12.812.978
Others	4.842.342	6.658.859	16.479.043	27.980244
Total	**49.347.964**	**17.905.926**	**60.428.635**	**127.682.525**

As we can see from the Table 6 above the largest origin is ECUS when analyzing Panama Canal transit volumes from the Atlantic to Pacific. The ECUS share in the total Atlantic – Pacific cargo flow as origin is 68% or it contributes to more than 86 million tons of cargo per year. The main ECUS destination is Asia with almost 51% share. The WCUS is second most important destination in Atlantic – Pacific trade in transit via Panama Canal and it presents the large importance of the new locks to the US seaborne trade and also represents US as largest country and contributor to Panama Canal transit. The total share of the US in Panama Canal transit from Pacific to Atlantic and vice versa in 2017 is 68% and there is great chance that this share will still increase. The second most important contributor to Panama Canal transit volume is China with 18% of market share followed by Chile and Japan both having 11% in 2017.

When comparing both transit directions via Panama Canal in 2017 we can conclude that Atlantic – Pacific trade is 57% larger as Pacific – Atlantic trade and it can be explained with the fact that countries and regions from the Atlantic side are more developed with larger scale of economy as well as their export potential is also dominating in the Panama Canal transit.

Another interesting factor is that there are more than 10 million of tons in 2017 being shipped from the ECUS to WCUS and 0,7 million of tons vice versa via Panama Canal and it shows the importance of the seaborne trade versus inland transportation. The only factor which can seriously influence the volumes between Asia and US especially EC of the US is the current trade policy and trade deals. The new USA focus on "America first" may have influence on so important exports to Asia and also on trade balance with other Transatlantic and Transpacific partners and alliances. The scope of new trade deals and arrangements can have influence on Panama Canal transit volume especially the US trade deals due to the large importance in total annual volume. Also, we have to mention that there are tensions of growing trade war between US and China and US and Europa what can lead to the slowdown of cargo flow to and from US.

3. Investments in US ports

Results of American Association of Port Authorities 2016-2020 port infrastructure investment survey show that US ports and their private sector partners are planning to spend almost 155 bn USD in port related investments through 2020. (please see Table 7) That is three times more comparing to previous survey for time period 2012-2016, when total planned investments were 46 bn USD. In addition, governmental investments in infrastructure to aid freight movements through ports could be up to 25 bn USD until 2020. Thus in total investments in ports and related infrastructure could reach very impressive 180 bn USD.

Table 7

Infrastructure investment plans for US ports and their private-sector partners, 2016 through 2020 (USD) [8]

Port Region	Ports' Projected Capital Expenditures for 2016-2020	Projected Private Sector Expenditures for 2016-2020	Total Projected Port and Private Expenditures for 2016-2020
North Atlantic	3.641.587.000	1.217.000.000	4.858.587.000
South Atlantic	7.592.716.466	1.787.000.000	9.379.716.466
Gulf	4.999.477.595	122.792.800.000	127.792.277.595
Great Lakes	503.200.000	504.500.000	1.007.700.000
North Pacific	1.293.438.518	2.734.000.000	4.027.438.518
South Pacific	4.573.279.326	3.139.655.000	7.712.934.326
Total	**22.603.698.905**	**132.174.955.000**	**154.778.653.905**

With the capacity to accommodate larger ships carrying more cargo, the new locks are redrawing world trade

routes and prompting ports and shipping infrastructure upgrades in US cities from New York to New Orleans. New and planned upgrade projects range from massive bridge raisings in Bayonne, New Jersey and Long Beach, California to port-rail projects in New Orleans and Beaumont, Texas. US ports are planning to to invest in terminals, berths, piers, new equipment, navigation dredging, expansions, facility rehabs, security, rail and environmental improvements. While port private-sector partners besides previosly mentioned investment objects are also focused to invest energy transfer facilities and storage. Main objects of governmental investments are port related infrastructure like highways, bridges and rails. The biggest investments are projected in ports along the Gulf Coast, which is emerging as a key distribution and logistics hub for exporters of liquefied natural gas and plastic resins. It's also where many new energy processing, production, and transfer facilities are being built.

Cities like New Orleans, Corpus Christi, Tampa, and Houston are seeing some of the biggest impacts of the Panama Canal expansion. Port of New Orleans has impressive development plans - new on-terminal intermodal container facility is projected to boost the port's annual capacity by 200,000 TEUs to a total 840,000 TEUs. The port is planning to add new train line and also larger capacity cranes. Another improvement is a new container-on-barge cargo route from New Orleans to Baton Rouge to expedite regional exports of plastic resins, oil, and grains. Panama Canal expansion affects also ports investments in Pacific and Atlantic Coasts. Port cities along the West Coast—many of which already benefit from deep harbors and an expansive railroad superstructure—are also feeling the effects of the Panama Canal expansion.

Not all the investments are related to Panama Canal expansion - some of the East Coast ports will continue to ready themselves for mega-vessels transiting the Suez. Before the expanded Panama locks were opened, Suez had more than 50% market share of Asia-US East Coast capacity. Since the new locks opened, Suez market share decreased to about 25%, and increased to 75% via on the head-haul. However, on the backhaul for the Asia-Panama-US East Coast services, many of these go via the Cape to save the canal toll costs which are higher than the cost of the additional fuel needed to travel the extra distance around Africa. In the backhaul, transportation time is generally less important than in the headhaul, as the cargo is of lower value and the additional cost of inventory too. [9]

Positive driving force for US ports development are also promising growth of US economy - retail sales trends highlight increasing consumer confidence, driving imports, while exports rose due to improving global demand. Throughput measured in TEUs for the first half of 2017 shows a strong year-over-year increase of 7.1%, well above real US GDP growth of 0.3% and 0.1% seen in the first and second quarters of 2017, respectively. Both coasts saw above average growth for the first half of 2017 - West Coast port volumes were up 6.4% over a year prior, while East Coast ports saw an 8.1% increase for the same period, led by South Carolina and Houston. On cargo flow side over the past few years, we have seen ECUS (Miami port etc.) and Gulf receiving essentially all US container volume growth whereas WCUS (Los Angeles ports, San Francisco ports) has been stagnant. Some industry specialists are attributing this to the Panama Canal expansion but author believes spreading risk, a lesser focus on transit time and more on dependability in arrival times and inland cost where rail lines build up the Mini Land Bridge choice with relatively low 1-way cost but later reversed this to 2-way charges. This has negative influence on US West Coast volumes.

The question remains without answer as of now about are those investments worth to the potential volume to be gained? We need to wait for some years to start to consider and valuate the potential return on investment in port and related infrastructure. Due to the fact that port related investments are being depreciated in 20-50 years depending on the type of asset there is long way to go while making motivated answers on the real ROI and other financial indicators. We have also to consider the different legislation in the US and Europa about the government investments in the port infrastructure operated by public but also private companies and the reasons behind. Author suggest to compare the increase of the container volume in TEU versus investments made in USD and to conclude about results to settle benchmark (new cargo in TEU/investments in USD). There are winners and losers after this project was accomplished but in some aspects we still need time to evaluate the impact of the new Panama Canal on port terminal infrastructure, related capital expenditures and the vessel sizes crossing the Panama Canal after the new locks are operational. Bigger ships do not mean shippers and consignees choose a given routing and those larger ships have been going through the Suez Canal to US East Coast anyway even after new Panama Canal opening. Mentioning all above author is not buying the argument that the Panama Canal has anything to do with the increased volumes of export/import cargo in the Americas region.

In regards to port capital investments, we have seen significant investment and especially US ports have pointed at the Panama Canal expansion as an excuse to get old infrastructure updated to accommodate larger vessels. Having say this we have to remember that state-owned public ports have to justify investments because it's federal and state money. It has to prove that there are economic benefits in terms of additional profits (or/and ROI) and it's hard to explain to the public that there is a need to invest significant amount of money in the port related assets just to maintain existing cargo flow or to get only incremental cargo volume growth.

Anyway, in last few years all over the US port authorities have spent large amount of capital investments for updating port related infrastructure (needed with or without Panama Canal), increasing terminal capacities (to accommodate increasing volumes that were coming with or without Panama Canal) and to accommodate new container line alliances (needing more capacity on fewer terminals).

From the Caribbean point of view, author believes that to the Panama Canal expansion can attribute expansion investments in major container transshipment hubs like Cartagena port and Kingston port. Immediately within Americas region we have to mention also PSA Panama port terminal investments related to new Panama Canal opening. It is proved that new Panama Canal opportunities are challenging the global port terminal competition in the region

Americas and there is long way to go to equalize the terminal capacities with newly built vessels. We will continue to observe cargo shift from place to place due to the global trends described in this article bringing change in Caribbean, US and other Americas port terminals.

4. Conclusions

We can conclude that new Panama Canal has caused significant investments in the port related infrastructure first of all within US and in Americas region. US ports will invest up to 180 billion of USD in the time frame from 2016-2020 and very significant part of those investments are related to Panama Canal expansion.

The new Panama Canal opening was followed by same level of volume increase in container related trade and it has opened new cargo segment to Panama Canal transit – LNG.

There is strong trend about increase of average vessel's size transiting Panama Canal. After new locks are open the biggest increase is expected in container segment and there are forecasts that until 2020 this segment can reach 50% of Panama Canal transit. In terms of new locks container segment reached 52% of market share already in 2017.

After new Panama Canal locks are in operations the maximum containers vessels size has increase from 4.400 TEU capacity to 14.000 TEU capacity. This will allow container shipping lines to have savings on transportation costs because larger vessel's normally means less transportation costs per container.

Investments in large port infrastructure not always correlates with return on investments. It's often common that local governments are also playing important role on securing port infrastructure with related investments and often the driving force is the increase of economic activity and not ROI or other economic indicators.

The total share of the US in Panama Canal transit from Pacific to Atlantic and vice versa in 2017 was 68% and there is great chance that this share will increase in future. This makes Panama Canal heavy depending on one single country's economy and political decisions.

Potential new trade deals as TTIP[7] and TTP [8] as well as existing NAFTA[9] deal with proposed changes initiated by US will have significant influence on Panama Canal transit volumes especially considering the role of the US due to the large importance in total annual volume.

New US trade policy and import duty increase for the specific commodity imports from EU, Canada and others may lead to trade war already within calendar year 2018 and could decrease the global trade with US in the same way having negative impact on Panama Canal transit volume.

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[7] The **Transatlantic Trade and Investment Partnership** (**TTIP**) is a proposed trade agreement between the European Union and the United States, with the aim of promoting trade and multilateral economic growth. TTIP is considered a companion agreement to the Trans-Pacific Partnership (TPP).

[8] **The Trans-Pacific Partnership (TPP),** or the Trans Pacific Partnership Agreement (TPPA), is a trade agreement between Australia, Brunei, Canada, Chile, Japan, Malaysia, Mexico, New Zealand, Peru, Singapore, the United States and Vietnam.

[9] The **North American Free Trade Agreement** (**NAFTA)** is an agreement signed by Canada, Mexico, and the United States, creating a trilateral trade bloc in North America. The agreement came into force on January 1, 1994. It superseded the Canada–United States Free Trade Agreement between the U.S. and Canada.

Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Application of R Package to Prediction of the Time to Failure of Elements of Automatic Railway Level Crossing System

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Abstract

Prediction of the time to failure of elements of automatic railway level crossing system is a crucial task which has a significant impact on the safety of railway traffic. Every year many accidents occur at level crossing in Europe -more than 300 deaths. Therefore, huge emphasis should be put on safe operation of automatic railway level crossing system. The ability to predict the time to failure of elements of automatic railway level crossing system can significantly improve both the throughput and the safety of level crossing. Based on maintenance data collected from 90 automatic railway level crossing systems distributed on the track, authors determined the probability density function (PDF) of the time to failure of elements of level crossing systems. In order to confirm the correct form of PDF function, two goodness of fit tests (Kolmogorov-Smirnov and Anderson-Darling) have been performed for normal, log-normal and exponential distributions. SQL Server has been used to collect data, R package to estimate PDF function of elements of automatic railway level crossing and to perform goodness of fit tests.
KEY WORDS: *railway transport, safety, goodness of fit test, computer systems*

1. Introduction

Level crossing is one of crucial places where accidents happen very often [8, 9]. According to European Union announcement, every year more than 300 deaths occur at level crossing in Europe. Therefore, huge emphasis should be put on safe operation of automatic railway level crossing system. The ability to predict the time to failure of elements of automatic railway level crossing system can significantly improve both the throughput and the safety of level crossing. Moreover, such approach can also reduce the costs of exploitation carried by carriers. In this paper, authors used maintenance data coming from railway level crossing systems collected over a 10-year period along with R package to determine the probability density function (PDF) of the time to failure of their elements. Data coming from more than 200 systems evenly distributed on the polish railway track have been taken into account while calculating PDF. Microsoft SQL Server 2012 has been used to store this data in database. R package is a free software that lends itself perfectly to read data from the database and calculate PDF [10]. Therefore, authors decided to exploit this package to this task.

2. Structure of Maintenance Data

Maintenance data have been stored in database running on Microsoft SQL Server 2012. In order to access this data Open Data Base Connectivity (ODBC) driver has been used. It uses ODBC interface by Microsoft that allows applications to access data in Database Management Systems (DBMS) using SQL as a standard for accessing the data. ODBC permits maximum interoperability, which means a single application can access different DBMS. Application end users can then add ODBC database drivers to link the application to their choice of DBMS. R package reads data using RODBC library that can be appended to the script of R program [13]. This library allows the programmer to access data from R package level using standard SQL commands. For example *sqlFetch* command reads the contents of any table stored in the database. Fig. 1 presents the print-screen of the part of a table that contains maintenance data coming from railway level crossing systems read by R program.

This table is composed of 8 columns. The first contains identifier for the railway track on which the system is installed. The second preserves the subsequent number for the system whose type is defined in third column. Fourth column contains identifier of element for the system whose type is defined in third column. Fifth column determines the date of failure for the element from fourth column and the sixth presents the date of repair for this element. The seventh contains the time in which the element remains in fault state. The last column is empty and was added to improve versatility of the table in future applications. For example first row of the table in Fig. 1 determines the date of failure and the date of repair for 6-th element (fourth column). It corresponds to the wheel sensors for railway level crossing system – number 1 in third column represents railway level crossing system. It can be seen that the structure of the table

is enough universal to preserve maintenance data for any automatic railway traffic control devices. Nevertheless, authors presents results only for railway level crossing system.

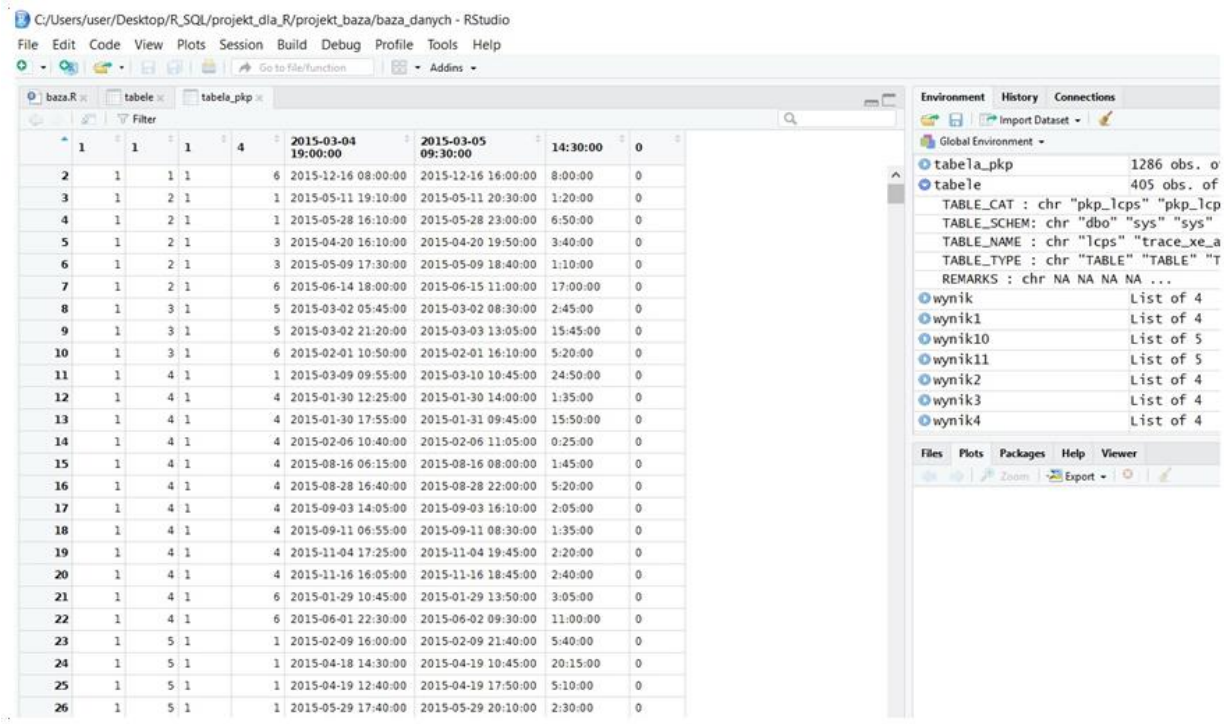

Fig. 1 Print-screen of the part of a table containing maintenance data for railway level crossing systems

3. Determination of Probability Density Function of Time to Failure for Automatic Railway Level Crossing Systems

Authors basing on maintenance theory of reliability [3, 6] assumed that PDF function of time to failure is described by normal, exponential or log-normal distribution. Determination of probability density function of time to failure is realized in two stages. In the first stage the parameters for each type of distribution have been calculated on the basis of available maintenance data using the method of maximum likelihood. In the second stage the goodness of fit test for each type of distribution and its parameters is carried out. Depending on the outcome of this test tested distribution is accepted or rejected. Authors decided to perform two test: Kolmogorov-Smirnov and Aderson-Darling.

The method of maximum likelihood is used in statistical inference to estimate parameters. We have a random variable with a known PDF $f(x,q)$ describing a quantitative character in the population. We should estimate the vector of constant and unknown parameters q according to sampling data: x_1, x_2,… x_n. Maximum likelihood estimation begins with the mathematical expression known as a likelihood function of the sample data. Loosely speaking, the likelihood of a set of data is the probability of obtaining that particular set of data given the chosen probability model. This expression contains the unknown parameters. Those values of the parameter that maximize the sample likelihood are known as the maximum likelihood estimates (MLE). We define the likelihood function as:

$$L\left(x_1, x_2 \ldots, x_n, q\right) = \prod_{i=1}^{n} f\left(x_i, q\right). \tag{1}$$

MLE consists in finding q which maximizes $L(x_1,x_2,...x_n,\ q)$. Maximum likelihood method is realized using *fitdistr* function available in R package library called MASS [12]. This library is appended to the script of R program.

Goodness of fit tests indicate whether or not it is reasonable to assume that a random sample comes from a specific distribution [1, 4]. They are a form of hypothesis testing where the null and alternative hypotheses are:

– H0: Sample data comes from the specific distribution;
– H1: Sample data does not come from the specific distribution.

Both tests - Kolmogorov-Smirnov and Anderson-Darling calculate the p-value. If you are testing at the α significance level and the p-value is smaller than α, you reject the null hypothesis which states that the sample data does not come from the specific distribution. Otherwise if the p-value is greater than α there is no evidence to reject null hypothesis and hence you can conclude that the data is likely to be the specific distribution.

Kolmogorov-Smirnov (K-S) test compares the empirical cumulative frequency denoted as $S(x)$ with cumulative distribution function (CDF) of an assumed theoretical distribution denoted as $F(x)$ in Fig. 2. x_1, x_2, …, x_n are the observed values of the ordered set of data and n is the sample size [5].

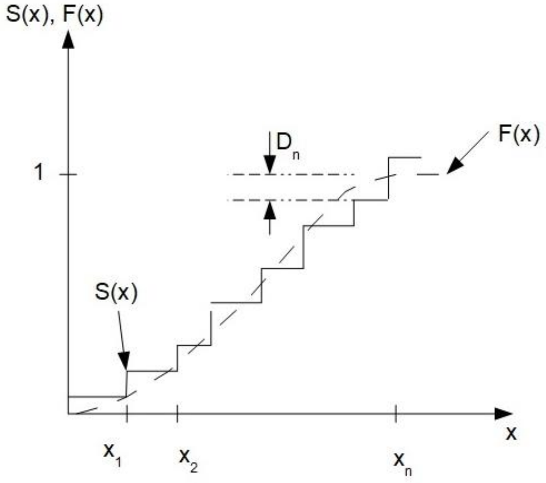

Fig. 2 Illustration of Kolmogorov-Smirnov test

K-S test calculates maximum difference D_n between $F(x)$ and $S(x)$ over the entire range of x:

$$D_n = \max_x |F(x) - S(x)|. \tag{2}$$

Theoretically, D_n is a random variable. p-value for K-S test is defined as:

$$P(D_n \geq D_{obs} \mid H_0), \tag{3}$$

where D_{obs} is the value observed (obtained) during the test. Therefore p-value is the probability of observing an effect of the same magnitude or more extreme given that the null hypothesis is true. This value is usually obtained from the available tables. K-S test is realized using *ks.test* function available in R package library called *stats* [14].

Unlike K-S, Anderson-Darling (A-D) test places more discriminating power at the tails of the distribution. It calculates the following statistic [7]:

$$A^2 = -\sum_{i=1}^{n}\left[(2i-1)\left\{ln\,F(x_i) + ln\left[1 - F(x_{n+1-i})\right]\right\}/n\right] - n, \tag{4}$$

where $F(x)$ is cumulative distribution function (CDF) of an assumed theoretical distribution and x_1, x_2,…, x_n are the observed values of the ordered set of data and n is the sample size. Based on A^2 the p-value is calculated. It is obtained based on A^2 and the type of specific distribution using dedicated formulas [2]. A-D test is realized using *ad.test* function available in R package library called *goftest* [11].

Tab.1 presents p-values obtained for K-S and A-D tests for selected element of railway level crossing system at the assumption that tested distribution is normal, exponential or log-normal and the significance level $\alpha = 0.05$.

Table 1

p-value for normal, exponential or log-normal distribution of time to failure for wheel sensors in railway level crossing system

Type of test	Type of distribution	p-value
Anderson-Darling	normal	5.05476e-07
	exponential	5.05476e-07
	log-normal	**0.0915295**
Kolmogorov-Smirnov	normal	0
	exponential	0
	log-normal	0.0168182

Results in Table 1 show that only log-normal distribution passed the test (p-value = 0.0915295 > = 0.05). This is satisfied only for A-D test. Fig. 3 presents histogram of time to failure and corresponding probability density function for wheel sensors in railway level crossing system.

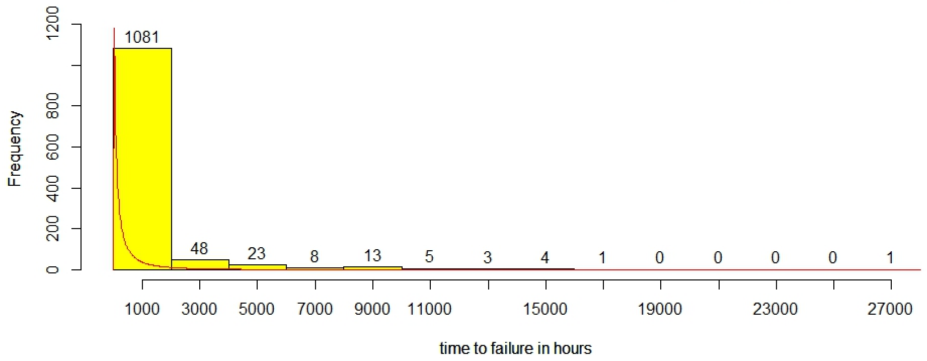

Fig. 3 Histogram of time to failure and corresponding probability density function for wheel sensors

4. Conclusions

Reliability of railway level crossing systems has an immense impact on the safety of railway traffic. Therefore, the prediction of time to failure of their elements can improve both the reliability and throughput of these systems as well as reduce the cost of expatiation. Authors used maintenance data coming from railway level crossing systems evenly distributed on Polish railway tracks that has been stored in database server. The structure of database tables is universal what in turn allows for the storage of data for any railway traffic control devices. In order to predict time to failure, authors estimated parameters of probability density function of time to failure based on real maintenance data stored in database. The access to database and parameters estimation have been realized using script written in R package. It turns out that time to failure of elements of railway level crossing systems can be described by log-normal distributions whose parameters are calculated using Maximum Likelihood Method.

Acknowledgment

This material is based upon work supported by National Centre for Research and Development under Grant No. PBS3/A6/29/2015 entitled „The system for maintenance data acquisition and analysis of reliability and safety of traffic control systems".

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Practical use of Approach Systems for Landing at Rzeszów-Jasionka Airport

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Abstract

The article presents the most popular landing approach systems used in air transport, which operate at the airport in Rzeszów. Their structure and principle of operation were analyzed. Moreover, their possibilities and limitations resulting from unfavorable meteorological conditions were examined. Landing systems are divided into two basic groups: precision and imprecise systems. The most interesting system is the ILS, precision approach system. However, this article briefly characterizes non-precision approach systems such as VOR (Very High Frequency Omnidirectional Radio Range), DME (Distance Measuring Equipment), NDB (Non – Directional Beacon). The main limitations of non-precision systems arise from field errors. The biggest terrain error of such systems is the terrain and close proximity of large objects. Another common disadvantage of these systems is the low precision of position determination. However, the precise system – ILS (Instrument landing system) also has many limitations resulting from field errors and its construction. What is more, the operation of the ILS system is largely dependent on meteorological conditions. However, the system is divided into 5 categories. Using the last category, you can perform a fully automated landing without RVR visibility (Runway visual range). The article also presents the hourly demand for a particular category of ILS in 2010-2016. The greatest demand for the ILS system occurs in October, November and December, this is due to the limited visibility caused by unfavorable meteorological conditions. During the research, it was also found that it would be profitable to raise the ILS category at the airport in Rzeszów to IIIA. Based on the developed maps presenting selected phenomena limiting visibility, a comparison was also made of the demand for the ILS system for other airports in Poland.
KEY WORDS: *landing approaches, ILS, VOR, DME, NDB, restrictions*

1. Introduction

Aviation is very important in the field of transport. Air transport is the safest mode of transport. With its help, not only people can move safely and quickly, but also much easier to transport various types of goods, including oversized goods. However, aviation would not be so safe and efficient if it were not for adequate navigation systems that significantly increase flight safety by providing relevant information for the pilot. The takeoff and landing of an aircraft are the two most difficult and demanding flight phases. This article presents a brief description of inaccurate landing systems and an ILS precision approach system was investigated. All this on the basis of the Rzeszów-Jasionka Airport. The systems described in this article have already been analyzed, in particular the precise ILS system, among others by: Merkisz. J., Galant. M., Bieda. M. [1]. However, these studies differ from each other primarily by the methodology, purpose of the study and the analyzed airport. The aim of this study was first of all to examine the impact of meteorological conditions on the functioning of the ILS system at the Rzeszów-Jasionka Airport. The functionality of the above system at the examined airport was examined. The survey was based on data from 2010-2016 METAR. The key element for us was the RVR (Runway visual range) value. The total number of working hours of the system in Rzeszów was determined, as well as the number of hours when, despite using the system, the take-off or landing operations could not take place due to the prevailing weather conditions. The profitability of introducing the next category of the ILS system at the examined airport was also examined. What is more, using the maps made in the Surfer 13 program, the approximate demand for the ILS system at selected airports in Poland is illustrated. The maps were made using also data from sources: [6-11].

2. Systems of Approach to Landing

VOR (Very High Frequency Omnidirectional Radio Range) is the most widely used angular auxiliary radio-based short-range system. It is not used at the very start or approach to landing, but it is designed to guide the SP on routes through the VOR beacon. Thanks to it, it is possible to determine on the aircraft the radial on which it is positioned. This system uses the phase comparison of transmitted signals from ground stations towards a specific bearing. Information on the azimuth is determined by comparing the two phase components of the beacon signal: the solid phase and the phase of the variable. ILS occurs in two versions: classic and Doppler. In the Doppler version the frequency band and range are identical as in the classic version, the propagation error is negligible, the field error takes the value of ± 0.5°, while the instrument error associated with the imprecision of the phase shift measurement is ± 1°

and the error allowed for the system is ± 1.5°. The disadvantage of the basic VOR system is high susceptibility to field error. Its greatest source is terrain sculpture and the neighborhood of larger objects, which have a large impact on the propagation of radio waves. The area under beacons must be aligned in an area with a radius of 300 m, while within a radius of one kilometer there must not be any artificial or natural objects that exceed the angular height of 2°. The D-VOR variant, i.e. the Doppler VOR, is more resistant to errors by using a wide aperture antenna [2].

NDB (Non – Directional Beacon) is a terrestrial non-directional transmitter operating on medium waves (in the range of 200-1600 kHz), having an antenna system with an omnidirectional character. It provides, along with the ADF (Automatic Direction Finders) on-board radiocomputer, bringing the aircraft to the area of the airport or a flight along the route. The NDB beacon emits an approximately carrier wave in the frequency range given above. Morse characters are emitted every 30 seconds by 1020 Hz tone, and in older types of radio beacons also 400 Hz. The identification mark consists of one, two or three letters. One letter is used by internal positioning stations, two or three for external stations and three letters for NDB [3]. The range of the beacon ranges from 10 NM to 100 NM. The ADF radiocompass receives signals with frequencies ranging from 150 kHz to 1750 kHz and determines the direction of the beacon with an accuracy between 2° -3°, via an omnidirectional antenna (signal reception is independent of direction) and a directional frame antenna. The indications of the system are not stable and are changing centrally over the beacons. This area is usually called a dead cone. Most often, the apex angle of the dead cone is about 45°. On the basis of the course, as well as the beacon angle of the beacon with the help of the ADF indicator, one can determine the bearing on the working NDB or bearing on the aircraft from a known location of the beacon [2].

The **DME** electronic radio modem is a radar, pulse, ultra-shortwave and standard distance system. It works in pulses in the frequency band from 960 MHz to 1215 MHz and the 1 MHz bandwidth. The system consists of [2, 4]: On-board transceiver interrogator, terrestrial reception – transmitting beacon, also referred to as a transponder. Together with the VOR, the radiodhaler creates an angle-distance system of the nearby range. This system measures the oblique distance between the aircraft and the radio beacon. The accuracy of measuring this distance is 800 m or 3% of the distance, while its range is close to 370 km for an altitude of 8000 m [3]. The distance measuring system radiodalmie operates on the principle of a response, it means that both its parts, on-board and terrestrial belong to the transceivers. The measurement is initiated by an on-board set, sending pairs of radio pulses called "query" to the ground device. This device receives them, identifies them and sends a "response". The distance in the on-board unit is measured by counting the time between sending the request pulses and receiving a response, after deducting 50 μs (the time between answering the request and sending the answer). Newer on-board kits convert further distance indications into speed and arrival time to radio beacons. The number of system channels is 256. Currently, DME beacon used as a complement to the ILS system is more and more frequently encountered. In this case, the DME antenna is mounted on the mast of the glide path transmitter, which is located near the touchdown point. The DMEs used in the set with the ILS system may be omnidirectional or sectoral beacons. Such a solution has an additional correction of the response delay time, thanks to which it shows the distance from the touchdown point [3].

ILS – Instrumental Landing System. It is a distance-angle system, and its main task is to guide the aircraft according to the prescribed landing course and along the designated approach path [2]. In addition to horizontal and vertical guidance, it may also provide distance indications from the most favorable landing point. The electronic signals transmitted into space are produced independently of each other and provide navigational information about deviations from the course, descent path, and distance from the runway threshold [3].

3. Evaluation of the ILS System Category

According to the recommendations contained in ICAO Annex 10, landing systems are divided into three categories (Table 1).

Table 1

ILS system categories, source: [2]

Category	Minimum decision height	Minimum RVR value
I	60 m (200 ft)	550 m
II	30 m (100 ft)	350 m
III A	> 30 m (100 ft) or without	200 m
III B	> 15 m (50 ft) or without	50 m
III C	0 m	0 m

CAT I relies solely on the altimeter indications for the height of the decision. CAT II and CAT III approaches use a radio altimeter to determine the decision height. In addition, category III C is able to provide a fully automatic approach to landing [1]. The system consists of two segments: the ground segment and the air segment. The terrestrial segment consists of five basic elements, including: course beacon (ILS Localizer) – located at the end of the runway, Glide Slope Transmitter – located next to the runway, and more precisely on the trailing touchdown point, three marker beacons (Markers) – located at different distances from the touchdown point, approach light system, appropriate signs painted on the runway. There are also situations in which markers are mounted together with the NDB beacon. In this way, so-called tenant (Compass Locator). Its task is to facilitate planning the entry into the region of the ILS direction at

the desired point. Currently, you can also meet with ILS kits, in which DME radio beacons were used instead of markers to calculate distances. The ILS on-board assembly is integrated with the VOR team and consists of three receivers: GP (Glide Path), VOR/LOC and a marker receiver.

Limitations of the ILS system. The basic disadvantage of the ILS system is that it has only one course line. Signal reflections are also a frequent phenomenon. The next limitation of the system is that it has only 40 work channels. The reason for this is interlacing in a given frequency band of the VOR beacons and the ILS course beacons. A serious problem of the ILS system is its work at low frequencies (especially when it comes to the radio beacon of the course), because then interference originates from radio stations operating at frequencies close to 108 MHz [2]. When installing the ILS system, the requirements regarding its location and the large costs of the installation itself are very important

Practical use of the ILS system. The main factor influencing the ability to perform the take-off and landing procedure is visibility. In the case of the ILS system, visibility along the RVR runway is very important. This visibility is described as the distance from which the pilot of an aircraft placed in the axis of the runway is able to see its markings or lights that outline it, or to identify its axis [5]. RVR may limit the work of the discussed system. At present, the second category of the system operates at the airport in Rzeszów (from October 2017), however, the research was carried out earlier, when the category I was still active at the airport. The research consisted of a detailed analysis of METAR meteorological messages. These are messages sent every 30 minutes, in which basic meteorological information is included, such as: wind direction and speed, cloud cover, temperature, dangerous phenomena, visibility and others. In the meteorological message the exact RVR value is given (if not, it means that the visibility is very good), on the basis of which and on the basis of the information presented in Table number 1, a thorough analysis was made. Table 2 presents the number of ILS system hours for category I. As can be seen, the largest demand for the system is in autumn and winter, which is obviously due to meteorological conditions. The biggest deterioration of visibility, of course, is caused by fogs, which are the biggest threat to the system. In winter, however, it is intensive snowfall.

Table 2

The number of operating hours of the ILS cat. I system, source: own study

CAT. I	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Sum
2010	54	53,5	17	5,5	6,5	1	1	4,5	3	0	16	54	**216**
2011	13	6	4,5	2	0	3,5	4	0	12	33,5	30	8	**116,5**
2012	5	29,5	2,5	4,5	2	4,5	2,5	5,5	10,5	20,5	18	4	**109**
2013	12	6	41,5	2,5	5,5	9,5	0	4	3	8,5	9,5	3,5	**105,5**
2014	3	7	11	4	2	1	0	6,5	4	16	25,5	31	**111**
2015	20	28,5	5	1	0	0	0,5	1,5	4	14	13,5	7,5	**95,5**
2016	21,5	1,5	13,5	19	5,5	1	1,5	0	8	5,5	20,5	6,5	**104**
Average	**18,36**	**18,86**	**13,57**	**5,50**	**3,07**	**2,93**	**1,36**	**3,14**	**6,36**	**14,00**	**19,00**	**16,36**	**122,5**

Table 3 shows the number of hours in which take-off and landing operations were delayed or completely canceled due to unfavorable weather conditions. This is the sum of hours when the visibility of the RVR was less than 550 m. As you can see, the presence of only the first category of the system in the analyzed period brought many losses, the most being as many as 126 hours in 2014. The lowest in 2013, when the number of hours with RVR 550-350 m was equal to 60.

Table 3

The number of operating hours of the other categories of the ILS system, source: own study

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Sum
2010	3,5	17	2,5	22	1	0	3,5	3	9	25,5	0,5	32,5	**120**
2011	1,5	2,5	0	1,5	1,5	4	7	4	11,5	16,5	33,5	2	**85,5**
2012	1,5	4	2,5	0	7,5	3,5	3,5	3	17	22	60	0,5	**125**
2013	0	0	4,5	0,5	3	6,5	0	1	1,5	24	9,5	9,5	**60**
2014	1,5	4	4,5	10	0,5	2	2	17	3	62,5	10,5	8,5	**126**
2015	0,5	18	0,5	0,5	1	0	1	4,5	9,5	20	33,5	13	**102**
2016	9	1	12	7	7,5	1,5	1	0	15	23	16	0,5	**93,5**
Average	**2,50**	**6,64**	**3,79**	**5,93**	**3,14**	**2,50**	**2,57**	**4,64**	**9,50**	**27,64**	**23,36**	**9,50**	**101,7**

The next category is category II, which is presented in Table 4. It is currently operating at the airport category ILS. It was officially put into use on October 19, 2017. On the basis of the table, it can be stated that the upgrade of the ILS system category at the airport in Rzeszów was the most-indicated investment.

Table 4

Number of ILS category II operating hours, source: own study

CAT. II	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Sum
2010	3,5	3,5	0,5	11	1	0	0,5	2,5	6,5	9	0	14,5	**52,5**
2011	1,5	2	0	1,5	1	3	1,5	2	6	3,5	12,5	0	**34,5**
2012	0,5	2,5	1	0	5	2	2	2,5	9,5	14	34,5	0,5	**74**
2013	0	0	4,5	0,5	1	2	0	1	1	8,5	4	4,5	**27**
2014	0,5	4	3,5	5,5	0,5	1,5	2	10	3	37,5	7	8,5	**83,5**
2015	0,5	9,5	0,5	0,5	1	0	0	4	7,5	4,5	24	4,5	**56,5**
2016	5,5	0	7,5	4	3	1	1	0	10	15,5	13	0,5	**61**
Average	**1,71**	**3,07**	**2,50**	**3,29**	**1,79**	**1,36**	**1,00**	**3,14**	**6,21**	**13,21**	**13,57**	**4,71**	**55,57**

Although Category II is not the lowest and to a large extent it already reduces losses related to impediments, the results of the other top categories are also presented below. Table number 5 applies to category III A of the system. Unfortunately, the number of hours in this case also did not turn out to be small and despite the introduction of the second category, the airport may still suffer significant losses due to restrictions on RVR.

Table 5

The number of working hours of category III A of the ILS system, source: own study

CAT. III A	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Sum
2010	0	13,5	2	10,5	0	0	3	0,5	2,5	15,5	0	14,5	**62**
2011	0	0,5	0	0	0,5	1	5,5	2	5,5	11	15,5	1	**42,5**
2012	1	1	1,5	0	2,5	1,5	1,5	0,5	7,5	7	25,5	0	**49,5**
2013	0	0	0	0	2	4,5	0	0	0,5	13,5	5	3,5	**29**
2014	1	0	1	4,5	0	0,5	0	6	0	24,5	2,5	0	**40**
2015	0	7,5	0	0	0	0	1	0,5	2	13,5	8	7	**39,5**
2016	1,5	0,5	4,5	3	4,5	0,5	0	0	5	7,5	3	0	**30**
Average	**0,50**	**3,29**	**1,29**	**2,57**	**1,36**	**1,14**	**1,57**	**1,36**	**3,29**	**13,21**	**8,50**	**3,71**	**41,79**

Table 6 presents the results of research for category III B, while Table 7 for category III C. The number of hours for these categories is already very small, especially for the last, highest category. While the largest sum for category B is equal to 6.5 hours, for category C it is only a maximum of 2 hours in the whole year. What's more, with the highest category, any demand for it appeared only in a year.

Table 6

The number of working hours of category III B of the ILS system, source: own study

CAT. III B	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Sum
2010	0	0	0	0,5	0	0	0	0	0	1	0,5	2,5	**4,5**
2011	0	0	0	0	0	0	0	0	0	1,5	4	1	**6,5**
2012	0	0,5	0	0	0	0	0	0	0	1	0	0	**1,5**
2013	0	0	0	0	0	0	0	0	0	1,5	0,5	1,5	**3,5**
2014	0	0	0	0	0	0	0	1	0	0,5	1	0	**2,5**
2015	0	1	0	0	0	0	0	0	0	2	1,5	1,5	**6**
2016	2	0,5	0	0	0	0	0	0	0	0	0	0	**2,5**
Average	**0,29**	**0,29**	**0,00**	**0,07**	**0,00**	**0,00**	**0,00**	**0,14**	**0,00**	**1,07**	**1,07**	**0,93**	**3,86**

Table 7

The number of working hours of category III C of the ILS system, source: own study

CAT. III C	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Sum
2010	0	0	0	0	0	0	0	0	0	0	0	1	**1**
2011	0	0	0	0	0	0	0	0	0	0,5	1,5	0	**2**
2012	0	0	0	0	0	0	0	0	0	0	0	0	**0**
2013	0	0	0	0	0	0	0	0	0	0,5	0	0	**0,5**
2014	0	0	0	0	0	0	0	0	0	0	0	0	**0**
2015	0	0	0	0	0	0	0	0	0	0	0	0	**0**
2016	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Average	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,14**	**0,21**	**0,14**	**0,5**

Presentation of the examined airport in comparison with other selected airports in Poland. As it was written earlier, the ILS system as well as non-precision systems has its limitations and drawbacks. The biggest threat to the analyzed system is fog. This phenomenon significantly reduces the RVR on which the use of the system depends. Below, Figs. 1 and 2 show the number of occurrences of fog and mist freezing at selected airports. As fog is the most common and the most significant phenomenon that reduces visibility, it can be used to determine the approximate demand for an ILS system at a given airport (Fig. 1, Fig. 2).

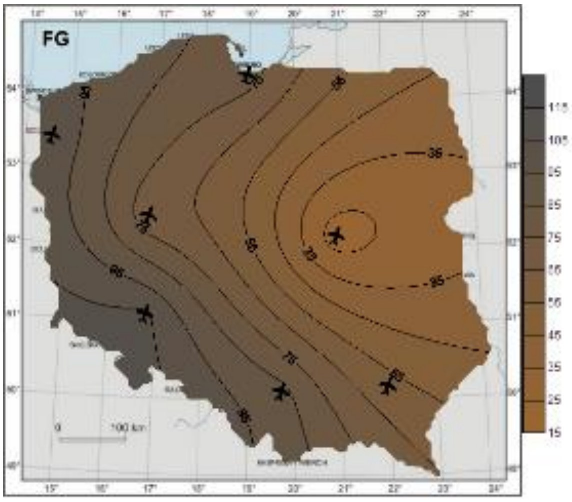

Fig. 1 The number of fog cases

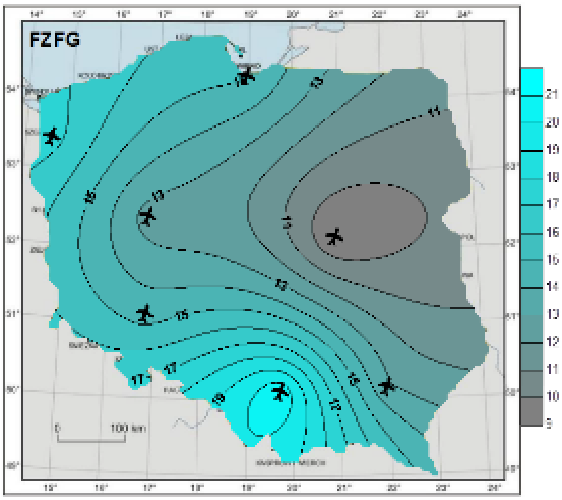

Fig. 2 Number of occurrences of freezing fog

As can be seen, the number of mists rises from the north-east to the south-west so that its smallest value is at Warsaw Chopin Airport and the largest one for the Wrocław-Starachowice Airport. The Rzeszów-Jasionka airport was second in terms of fog, just outside of Warsaw. However, the other airports are definitely closer to the airport in Wroclaw. This is obviously due to the location of individual airports, because fogs are more often formed in mountainous and waterlogged regions, as well as near large water reservoirs. What is very important, often in the vicinity of larger and industrialized cities, so-called city haze, which is a mixture of ordinary fog with smoke and municipal exhaust. In the case of freezing mist, the average number of occurrences is no longer evenly distributed, but also its lowest value is for the Warsaw airport. However, its highest value was obviously noted at the airport in Krakow, which is located near the mountains, which explains such a quantity. The Rzeszów airport in this case is on the third place after Warsaw and Poznan. Wrocław and Gdańsk are located just behind Rzeszów. However, a lot of cases have been recorded also at the Szczecin airport, which also explains its location.

4. Conclusions

This article briefly describes the basic navigation systems used in air transport. The main division of systems are imprecise and precise systems. The article presented the limitations of both non-precision systems and the precise ILS system. The conducted research presents the practical use of the precise ILS landing system. On the basis of surveys and developed maps, an assessment of the demand for the ILS system at selected airports in Poland was also made. The above studies show that:

– The ILS precision approach system also has many disadvantages and limitations. First of all, this system is largely dependent on the weather. The biggest threat to the system is fog. Although it is a landing approach system, used mainly in difficult meteorological conditions, it also has its own acceptable parameters on which it can operate. The largest demand for the system occurs in autumn and winter, when visibility at the airport is often very poor. This system occurs in 5 categories, the last, with the last III C, allowing a fully automated approach, even during zero visibility.

– The investment in the second category of the system at the airport in Rzeszów was the most justified, and moreover, the research showed that there is also a high demand for the category II A of the ILS system at the examined airport. The total sum of hours in the audited period, which the visibility of the RVR did not allow to perform the flight as planned, due to the lack of category III A is 292.5. It is even more onerous due to the fact that the sum of these hours is not evenly distributed. The vast majority of these hours are included in the period from September to December. Thus, when in 2015 the total hours for the whole year was 39.5, the sum of hours only for the period September-December was 30.5.

– The average number of fog occurrences in Poland is 65, which shows that Rzeszów, like Warsaw, is below this average. The Poznań airport is still in the middle, while the others exceed it by more than a half. As for the freezing fog, its average value for the area of Poland is 15 occurrences. This proves that this time the airports in Warsaw, Poznań and Rzeszów were lower than the average, while the amount of fog equal to 15 was recorded in Wrocław and Gdańsk. The other two (Szczecin and Krakow) exceeded the average value.

– On the basis of the research, it was also found that the largest system limitations related to RVR visibility occur at the airport in Krakow. The demand for this airport for category III A of the system is 325 hours. In addition, there was an equally high demand for category III C, which amounted to 306.5 hours. The second airport, where air transport is frequent due to frequent visibility restrictions, is the Poznań-Ławica airport. Here, the demand for category III A is in total 323 hours. As far as the difficulties related to frequent reduction of visibility and limitations of support systems are concerned, the airport in Gdańsk was the best. It is a city where air transport does not have to deal with many difficulties related to meteorology or supporting devices.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Development of Transit Time Parameter for Transportation Flows of Priority Mail

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Abstract

The paper is focused on estimation of transit time development for postal transportation services, namely end-to-end services for single piece priority mail. There have been defined requirements by European Commission on postal measuring systems (for Quality of Service) with possibility of independent end-to-end measurement. The aim of this measurement is to estimate QoS by transit time of end-to-end services for single-piece priority mail provided to customer by domestic mail in each European country and by cross-border mail among European countries. The main objective of this paper is to research possible development of transit time parameters following from mentioned independent measurements. This development could relate to changes in some other indicators connected with layout and organization of logistic network, capacities for processing of concerned postal items and naturally ensuring the whole process of postal service provision. Using of analytic tools for expression of potential influences or dependences could create important supporting step as well. Measurement system created by sample of test postal items flows is based on real traffic mail flows on fixed postal transportation network. The results respect measurement system specifications and analysis of postal transport network efficiency by mentioned procedure could help to find the most appropriate ways to improve the quality of postal services.
KEY WORDS: *transit time, priority mail, traffic flows, development, correlation, trend, prognosis*

1. Introduction

The basis for creation of acquis communautaire for postal market, i.e. uniform rules respected in individual EU sectors, is the Green Paper on the Development of the Single Market in Postal Services. On its basis Directive 97/67/EC of the European Parliament and of the Council on common rules for the development of the internal market of Community postal services and the improvement of quality of service (hereinafter the Postal Directive) was processed and on 15 December 1997 also approved. Objective of this Directive is to create a single European postal market under conditions of market economy.

This Postal Directive established universal postal service in such way that all member states shall ensure that all users can enjoy their right to this universal postal service. This contains permanent provision of this service in a specified quality and at all the access points in their territory at affordable prices for all users. It also describes that the member shall take steps to ensure that the density of points of contact and of the access points, e.g. mailboxes and post offices, takes into account the needs of users. This service must be provided every working day and not less than five days a week as a minimum. Universal postal service must include clearance, sorting, transport, and delivery of postal items up to 2 kg and postal packages up to 10 kg, as well as services for registered items and insured items. This universal postal service covers both national and cross-border services.

Each member state shall further ensure that in the frame of universal postal service all the users are offered an identical service under comparable conditions that are accessible without any form of discrimination whatsoever, especially without discrimination arising from political, religious, or ideological considerations. This service shall not be interrupted or stopped except in cases of force majeure, shall evolve in response to the technical, economic and social environment and to the needs of users [1].

The latest directive regulating EU’s postal service sector is Directive 2008/6/EC of the European Parliament and of the Council amending Directive 97/67/EC with regard to the full accomplishment of the internal market of Community postal services. This third Postal Directive was approved 20 February 2008 and defines conditions governing the provision of postal services, provision of a universal postal service within the Community, financing of universal services under conditions that guarantee the permanent provision of such services, tariff principles and transparency of accounts for universal service provision, setting of quality standards for universal service provision and the setting-up of a system to ensure compliance with those standards, harmonization of technical standards, and creation of independent national regulatory authorities.

Each member state may designate one or more undertakings as universal service providers in order that the whole of the national territory can be covered. Member states may designate different undertakings to provide different elements of universal service and/or to cover different parts of the national territory. When they do so, they shall determine in accordance with Community law the obligations and rights assigned to them and shall publish these obligations and rights. The conditions, under which universal services are entrusted, must be based on the principles of transparency, non-discrimination and proportionality, thereby guaranteeing the continuity of the universal service provision, by taking into account the important role it plays in social and territorial cohesion [1].

2. Quality of Postal Services

Regarding quality of services, member states shall ensure that quality-of-service standards are set and published in relation to universal service. Quality standards shall focus, inparticular, on routing times and on the regularity and reliability of services. Independent performance monitoring shall be carried out at least once a year by external bodies having no links with the universal service providers under standardized conditions, using annually repeated methodology, and shall be the subject of reports published at least once a year. The Postal Directive lays down quality standards for intra-Community cross-border service, that within the time limit of D+3 85% of items will be delivered and within the time limit of D+5 97% of items will be delivered, where D represents the date of induction and the number represents the number of working days which elapse between that date and that delivery to the addressee.

In the quality area, not only regulations of Postal Directive need to be respected (such as meeting defined standards for intra-Community cross-border services), but also European standard EN 13850:2012 Postal services - Quality of service - Measurement of the transit time of end-to-end services for single piece priority mail (SPPM) and first class mail must be fully met. This regulation determines methodology for calculating transit time between the endpoints of national and cross-border priority letter mail cleared, sorted, and distributed by postal operators. The overall result of service quality can be expressed as a percentage of mail delivered within $D+n$ days between the endpoints. This service quality indicator does not measure overall postal operator's efficiency and does not include any other service efficiency indicators, only those that are related to the transit time [1]. Service standard for SPPM in Czech Republic is given by Regulation Nr. 464/2012 Coll. Relevant part sets, that by measuring of transit times per calendar year there must be achieved result at least 92 % of postal mail delivered on the first working day following day of its posting [3].

At first, this regulation defines used terminology, which is followed by regulations related to calculation and expression of transit time, methodology, including the proposal of a representative sample, geographic stratification, geographic distribution group, estimates (accuracy, measurement results, calculation of accuracy), test items characteristics, reports, and audited quality management.

A similar regulation that needs to be fully met is a standard EN 14508:2016 Postal services - Quality of service - Measurement of the transit time of end-to-end services for single piece non-priority mail and second class mail. This standard follows the standard EN 13850:2012 and is compatible with its requirements. Additionally, it defines methodology for calculating transit time between the endpoints of national and cross-border non-priority letter mail cleared, sorted, and distributed by postal operators. This standard is not applied in Czech Republic because the postal operators do not provide second-class services [1].

3. Modelling of Transit Time Parameter Development

Quality is usually understood as speed and reliability of provided service as well as its availability. Service's speed is defined by time between posting and delivering the consignment, for express services it may be for example a matter of hours. Speed and reliability can be usually shown as a share of monitored postal consignments delivered the next day after their posting. According to monitoring since 2005 national postal operator (NPO) achieved a result about 90 % in previous years, which is a result comparable with the most advanced European public postal operators. Availability of NPO services is indisputable due to the number of post offices (actually max. 3200). The monitoring is carried out so, that a monitored letter post is thrown into a mailbox and the time, in which the mail is delivered into addressee's letter-box, is measured. For the following years, it is planned to monitor consignments delivered even into businesses or directly to the addressee only. The measurement results achieved in 2010 are better than the results of previous years and also the limit (92.5 %) based on original standard EN 13850 was easily met. However, the limit set for 2011 (94 %) NPO did not meet (achieved result of 92.15 %) and the same had been expected in 2012 with the limit 95 % [1].

The main objective of this paper is to research possible development of transit time parameters following from mentioned independent measurements. This development could relate to changes in some other indicators connected with layout and organization of logistic network, capacities for processing of concerned postal items and naturally ensuring the whole process of postal service provision. Using of analytic tools for expression of potential influences or dependences could create important supporting step as well.

At first there has been explored correlation between related significant parameters (values see in Table 1) as transit time – percentage of D+1 on-time items $\boldsymbol{x_1}$ and the number of post offices including sorting centers and other nodes processing postal items $\boldsymbol{x_2}$ [4]. Real correlation has not been confirmed in accordance with results of testing $\boldsymbol{t}$-statistics of independence. See following Eq. (1-3):

$$r_{12} = \frac{n\sum x_1 x_2 - \sum x_1 x_2}{\sqrt{\left[n\sum x_1^2 - \left(\sum x_1\right)^2\right] \cdot \left[n\sum x_2^2 - \left(\sum x_2\right)^2\right]}}; \tag{1}$$

$$H_0 : \rho = 0 \cdots H_1 : \rho \neq 0; \tag{2}$$

$$t = \frac{r_{12}}{\sqrt{1 - r_{12}^2}} \sqrt{n-2}, \tag{3}$$

here r_{12} - correlation coefficient of above-mentioned parameters x_1 and x_2; n - number of particular measurements, thus scope of enter data; H_0 - null hypothesis of parameters independence; H_1 - alternative hypothesis of parameters dependence; t - testing statistics of importance [2].

Table 1

Parameter values

Parameter	2003	2004	2005	2006	2007	2008	2009	2010
x_1	93,51	94,87	96,01	94,06	89,15	90,6	92,09	93,19
x_2	3415	3405	3401	3387	3387	3392	3353	3322
Parameter	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**-**
x_1	92,31	94,37	93,11	93,99	93,78	93,91	93,44	-
x_2	3309	3277	3249	3162	3124	2984	-	-

Next step was regression analysis for transit time parameter. We search such function formula, which will have zero sum of residues (difference between real data $\boldsymbol{y}_\mathbf{i}$ and smoothed value from regression $\boldsymbol{Y}_\mathbf{i}$, thus minimal sum of squared errors $\boldsymbol{S}$. Regarding the fact that we work with one-year data, then exploration of individual components of time series including seasonability is irrelevant. See Eq. (4) below [2]:

$$S = \sum \left(y_i - Y_i\right)^2 \rightarrow \min. \tag{4}$$

On the basis of regression results there can be stated quadratic function for development of transit time parameter in D+1 in following form Eq. (5), concrete formula for regression is reflected by Eq. (6) [2]. Function starts in 2008 year because of dropped value in 2007, when one of big sorting centers within postal network was modernized and some problems occurred with introduction of new operational conditions due to extensive changes. The course of function is evident on Fig. 1. Determination index $\boldsymbol{R}_2$ equals 0.78. Function including 2007 value see on Fig. 2, formula Eq. (7) with determination index 0.89, which is although higher than by previous function, but reflects extraordinary state of operational condition in 2007 year.

$$y = \beta_0 + \beta_1 x + \beta_2 x^2; \tag{5}$$

$$Y = 89{,}949 + 1{,}0875 - 0{,}0741x^2. \tag{6}$$

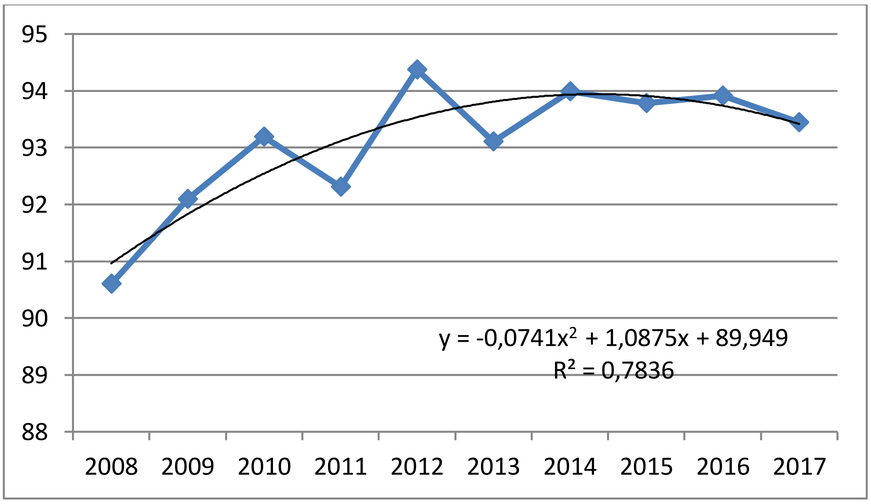

Fig. 1 Regression from 2008 year

$$Y = 88{,}134 + 1{,}4395x - 0{,}088x^2 \,. \tag{7}$$

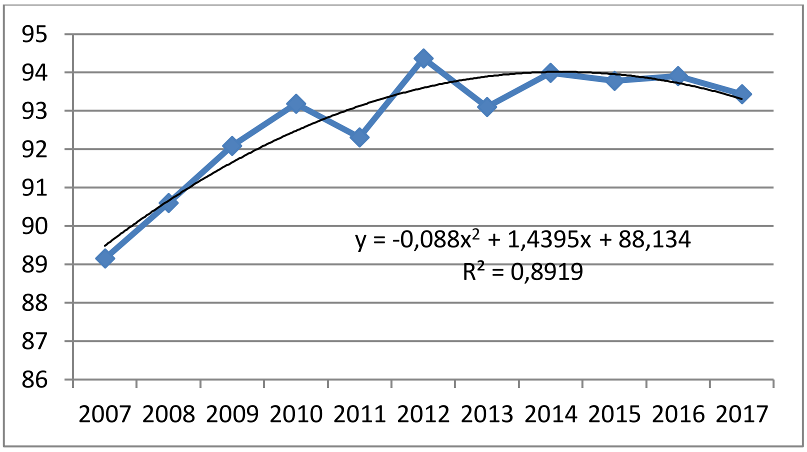

Fig. 2 Regression from 2007 year

Theoretical consideration with regression function of all available data from 2003 year unfortunately does not give reliable result, even when 2007 year value has been released, see Fig. 3 and Eq. (8) with determination index 0.02. Prognosis of this result is evidently baseless.

$$Y = 176{,}36 - 0{,}0412x \tag{8}$$

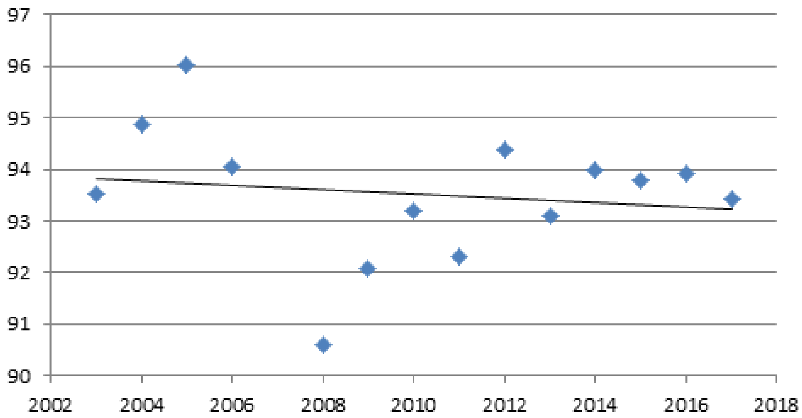

Fig. 3 Regression from 2003 year without 2007 value

4. Conclusions

The results of regression do not give unequivocal results. Considering all available data we do not rely on results due to relatively significant differences in levels of transit time parameter of on-time performance. In the course of time there have been realized important changes in postal network in relation to changes in structure of demanded services and their provision. Partially reliable function could be regression from 2008 year, but its course and estimations for next years have decreasing character (e.g. for 2018 and 2019 values 92.96 % and 92.34%). But this trend is not admissible – this fact alone due to mentioned obligatory service norm 92 % stated by Regulation Nr. 464/2012 Coll. Current situation reflects developing and adapting process of postal operator to new continuously changing market conditions and real possibilities of technological and operational upgrade.

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Proceedings of 22nd International Scientific Conference. Transport Means. 2018.

Use of Acoustic Emissions to Determine the Technical Condition of Mechanical Gearbox

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Abstract

The aim of the article is to find out the technical condition of a mechanical four-speed gearbox in an off-road vehicle using acoustic diagnostics. This method has been developing very fast recently and is supposed to be used not only for a signal analysis itself but also for a failure occurrence prediction - our future aim. In our article we observe the technical condition of a mechanical four-speed gearbox covering 160000 km. During the experiment we analysed an acoustic signal expressed by the Fourier transform. We expressed graphically the dependence of a noise level put in decibels on a frequency put in Hz. A measuring device Ultraprobe 15000 kit including its software support UE Spectralyzer version 4.2 were used for the measurement.

KEY WORDS: *acoustic emissions, root mean square of a noise, technical condition of mechanical gearbox.*

1. Introduction

Acoustic emission (AE) has proven to be an effective non-destructive technique to investigate the behaviour of material under mechanical stress [1]. Acoustic emission is commonly defined as transient elastic waves within materials that are caused by localized stress energy. These waves are short lived bursts of energy that are caused by a sudden internal change of state within a material. All materials have specific elastic properties. Any imposed force on a material can cause strain or compression and the elastic properties determine how that material will return to its original condition. When a crack propagates, a rapid release of energy called an acoustic emission event occurs. This acoustic emission event corresponds to an acoustic emission burst signal in the collected data. Compared with vibration techniques, acoustic emission offers several advantages. For example, acoustic emission techniques are capable of incipient fault detection. Additionally, it is sensitive to fault location, allowing its use for fault location detection. When applied to rolling element bearings, it has been shown that acoustic emission techniques can detect faults earlier than other technologies [2]. Compared with vibration centred approaches, acoustic emission offers several advantages. For example, acoustic emission techniques are capable of incipient fault detection. Additionally, it is sensitive to fault location, allowing its use for fault location detection. Also, acoustic emission sensors can retrieve information in frequencies that are much higher than vibration signals. However, there are a number of difficulties in the implementation of acoustic emission techniques. Namely, in comparison with vibration sensors, acoustic emission sensors require a much higher sampling rate (typically above 1 MHz).

Acoustic emissions are defined as transient elastic waves generated from a rapid release of strain energy caused by a deformation or damage within or on the surface of a material [3-5]. In the application to rotating machinery monitoring, AE are defined as transient elastic waves generated by the interaction of two media in relative motion. Sources of AE in rotating machinery include impacting, cyclic fatigue, friction, turbulence, material loss, cavitation, leakage, etc. For instance, the interaction of surface asperities and impingement of the bearing rollers over a defect on an outer race will result in the generation of acoustic emission. These emissions propagate on the surface of the material as Rayleigh waves and the displacement of these waves is measured with an AE sensor. Rayleigh waves are a combination of longitudinal and transverse waves. It should be noted that surface defects such as cracks and scratches attenuate Rayleigh waves, in addition, the surface finish of metals can also influence attenuation [6, 7].

In the paper we present advanced computational models suitable for the development of a modern powertrain in the field of noise and vibration. The aim is to decide how detailed the model should be to correctly describe the vibrational and acoustic performance of the powertrain [8].

2. Description of Approach to Detecting a Technical Condition of Vehicle Gearbox

2.1. Possibilities of Detecting the Technical Condition of Vehicle Gearbox with Using Noise

Noise as a contactless measurable diagnostic value might be used as a source of information about a device technical condition. The noise is made by frictional forces and microscopic power impulses generated by mutual movement of rough or inaccurately smoothed surfaces at the point of a pair of parts contact. The disadvantage of the noise diagnostics is the existence of spurious reflections and interference in enclosed space. There are indicated main characteristics of vibrations in acoustic emission. Acoustic amplitude y of a harmonic wave for spreading in the x direction is expressed by the following equation [1, 9].

$$y = A\sin\omega\left(t - \frac{x}{c}\right), \tag{1}$$

for acoustic velocity *v* of a harmonic wave for spreading in the *x* direction it is expressed by [1, 9]

$$v = A\,\omega\,cos\,\omega\left(t - \frac{x}{c}\right), \tag{2}$$

where *A* – amplitude; *c* – wave spreading velocity; *ω* – angular velocity.

Acoustic pressure *p* during the wave passage is expressed by the equation [1, 9]:

$$p = \rho c v = p_A\,cos\,\omega\left(t - \frac{x}{c}\right) = A\omega\rho c\,cos\,\omega\left(t - \frac{x}{c}\right), \tag{3}$$

where p_A – acoustic pressure amplitude; *ρ* – environment density.

Sound rate *I* is a vector quantity usually defined as the mean value of specific sound power [1, 9]

$$I = \frac{dP}{dS}, \tag{4}$$

where sound power *P* is determined by [1, 9];

$$P = pSv, \tag{5}$$

where *S* is the plane perpendicular to the direction of waves spread.

The acoustic values are usually expressed in the levels related to referential values expressed in decibels. Therefore, for the introduced values the following equations apply [1, 9]:

- sound power level L_W, where $P_0 = 10^{-12}$ W,

$$L_W = 10\,log\,\frac{P}{P_0}; \tag{6}$$

- sound pressure level L_p, where $p_0 = 2\cdot10^{-5}$ Pa,

$$L_p = 20\,\log\frac{p_{ef}}{p_0} = 10\,log\,\frac{p_{ef}^2}{p_0^2}; \tag{7}$$

- sound rate level L_I, where $I_0 = 10^{-12}$ Wm^{-2},

$$L_I = 10\,\log\frac{I}{I_0}. \tag{8}$$

2.2. Description of Approach to Detecting a Technical Condition of a Measured Bearing

The speed of repetitive pulses causes a failure frequency which enables us to locate the damage to the roller bearing. The calculation of the failure frequencies are in Eqs. (10) – (13). For this it is necessary to know the type of a bearing and its production code. The presented technique is validated using the acoustic emission signals of seeded fault steel bearings on a bearing test rig. The result is an effective acoustic emission–based approach validated to diagnose all four fault types: inner race, outer race, ball, and cage [1, 10].

For the kinematic frequencies of impulses, provided the motion is all rolling, the formulae [11] apply:

BPFO - Ball Pass Frequency – Outer Race (outer ring defect)

$$f = \frac{n}{2}\,f_r\left(1 - \frac{BD}{PD}cos\,\beta\right); \tag{9}$$

BPFI - Ball Passing Frequency Inner Race (inner ring defect)

$$f = \frac{n}{2}\,f_r\left(1 + \frac{BD}{PD}cos\,\beta\right); \tag{10}$$

BSF - Ball Spin Frequency (bearing defect – of a bearing ball or a bearing roller)

$$f = \frac{PD}{2BD} f_r \left(1 - \frac{BD}{PD} cos\,\beta\right)^2 ; \tag{11}$$

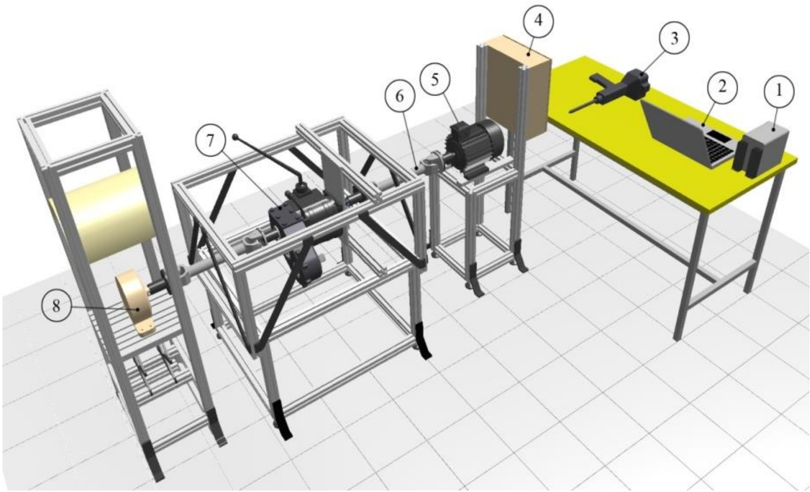
FTF - Fundamental Train Frequency (snap ring defect)

$$f = \frac{1}{2} f_r \left(1 - \frac{BD}{PD} cos\,\beta\right), \tag{12}$$

where n - the number of bearing balls or rollers; f_r - frequency given by the relative revolution (speed) of the inner and the outer ring; BP - the diameter of a bearing ball or roller; PD - pitch diameter; β - contact angle [11].

3. Experiment Description

The measurement was carried out on the laboratory stand which is shown in Fig. 1. The main parts of this stand are the frame for gripping the measured device - a gearbox of vehicle (*7*), the asynchronous motor with speed control ranging between 10 and 3000 rev/min (*5*), a cardan shaft with a flange (*6*), the MOVITRAC MCLTE B0040-5A3-4-00 frequency converter (*4*), the Ultraprobe 15000 measuring device (*3*), a notebook with software UE Spectralyzer version 4.2 (*2*), the Control unit for break AHB12 (*1*), AHB Series Compressed air cooled Hysteresis Brakes (*8*) with torque 1 – 12 Nm, speed up to 12000 rpm, kinetic power with air-cooled continuous 1800 W and max. 5 minutes 2800 W, kinetic power without air-cooled continuous 250 W and max. 5 minutes 2200 W.



1 - Control unit for break AHB12;
2 - Laptop with DEWE software;
3 - the Ultraprobe 15000 kit;
4 - Speed control panel;
5 - Electric motor;
6 - Cardan shaft;
7 - The gearbox with transfer box;
8 - Air-cooled brake AHB-12.

Fig. 1 Testing stand for acoustic and vibrating measurement – 3D model [1]

The aim of this article is to determine the predicted time (detection of potential failure), it is necessary to determine the cause of incipient failure. Only then will it be determined whether the failure occurred in a roller element, the inner, the outer ring and the cage of roller bearing or in the gear tooth. This is based on the assumption that each part listed above is of a different relative speed to the shaft and of a different frequency at which the failures occur.

4. Results and Discussion

In order to observe the change in gearing conditions, we chose the engine input speed to 2000 revolutions per minute. These input speeds cause a basic harmonic frequency of 33.3 Hz or their multiples. Another selected parameter moves to the third gear in the main gearbox and the "road" mode in the auxiliary gearbox. The mechanical gear has been regularly monitored until the third gear gears located on the main gearbox shaft have been damaged.

4.1. Calculation of Gearbox Roller Bearing Faults

In order to find out the technical condition of the main gearbox we first calculated the frequencies of single roller bearings faults using the Eqs. (9) – (12). In the gearbox there are the following roller bearings SKF6305, SKF 6208, SKF 6203, SKF3207BN, SKF6307, and SKF 6306N [1].

According to the location of roller bearings in the main gearbox, we calculated the frequencies of roller bearings faults based on single shafts revolutions, Table 1.

Table 1

Calculated values of the frequencies of roller bearings faults at input revolutions of 2000 rpm [1]

Location and specification of a roller bearing	Roller bearing revolutions [RPM]	BPFO [Hz]	BPFI [Hz]	BSF [Hz]	FTF [Hz]
SKF6208	2000	119.243	180.757	77.863	13.249
SKF3207BN	1266	77.871	112.029	49.151	8.652
SKF6307	1266	64.593	104.207	42.479	8.074
SKF6306N	938	47.736	77.331	31.182	5.967
SKF6305	938	40.253	69.180	27.505	5.750

Subsequently, the tooth frequency values in the main gearbox were calculated based on the input values already stated. When analyzing the measurement, it is necessary to focus on the gearing speeds generated by the 3rd gear, which in this case is 500 Hz from the permanent gear on the drive shaft and 421.88 Hz from the 3rd gear gearshift gear, see. Table 2. The other tooth frequencies are suppressed because the individual toothed gears, if they are in mesh, are not loaded.

Table 2

Calculated values of frequency of gearbox toothed gears depending on input revolutions

Pos.	Name of toothed gears	The number of teeth	Basic combustion engine harmonic frequency at 2000 rpm [Hz]	Tooth frequency at 2000 rpm [Hz]
1	Drive shaft and constant mesh gear	15	33.33	500
20	Constant mesh gear on line shaft	32	15.63	
19	Back gear 3rd speed gear	27	15.63	421.88
4	Driven back gear 3rd speed gear	20	21.09	

Table 3

The operating time for each speed gear of the gearbox and transfer box

Speed gear in transfer box	Operating time (%)	Speed gear in gearbox	Operating time (%)	Equation for calculation	Operating time (hour)	Operating time (km)
Overdrive	90	1	5	$t_{s1} = 0.9 \times 0.05 \times T$	162.6	7200
		2	10	$t_{s2} = 0.9 \times 0.1 \times T$	325.2	14400
		3	35	$t_{s3} = 0.9 \times 0.35 \times T$	1138.1	50400
		4	50	$t_{s4} = 0.9 \times 0.5 \times T$	1625.9	72000
Reduction	10	1	5	$t_{t1} = 0.1 \times 0.05 \times T$	18.1	800
		2	20	$t_{t2} = 0.1 \times 0.2 \times T$	73.3	3200
		3	35	$t_{t3} = 0.1 \times 0.35 \times T$	126.5	5600
		4	40	$t_{t4} = 0.1 \times 0.4 \times T$	144.5	6400
Total time (T)					3613.0	160000

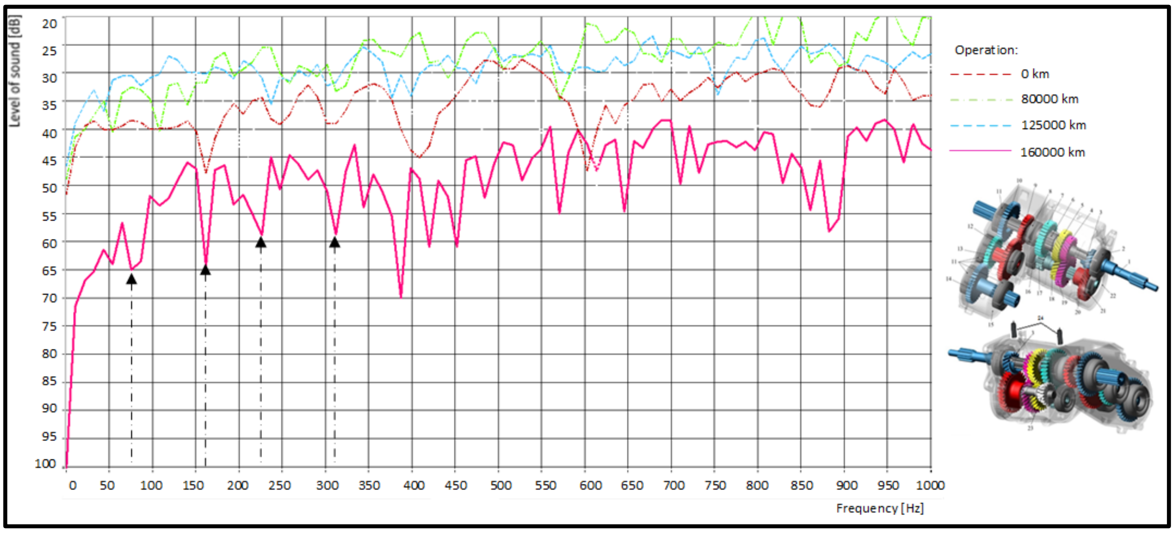


Fig. 2 Expression of the dependence of gearbox technical condition on the noise level and the frequencies calculated from FFT

Fig. 2 shows that during the operation covering 160000 km a failure on the roller elements of the SKF6208 bearing is definitely identified, see position 2. Using the formula 8 for a given bearing, a failure frequency value BSF (ball spin frequency), which is 77.86 Hz, was calculated. This value along with its other three multiples are put in Fig. 2. It also shows that the noise level changes during the mechanical gearbox operation. In the graph there are curves expressing the noise level at the beginning of the operation covering 80000 km, 125000 km, and at the end of the operation which is 160000km.

5. Conclusion

The aim of the article is to introduce the area of acoustic emission and the diagnostics of engineering systems. In our case it is a mechanical four-speed gearbox with a two-speed auxiliary gearbox. In this mechanical gearbox we focused on analysing an acoustic signal created by antifriction bearings and single gear wheels. The experiment took 3613 hours covering 160000 km which is expressed in Table 3. At the end of our experiment we identified the failure of bearing roller elements which occurred on the input shaft grip as shown in Fig. 2. Remaining bearing parts have not shown signs of excessive wear. This diagnostic method is a suitable tool for better identification of a failure in a gearbox. When using this method, it is possible to detect the beginning of wear, thereby preventing the occurrence of emergency conditions - the main aim of diagnostics. The acoustic diagnostics used is fully no-demounting and saves maintenance cost. Our aim in the future is to observe this mechanical system and determine limit values for performing a maintenance action.

Acknowledgment

Presented work has been prepared with the support of the Ministry of Defence of the Czech Republic, Partial Project for Institutional Development and Specific Research, Department of Combat and Special Vehicles, University of Defence, Brno.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Method for Determining Material Flow Variant between Distribution Warehouse and Recipient

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Abstract

The paper presents a method supporting the decision on palletizing or depalletizing shipments from the distribution warehouse to the recipient on the base of total shipment cost. The method was then used to solve four different examples. The evaluation of the results is presented and discussed in Conclusion.
KEY WORDS: *supply chain, palletization, shipping costs*

1. Introduction

The cargo palletization is used since 1930s [1]. In the last century some handbook-type publications explaining palletization were published (eg [5]), but not all issues in this area have been explained in detail. One of the most frequent problems in distribution (especially in the warehouse-to-retailer level) is: whether the palletized load units (pu) formed in the warehouse should be loaded into the freight vehicle in full (variant 1), or should be decomposed and each package of the product should be loaded separately (variant 2). The first variant saves the costs resulting from the decomposing process, while the losses result from higher transport costs (worse use of cubage and load capacity of the vehicle). In the second option, the opposite is true. The solution depends on a case and should be sought for both variants under identical conditions. The implementation costs for both options can be summarized as follows:

$$K^{I} = K^{I}_{ZP} + K^{I}_{TP} + K^{I}_{US} \text{ in variant 1, and} \tag{1}$$

$$K^{II} = K^{II}_{TP} + K^{II}_{RP} + K^{II}_{US} \text{ in variant 2,} \tag{2}$$

where K^{I} – total cost of variant 1 of shipment; K^{I}_{ZP} – cost of securing cargo for transport in variant 1 of shipment; K^{I}_{TP} – cost of moving a single palletized unit to the cargo space of the vehicle in variant 1; K^{I}_{US} – cost of using freight vehicles in variant 1; K^{II} – total cost of variant 2 of shipment; K^{II}_{TP} – cost of moving a single palletized unit to the cargo space of the vehicle in variant 2; K^{II}_{RP} – cost of decomposing palletized unit and placement packages into cargo space in variant 2; K^{II}_{US} – cost of using freight vehicles in variant 2.

Then, the indicator of shipment palletization cost-effectiveness p can be introduced:

$$p = K^{I} / K^{II}. \tag{3}$$

Palletizing shipments is profitable when $K^{I} < K^{II}$, or when $p < 1$.

The flow diagram for a process shaped in both variants with appropriate cost components is shown in Fig. 1.

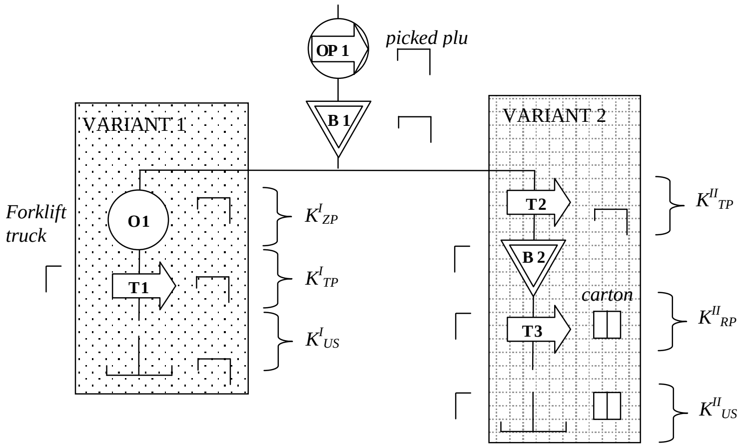

Fig. 1 Material flow diagram for two variants of shipment process in distribution warehouse

2. Research Method

2.1. The Cost of Putting a Single Palletized Unit into the Cargo Space

The cost of loading one palletized unit to the vehicle in variant 1 is calculated as follows:

$$K_{TP}^{I} = K_{LTP}^{I} + K_{UTP}^{I}; \tag{4}$$

$$K_{LTP}^{I} = R_{TP}^{I} \cdot k_{LTP}^{I}\left(1+\gamma_L\right); \tag{5}$$

$$K_{UTP}^{I} = R_{TP}^{I} \cdot k_{UTP}^{I}, \tag{6}$$

where K^I_{LTP} – cost of human work to load a single palletized unit in variant 1; K^I_{UTP} – cost of mechanized (ie. by forklift truck) work to load a single palletized unit in 1 variant; γ_L – company costs index; k^I_{LTP} – hourly rate of the employee transporting palletized units to the vehicle's cargo space [€/h]; k^I_{UTP} – cost of the working time of the device transporting palletized units to the vehicle cargo space [€/h]; labor consumption (time needed to carry out) the loading process in variant 1, wherein:

$$R_{TP}^{I} = t_{cTP}^{I} \cdot \lambda / 60 \,[\mathrm{h}] \tag{7}$$

and

$$t_{cTP}^{I} = t_{TP01}^{I} + L_{TP}^{I}\left(t_{TPvL}^{I} + t_{TPvE}^{I}\right) + \left(t_{TPo}^{I} + t_{TPk}^{I} + t_{TPiv}^{I}\right) + t_{TPT}^{I} + t_{TP02}^{I} \;[\mathrm{min}], \tag{8}$$

where λ – number of transport cycles (number of palletized units to be loaded); t^I_{cTP} – time of loading single palletized unit in variant 1 [min]; t^I_{TP01} – time of picking up palletized unit from the flor [min]; L^I_{TP} – distance of the one-way travel to load palletized unit to the cargo space of the vehicle [m], t^I_{TPvL} – time to travel 1 meter with a load [min/m]; t^I_{TPvE} – time to travel 1 meter without a load [min/m]; t^I_{TPo} – time of manual operations on palletized unit [min]; t^I_{TPk} – time of identification and control [min]; t^I_{TPiv} – time of information processing [min]; t^I_{TPT} – forklift turning time [min]; t^I_{TP02} – time of putting away pu to the ground [min].

After substituting expressions (5 - 8) to (4) and transformations, we obtained:

$$K_{TP}^{I} = \lambda\left(t_{TP01}^{I} + L_{TP}^{I}\left(t_{TPvL}^{I} + t_{TPvE}^{I}\right) + \left(t_{TPo}^{I} + t_{TPk}^{I} + t_{TPiv}^{I}\right) + t_{TPT}^{I} + t_{TP02}^{I}\right) \cdot \left(k_{LTP}^{I}\left(1+\gamma_L\right) + k_{UTP}^{I}\right) / 60. \tag{9}$$

For variant 2, the costs of transporting palletized unit to the cargo space of the vehicle are similar:

$$K_{TP}^{II} = \lambda\left(t_{TP01}^{II} + L_{TP}^{II}\left(t_{TPvL}^{II} + t_{TPvE}^{II}\right) + \left(t_{TPo}^{II} + t_{TPk}^{II} + t_{TPiv}^{II}\right) + t_{TPT}^{II} + t_{TP02}^{II}\right) \cdot \left(k_{LTP}^{II}\left(1+\gamma_L\right) + k_{UTP}^{II}\right) / 60. \tag{10}$$

The time values in formula (8) can be determined on the basis of unit time standards, as it is done in Methods-Time Measurement (MTM – see [3 - 4]), the values of γ_L and k^I_{UTP} can be determined using the method given in [2].

2.2. The Cost of Securing Palletized Units in Variant 1

The cost of securing palletized unit in variant 1 is defined as follows:

$$K_{ZP}^{I} = K_{LZP}^{I} + K_{UZP}^{I}, \tag{11}$$

where K^I_{LZP} – cost of human work to secure the palletized unit for transport; K^I_{UZP} – cost of equipment operation to secure palletized unit for transport.

Then:

$$K_{LZP}^{I} = R_{LZP}^{I} \cdot k_{LZP}^{I}(1+\gamma_L) \tag{12}$$

$$K_{UZP}^{I} = R_{UZP}^{I} \cdot k_{UZP}^{I} \tag{13}$$

where γ_L – company costs index; k^I_{LZP} – hourly rate of the employee securing palletized units for transport [€/h]; k^I_{UZP} – cost of the working time of the device securing palletized units for transport [€/h]; R^I_{LZP} – human labor consumption (time needed to carry out) of palletized unit securing [h]; R^I_{UZP} – mechanical labor consumption (time needed to carry out) of palletized unit securing [h]; wherein:

$$R_{LZP}^{I} = t_{cLZP}^{I} \cdot \lambda / 60 \,[\mathrm{h}]; \tag{14}$$

$$R_{UZP}^{I} = t_{cUZP}^{I} \cdot \lambda / 60 \,[\mathrm{h}], \tag{15}$$

where λ – number of palletized units to be loaded; t^I_{cLZP} – time of securing single palletized unit for transport by employee [min]; t^I_{cUZP} – time of securing single palletized unit for transport by mechanical device [min].

Then:

$$K^I_{ZP} = \lambda\left(\left(t^I_{cLZP} \cdot k^I_{LZP}\left(1+\gamma_L\right)\right)+\left(t^I_{cUZP} \cdot k^I_{UZP}\right)\right)/60\,. \tag{16}$$

The values of t^I_{cLZP} and t^I_{cUZP} can be determined on the basis of Methods-Time Measurement (MTM – see [3, 4]) standards, the value k^I_{UZP} can be determined using the method given in [2].

2.3. The Costs of Using Freight Vehicles in Both Variants

The cost K^I_{US} of using vehicles in 1 variant is defined as follows:

$$K^I_{US} = n^I_s \cdot K^I_s\,, \tag{17}$$

where n^I_S – number of vehicles used in first variant; K^I_S – cost of using one vehicle in variant 1.

Similarly, the cost K^{II}_{US} of using vehicles in variant 2 is defined as follows:

$$K^{II}_{US} = n^{II}_s \cdot K^{II}_s\,, \tag{18}$$

where n^{II}_S – number of vehicles used in second variant; K^{II}_S – cost of using one vehicle in variant 2.

To facilitate practical application of proposed method, the *coefficient of cargo space usage* β^I_S has been introduced for the first variant and β^{II}_S for the second variant:

$$n^I_S = \left\lceil \frac{\sum_{i=1}^{m+\lambda} l_i \cdot w_i \cdot h_i}{\beta^I_{emp} \cdot L^I \cdot W^I \cdot H^I} \right\rceil, \tag{19}$$

where L^I, W^I, H^I – length, width and height of the cargo space of the vehicle used in 1 variant; m – number of unit loads (packages) in dispatch; λ – number of pallets on which the shipment was completed; l_i, w_i, h_i – length, width and height of the i-th palletized unit, i = (1, ..., m + λ); β^I_{emp} – empirical coefficient of cargo space usage in the 1 variant, equal to the average volume of shipment divided by the sum of the cubic volume of vehicle bodies carrying out this shipment, $\beta^I_{emp} \in$ <0, ..., 1>, and:

$$n^{II}_S = \left\lceil \frac{\sum_{i=1}^{m} l_i \cdot w_i \cdot h_i}{\beta^{II}_{emp} \cdot L^{II} \cdot W^{II} \cdot H^{II}} \right\rceil, \tag{20}$$

where: L^{II}, W^{II}, H^{II} – length, width and height of the cargo space of the vehicle used in 1 variant; m – number of unit loads (packages) in dispatch; λ – number of pallets on which the shipment was completed; l_i, w_i, h_i – length, width and height of the i-th package, i = (1, ..., m + λ), β^I_{emp} – empirical coefficient of cargo space usage in the 1 variant, equal to the average volume of shipment divided by the sum of the cubic volume of vehicle bodies carrying out this shipment, $\beta^{II}_{emp} \in$<0, ..., 1>.

In practice, determining the values of $\frac{\sum_{i=1}^{m+\lambda} l_i \cdot w_i \cdot h_i}{L^I \cdot W^I \cdot H^I}$ and $\frac{\sum_{i=1}^{m} l_i \cdot w_i \cdot h_i}{L^{II} \cdot W^{II} \cdot H^{II}}$ is easiest when using a computer system supporting warehouse management.

The concept of the multiplication factor of shipment μ *was* introduced, whereby:

for variant 1:

$$\mu^I = \frac{\sum_{i=1}^{m+\lambda} l_i \cdot w_i \cdot h_i}{L^I \cdot W^I \cdot H^I}\,; \tag{21}$$

for variant 2:

$$\mu^{II} = \frac{\sum_{i=1}^{m} l_i \cdot w_i \cdot h_i}{L^{II} \cdot W^{II} \cdot H^{II}}\,. \tag{22}$$

Then, after substituting (21) and (22) to (20) and (19) and to (17) and (18), the costs of using vehicles for both variants can be given as follows:

$$K_{US}^{I} = \left\lceil \frac{\mu^{I}}{\beta_{emp}^{I}} \right\rceil \cdot K_{s}^{I} \tag{23}$$

and

$$K_{US}^{II} = \left\lceil \frac{\mu^{II}}{\beta_{emp}^{II}} \right\rceil \cdot K_{s}^{II} . \tag{24}$$

The cost of using one vehicle (K^{I}_{S} or K^{II}_{S}) can be calculated as the kilometer rate [€/km] multiplied by the number of kilometers driven on a given route.

2.4. The Cost of Decomposing Palletized Unit and Placing Packages in the Cargo Space of the Vehicle in the 2 Variant

The cost of decomposing palletized unit and placing the packages in the cargo space of the vehicle is defined as:

$$K_{RP}^{II} = R_{RP}^{II} \cdot k_{LRP}^{II} \cdot \left(1+\gamma_{L}\right); \tag{25}$$

$$R_{RP}^{II} = t_{cRP}^{II} \cdot m / 60\,[\mathrm{h}], \tag{26}$$

where k^{II}_{LRP} – hourly rate of the employee decomposing palletized unit and arranging packages in the cargo space of the vehicle; R^{II}_{RP} – labor consumption (time needed to carry out) of decomposing the palletized unit and placing packages in the cargo space of the vehicle; m – number of unit loads (packages) in dispatch; t^{II}_{cRP} – time of arranging single unit load (package) in the vehicle's cargo space [min].

Time of arranging single unit load (package) in the vehicle's cargo space is defined as follows:

$$t_{cRP}^{II} = t_{RP01}^{II} + L_{RP}^{II} \cdot \left(t_{RPvL}^{II} + t_{RPvE}^{II}\right) + \left(t_{RPo}^{II} + t_{RPk}^{II} + t_{RPiv}^{II}\right) + t_{RPT}^{II} + +t_{RP02}^{II} , \tag{27}$$

where t^{II}_{RP01} – time of picking up package from the floor [min]; L^{II}_{RP} – distance of the one-way travel to put package in the cargo space of the vehicle [m]; t^{II}_{RPvL} – time to travel 1 meter by the employee with a load [min/m]; t^{II}_{RPvE} – time to travel 1 meter by the employee without a load [min/m]; t^{II}_{RPo} – time of manual operations on packages [min]; t^{II}_{RPk} – time of identification and control [min]; t^{II}_{RPiv} – time of processing information [min]; t^{II}_{RPT} – turning time [min]; t^{II}_{RP02} – time of putting away package to the vehicle [min].

Then:

$$K_{RP}^{II} = m\left(t_{RP01}^{II} + L_{RP}^{II}\left(t_{RPvL}^{II} + t_{RPvE}^{II}\right) + \left(t_{RPo}^{II} + t_{RPk}^{II} + t_{RPiv}^{II}\right) + t_{RPT}^{II} + t_{RP02}^{II}\right) \cdot \left(k_{LRP}^{II}\left(1+\gamma_{L}\right)\right) / 60 . \tag{28}$$

Time values in formula (27) can be determined on the basis of unit time standards [2].

3. Case Study

The method of choosing the variant of shipment realization discussed in this paper was applied to the solution of four cases for λ = 48. In the first case high costs of road transport and low labor costs in the warehouse were assumed. In the second case low costs of road transport and high costs of labor in the warehouse were assumed. In the third case transport and storage costs are assumed like in case 2, but increased coefficient of cargo space usage was assumed. In the fourth case 4 cost parameters are as in case 3 and a higher dispersion of the shipment was assumed (m = 800).

Table 1

List of values of parameters identical for the investigated cases

Parameter	Value
γ_L	0.7
$k^{I}{}_{UTP} = k^{II}{}_{UTP}$ [€/h]	13.5
$\mu^{I} = \mu^{II}$	5
$\beta^{II}{}_{emp}$	0.78
$k^{I}{}_{ULP}$ [€/h]	8.16
$t^{II}{}_{RPT}$ [min]	0.018

Parameter	Value
$t^{I}{}_{cUZP} = t^{I}{}_{cLZP}$ [min]	1.5630
$t^{I}{}_{TPyL} = t^{II}{}_{TPyL}$ [m/min]	0.0113
$t^{I}{}_{TpyE} = t^{II}{}_{TpyE}$ [m/min]	0.0096
$t^{I}{}_{TPT} = t^{II}{}_{TPT}$ [min]	0.0698
$t^{I}{}_{TP02} = t^{II}{}_{TP02}$ [min]	0.4560
$t^{II}{}_{RP01} = t^{II}{}_{RP02}$ [min]	0.3300

Parameter	Value
$L^{I}{}_{TP}$ [m]	30
$L^{II}{}_{TP}$ [m]	25
$L^{II}{}_{RP}$ [m]	5
$t^{I}{}_{TP01} = t^{II}{}_{TP01}$ [min]	0.4699
$t^{II}{}_{RPyL} = t^{II}{}_{RPyE}$ [m/min]	0.0120

Table 2

List of values of parameters different for the investigated cases

No.	Parameter	Case 1	Case 2	Case 3	Case 4
1	k^{I}_{LZP} [€/h]	7.6	9.4	9.4	9.4
2	k^{I}_{LTP} [€/h]	9.2	18.4	18.4	18.4
3	β^{I}_{emp}	0.45	0.45	0.65	0.65
4	K^{I}_{S} [€]	160	145	145	145
5	k^{II}_{LTP} [€/h]	9.2	18.4	18.4	18.4
7	K^{II}_{S} [€]	160	145	145	145
8	k^{II}_{LRp} [€/h]	7.6	9.4	9.4	9.4
9	m	300	300	300	800

Values of parameters used for calculations, identical for all cases, are presented in Table 1, while in Table 2 the values of differentiated parameters for individual cases are gathered. Values of parameters appearing in formulas (1) - (28) not included in Tables 1 and 2 are 0.

Fig. 2 presents the values of the p indicator obtained using the methods described in the present paper for the parameter values from Tables 1 and 2.

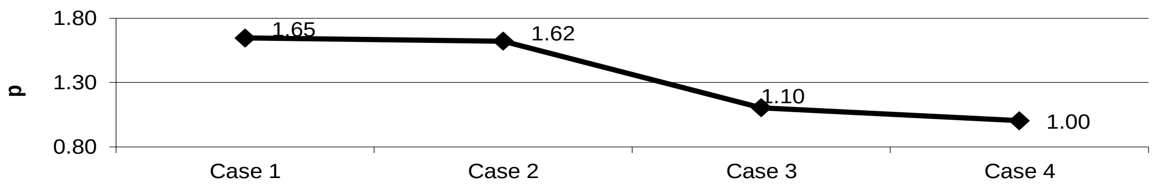

Fig. 2 The value of the i-indicator for the profitability of shipment palletizing

4. Conclusions

As can be seen from Fig. 1, in the examined cases palletizing of shipments is at the limit of cost-effectiveness (p = 1) only in the fourth case which assumes increased labor costs in the warehouse, increased use of the cargo space of vehicles, reduced transport costs and considerable dispersion of shipment.

However, the obtained results do not definitively indicate the superiority of the second variant, because in the situation of further reduction of transport costs, increased labor costs and increased dispersion of shipments in the warehouse, the palletizing of shipments will definitely become profitable. Besides, the method presented in this study does not include costs related to the increased probability of damage to cargoes and errors in variant 1. Also the number of pallets on which the shipment is completed is arbitrarily determined, which may introduce additional inaccuracies. Certainly, a formalized method of filling the pallet unit would be helpful to determine the number of pallets definitively [6 - 7].

Computer implementation of the discussed method allows for quick determination of the value of the p indicator, and consequently for a quick selection of the variant of the shipment realization.

It should therefore be stated that the method described in this study can certainly be helpful in practice when making the final decision regarding the palletizing of shipments.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Air Traffic Controller Workload Environment – ATC Communication Aspect

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Abstract

Workload inside the Air Traffic Controller (ATCO) environment consists of elements of several main areas, which cover all possible Air Traffic Control (ATC) activities. Aside from flight rules procedure tasks inside specific areas, Air Traffic flow structure and density; in particular ATC technology usage and the ATC Communications, are playing a very significant role. In order to continue in the ATCO Workload experimentation by the simulation testing with the CASS (Connective Autonomous Surveillance System), we are firstly obliged to describe precisely all elements which contribute to ATCO workload environment. The main outcome of this paper, dealing with ATCO workload, is to describe one of these elements inside the Workload area, which is the ATC Communication area.
KEY WORDS: *Workload; Air traffic controller; ATC Communication workload; ATC Human factor*

1. Introduction

Air Traffic Controller (ATCO) workload is defined by the time devoted to all activities necessary to ensure air traffic over a precisely defined period. The well- known fact is that the human factor plays a very important role in this area, which based on the specific capabilities of each individual to cope with air traffic control (ATC) issues. Between elements, with major impacts onto the ATCO workload, we can mentioned flying rules application in the designated area, the air traffic density, in the specified part of the airspace within a certain period. The same role will play ATC technologies usage and finally yet importantly, adequate communication between the pilot and the executive air traffic controller at the ATC workplace as well as the coordination with other Air traffic service units [2 - 5].

2. Workload Characteristics

The basis for assessing the workload is the categorization of the workplace of the air traffic controller and the determination of load coefficients for individual operations.

First of all, an airplane flying through a certain area must be guided by someone in order to ensure flight safety, mutual coordination with other traffic in the area and, if possible, compliance with the flight. This of course requires, on the other hand, some activities done by the ATC personnel, which is primarily direct flight control achieved through:

- air traffic monitoring;
- ensuring the necessary two-way communication;
- achieving specified flight parameters (flight level, vertical and horizontal spacing, flight speed).

Workload can be exemplified on an airplane flight through a sector where workload is associated with a routine activity, such as a two-way radio communication. If the airplane asks for a new flight level, it is necessary to monitor the beginning of the descent or climb and reaching the specified flight level. When more airplanes move in the same space and at the same time, the personnel must also monitor the space so as to avoid the risk of potential conflicts. Thus we can formulate the resulting workload (*WL*) equation as stated below:

$$WL = \omega R \times nCros + \omega Vert \times nVert + \omega Conf \times nConf \ .$$

The ωR, $\omega Vert$, $\omega Conf$ symbols represent the time of solution, alias duration of activities connected with flying through the area, altitude changes and conflict resolutions, while *nCros, nVert, nConf* symbols define the number of events associated with aircraft flying through the area, altitude changes, and conflict resolution [1]. By comparing flight plan data and information on individual flight conditions it is possible to determine the real ATC load.

The results of workload analyses of workplaces and individual positions of air traffic controllers clearly show that radiotelephonic communication is the main factor of work activity. Fig. 1 shows an example of the individual tasks, as presented in the EUROCONTROL studies about the RAMS (Re-organized ATC Mathematical Simulator) ATC simulation model that each ATC workplace must fulfill to secure its operations in a particular environment.

All these activities also result in workload, not only for R/T communication of individual positions within the unit providing direct control inside the air traffic service, or allocated airspace sectors.

3. Communication Environment Characteristics

Furthermore, in this part we will focus on the activities running in the ATC communication environment with a potential link to the workload while performing air traffic in the tactical phase of organizing and managing air traffic

flow. This phase describes the implementation of activities on the day when the flight is carried out. Gradually we will characterize the environment of mutual communication between the pilot and air traffic controller, the communication and mutual coordination in the Air traffic service workplace and the communication between the individual stations while ensuring the coordination of the air traffic services using all available technologies.

If we remain based on the Example of RAMS tasks (Fig. 1), we can characterize the following:

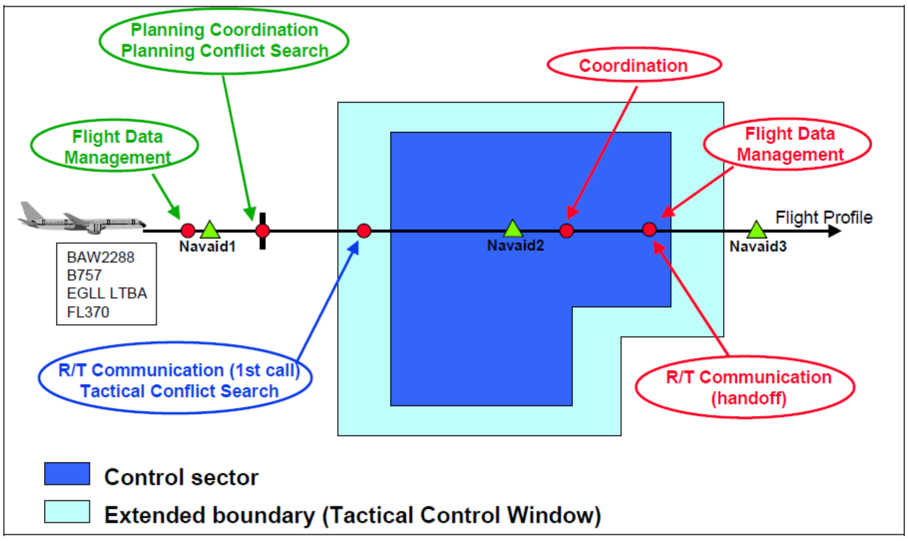

Fig. 1 Example of RAMS tasks [7]

3.1. Communication Environment of the ATC Workplace at 3 Basic Levels

• ground – air – ground communication	coordination between the ATCO and pilot;
• ground – ground communication	coordination activities inside the air traffic service (ATS) station;
• ground – ground communication	coordination of two ATS stations.

3.2. Communication Environment for Individual Activities

- Flight Data Management

The individual activities in this area will be implemented within the coordination procedures provided by the Central Flow Management Unit (CFMU), then at the ATS active station, and finally within the framework of the coordination of two neighboring ATS stations. The activity is the same for both civilian and military Air traffic service providers; the only difference is in the technological equipment of the workplace. Activities, related to this area, are aimed at informing the relevant air traffic service stations about the intended use of their subordinate part of airspace. This will be achieved by flying platforms in the amount as specified, ensuring the necessary operations for flying through the specified area, and preparing the exit environment from the designated part of the airspace for the following air traffic service (ATS) station.

In addition, if the airspace is classified as TMA or CTR, it is necessary to take into consideration, while performing Flight Data Management for a take-off or landing airport, information related to flight planning, ATC approvals and take-off information. For landing, the Airport air traffic service station is the place providing information on the specified inbound routes, landing time and, eventually, information about taxiing to the specified point or spot on the apron.

Direct flight control is not performed.

- Co-ordinations + Conflict Search

The individual activities in this area will be implemented within the coordination procedures at the ATS station (regional airport) servicing the planned flights, take-offs or landings. Another activity will rest in coordinating two or more ATS stations that participate in preparing air traffic in the specified airspace or location. The activity is the same for both civilian and military air traffic service providers; the only difference is in the technological equipment of the workplace. The coordination itself is focused on the defined flight profile (i.e. time, flight direction, altitude, speed) or its changes made to ensure safety of air traffic. This fulfills the basic condition for activities in the field of preventing conflicts in air traffic, primarily by comparing the times and altitudes of specific flights, arrivals or departures.

Direct flight control is not performed.

- R/T Communication

This area of communication environment is the most demanding in terms of workload on the air traffic controller. The activities in a civilian workplace are totally different from those in a military air traffic service unit, mainly in terms of manning, work technology and performance in individual positions. The technological equipment of

the workplace is also different. While performing these activities the main effort will be focused on the coordination at the ATS station and, above all, communication between the ATCO and pilot. Individual activities shall include information on:

- Flying into the specified airspace;
- Confirming airplane identification;
- Expected route and time of flight, take-off, landing (STAR; SID info);
- Possible changes in flight permission, level, or heading;
- Reaction to an unexpected development of air situation (emergency, technical fault);
- Exiting the specified part of airspace;
- Transfer to another service provider (neighboring ATS, another workplace within one ATS unit).

Characterized by direct air traffic control.

- Radar Tasks

Individual activities in this field include coordination of two ATS stations, and coordinating activities at one ATS station. The activity is the same for both civilian and military air traffic service providers using a radar station. The military ATS, in addition, deals with the radar control for combat use; the only difference is in the technological equipment of the workplace. The workload on the controller lies primarily in the mental assessment of the situation development in the airspace by means of his representation on the air traffic controller display unit in the ATC workplace. Individual activities will include:

- Identification of a radar sign and its association with the specific target;
- Monitoring the development of air situation in the space of interest;
- Reaction to an unexpected development of air situation (emergency, technical fault);
- Passing on the radar identity (position, altitude, flight direction) to another ATS workplace.

Direct flight control not performed.

4. Aspects of Direct Control - Radio Communication

In the framework of direct flight control, i.e. two-way ground-air communication between ATCO and PILOT, it is obvious that the workload on the human factor in terms of communication will show the highest values.

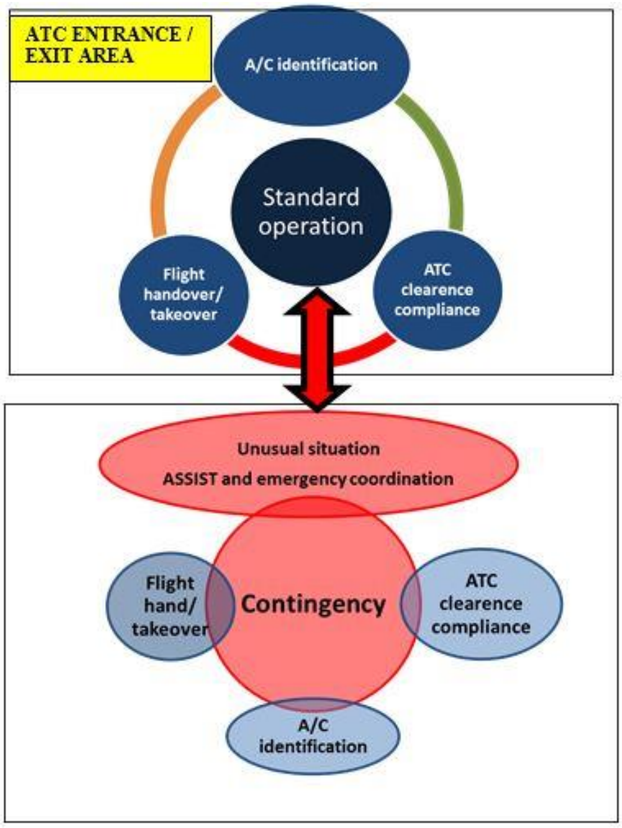

Fig. 2 ATC Control Sector Communications Cycle (MATC Kalvoda, 2018)

In addition, it will be necessary to establish all communication activities in the air traffic service station as accurately as possible. Using the model, as shown in the Fig. 1, we will define the R/T communications activities that should take place over a certain time at the air traffic services station. The main task will accomplish the ATCO – Executive Controller. His effort inside direct R/T Communication we can divided into 4 activities presented in Fig. 2.

Beside the most frequent periods of standard operation, there is a significant change of workload values in case of contingency situations. Despite the seriousness of unusual situation, fundamental change of workload values is obvious in any kind of contingency. Taking above aspects into consideration, it is highly recommended to establish corresponding percentage values as follows (Table 1).

Table 1

Example of possible Workload value estimate - Standard Operation (MATC Kalvoda, 2018)

	A/C identification entrance R/T acivities elements	Workload value	40%
STANDARD OPERATION	- Position report	++++++++	10
	- Callsign report	++++++	6
	- Squawk confirmation	+++++	5
	- Maneuvers report	++++	4
	- Flight level report	++	2
	- heading report	+	1
	ATC clearence compliance elements	**Workload value**	**30%**
	- Squawk confirmation	+++++++	12
	- Callsign report over entry/exit point	++++	8
	- Flight level report	+++	3
	- Heading confirmation	++	2
	- Destination confirmation	+	1
	Flight handover/takover elements	**Workload value**	**30%**
	- Transfer of control and frequency change	++++++++	15
	- Traffic/additional information	+++++	5
	- Transponder change	+++	3
	- Callsign change	++	2

Table 2

Example of possible Workload value estimate – Contingency (MATC Kalvoda, 2018).

	Unusual situation elements	Workload value	60%
CONTINGENCY	- Nature of emergency situation	++++++++	10
	- Fuel shortage	+++++	5
	- Communication failure	++++	5
	- Malfunction of aircraft instruments	+++	3
	- Separation instruction	++	2
	ATC clearance compliance elements	**Workload value**	**30%**
	- Squawk confirmation	+++++++	12
	- Callsign report over entry/exit point	++++	8
	- Flight level report	+++	3
	- Heading confirmation	++	2
	- Destination confirmation	+	1
	Flight handover/takover elements	**Workload value**	**30%**
	- Transfer of control and frequency change	++++++++	15
	- Traffic/additional information	+++++	5
	- Transponder change	+++	3
	- Change of callsign	++	2
	A/C identification entrance R/T activities elements	**Workload value**	**40%**
	- Squawk confirmation	++++++++	10
	- Callsign report over entry/exit point	++++++	6
	- Flight level report	+++++	5
	- Heading confirmation	++++	4
	- Destination confirmation	++	2

As mentioned above, it is necessary to take into account aspects of contingency situations. Different management of work in military, as well as procedures and nature of air traffic changes the values of the workload, especially in times of emergency. Consequently, these values could be change with respect to resolving unusual situation (Table 2).

In order to describe R/T Communication „workload value“ example for presented specific area, we have to precise activities by which the Executive controller will fulfil his task. Than in accordance with “ATC experiences assessment” we can allocate corresponding percentage of activities elements as mentioned above.

5. Datalink Military Environment - Radio Communication Example

It is a modern means of communication environment, mainly used in military for combat reasons and in remote areas in a civilian aviation too (Fig. 3). These procedures are potentially usable for air traffic services, especially in areas where the terrain is so distinctive. Surprisingly, there are many communication problems related to VFR flights operating low level in controlled airspace. Therefore, it is highly advisable to consider a implementation this procedure in order to avoid inadequate workload to pass any information. Regardless of these problems, datalink communication can greatly reduce workload values. Below, on Table 3, there are shown desire values of datalink exchange in comparison with ordinary procedures.

Table 3

Times for passing on commands via R/T communication and DATALINK [6]

Descriptions of ATC activities	R/T communi-cation time	DATALINK Estimated time	
First contact of an airplane entering the ATS station designated sector	15´´	10´´	DATALINK IS NOT APPLIED
First contact of an airplane entering another sector of the ATS station	10´´	8´´	
Aircraft pilot´s report on reaching the specific flight level	6´´	5´´	
Instruction for changing the specific SSR code	6´´	4´´	
Instruction on changing flight plan.	10´´	5´´	
Instruction on moving to another ATS station.	5´´	4´´	

The first experience with use of the data environment for the controller – pilot – controller transfer of information demonstrates that such systems can reduce the real workload placed on the ATC personnel, i.e. primarily shortening the time required to perform a specific activity. Table 1 shows an example of such activities. Here, with precisely defined activities of the controller or pilot, we have verified the ability to pass on relevant information within the data environment. In this case, the R/T phraseology of the air traffic controller are eliminated by means of data transmissions, followed by an immediate correct response to the command by the crew of the aircraft in the sector [6].

Fig. 3 On board Military Datalink example

6. Conclusion

Based on the above stated characteristics and description of the ATC communication working area, it is possible, after conducting the experiments and questionnaire surveys inside military ATC Executive Controller environment, to determine the real coefficients for each activity from the perspective of the ATC workload. This will open for us certain possibilities to describe more precisely the ATC aspect of Air Traffic Controller Workload Environment.

By using the example of Datalink exchange milieu, we can state the value of workload of R/T Communication could be reduce.

By working and searching with above- mentioned issue, statement and research results, we can support the way, how the ATC Workload R/T Communication coefficient criteria, could be considered.

Presentation of real Workload during all simulation exercises will help us to check individual level of Human performance as well as threshold of workload of military ATC Executive Controller.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

The Impact of Meteorological Conditions on the Limitations of Approach Systems at the Lech Walesa Airport in Gdansk

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Abstract

The geographical location of Lech Walesa Airport was described in relation to the country and the nearest city. Its most important elements as well as, main users have been characterized. Also, the approach systems that are located at the airport were described. The approach systems have been analyzed in terms of the manner of operation and the constraints associated with meteorological conditions for landing operations at the selected airport. Based on the collected climatic data from 2000-2016, using the graphs, atmospheric analysis related to the limitations of the approach systems of the selected airport was made. The METAR (METeorological Aerodrome Report) message has been considered in terms of the data it may contain, as well as data relevant to the development of the topic of work. Fog and RVR (Runway Visual Range) have been described in more detail, due to their impact on the operations of take-offs and landings at the Lech Walesa Airport. On the basis of the number of fog and RVR limitations published in the METAR messages from 2010-2016, charts for long-term and yearly runs were made, which were then analyzed. The limitations of the Gdansk airport compared to other six airports located in Poland were analyzed by isolines maps for the whole area of the country, based on selected METAR messages from 2010-2016. The visibility data along the runway has been compiled with the operational restrictions of all categories of the ILS (Instrument Landing System) system and the appropriateness of introducing a higher category system was estimated. It was found that at the Lech Walesa Airport the safety of performing take-off and landing operations, including landing approach systems, largely depends on the occurrence of hazardous atmospheric phenomena.
KEY WORDS: *ILS, Instrument Landing System, changeability, fog, RVR, Runway Visual Range, north-western Poland*

1. Introduction

Take-off and landing operation are stages of flight that are the most exposed to external factors that could lead to a disaster, due to the low level of their performance, which in the case of any problems with the aircraft significantly limits the crew's time capabilities, allowing to take appropriate decisions and actions, aimed at achieving a safe landing. Especially the final stage of the flight, which is an approach, requires support from appropriate systems, thanks to which the implementation of this procedure becomes less dangerous, especially in cases where visibility is significantly limited.

Lech Walesa airport is located in northern Poland (54°22’39” N, 018°27’58” E) by the Baltic Sea, 10 km from Gdansk (Fig. 1). The elevation of the airport is 489 ft. In 2015 (the latest data) 40 259 air operations were performed at the airport, which allowed to served 3 706 180 passengers and 3 414 226 kg of cargo.

Fig. 1 Location of Lech Walesa airport [3]

At this airport, approach systems such us RNAV/GNSS (Area Navigation/Global Navigation Satellite Systems), DVOR/DME (Doppler VHF Omnidirectional Range/Distance Measuring Equipment) and ILS (Instrumental Landing

System) is used, only ILS is a precision system. In the main direction (RWY 29), the airport has ILS CAT II, which allows pilots to land at a decision height between 60 m (200 ft) and 30 m (100 ft), and visibility on the runway no less than 300 m values for individual ILS categories are described in Table 1.

Table 1

Values for ILS categories [2]

ILS category	Decision height	RVR
I	≥ 60 m (200 ft)	≥550 m (visibility ≥ 800 m)
II	< 60 m (200 ft) and ≥ 30 m (100 ft)	< 550 m and ≥ 300 m
III A	< 30 m (100 ft) and ≥ 15 m (50 ft)	< 300 m and ≥ 175 m
III B	< 15 m (50 ft)	< 175 m and ≥ 50 m
III C	< 15 m (50 ft)	< 50 m

In order to estimate the magnitude of the impact of the fog on the landing operations at the airport in Gdańsk, the number of phenomena occurring at the airport described was analyzed, based on the monthly average data collected from https: // en. tutiempo.net [5]. Data for the Gdańsk airport (IATA code: GDN, ICAO code: EPGD) come from the period 2000-2016. The page shows the number of fog days, which gives only general information about its occurrence. In order to achieve greater accuracy in the occurrence of the described phenomenon, METAR messages from 2010-2016 were analyzed (over 120,000 messages), which allowed to determine the exact number of phenomena in individual months, as well as to determine in which periods of the day fog usually occur. Analysis of METAR messages also allowed to determine the RVR (Visual Visual Range) value, which allows to assess how often the conditions are worse than in the case of ILS CAT II.

2. Analysis of Visibility

The study analyzed the average visibility values for individual months in the years 2000-2016 based on meteorological data. Based on them, charts showing long-term changes were made (Figs. 2 and 3). The graphs show that the best visibility is recorded in June and July – on average it exceeds 10 km, while the worst visibility occurs in the cold period of the year (January, February, November, December) – on average around 7 km. The graphs also show that in the summer of 2002 there was a significant increase in visibility, compared to this period in the remaining years. Additionally, in winter the differences between visibility in particular years are significant, which indicates significant differences in weather conditions in this period of the year.

3. Analysis of Fog Phenomena

The study also looked at the incidence of fog in the course of the year. The research shows that on average, the fog was the slightest in June (about 3 days), and most often the fog occurred in November (about 9 days). It results from many years that the number of days with fog differs significantly from one year to another (Fig. 4). This is the effect of the geographical location of the airport – a short distance from the coast of the Baltic Sea. The influence of air masses from the sea contributes to an increase in the frequency of fogs especially in autumn and winter.

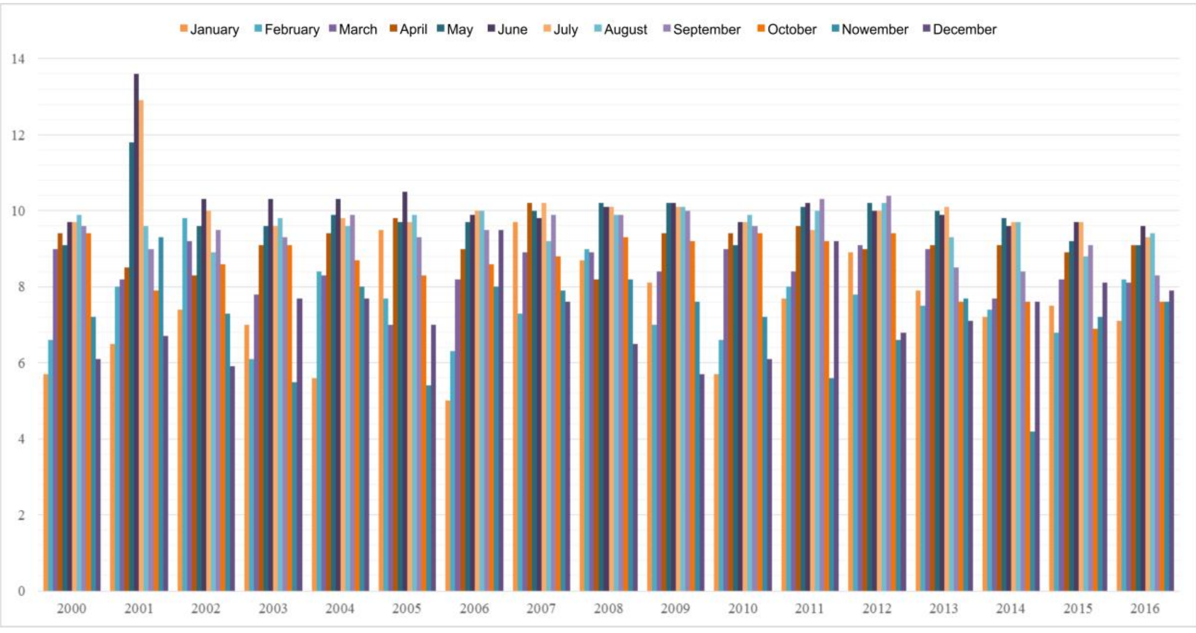


Fig. 2 Average visibility in the course of many years (2000-2016)

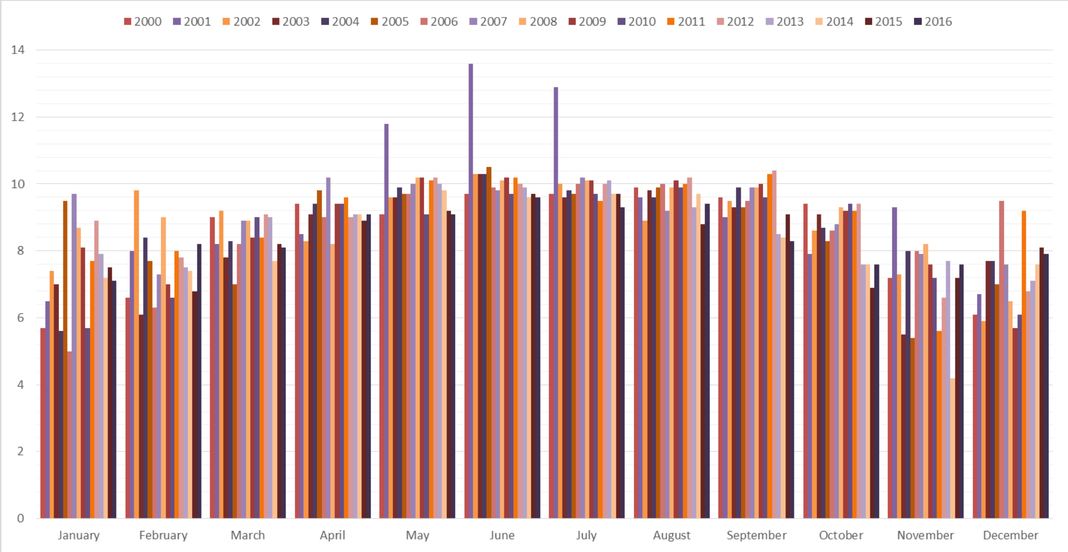


Fig. 3 Average visibility in the course of the year (2000-2016)

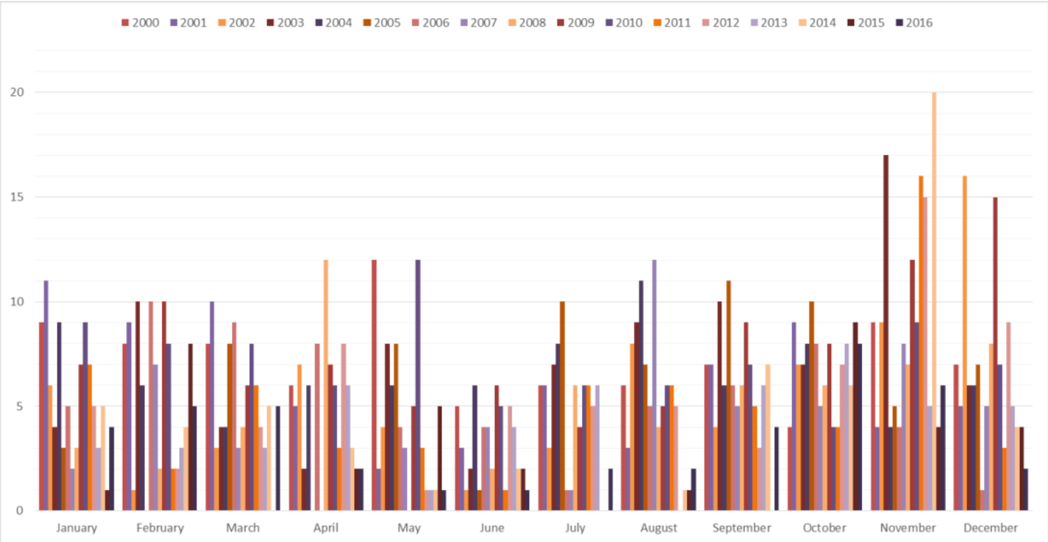


Fig. 4 Number of days with fog in the course of the year (2000-2016)

At work, for a detailed analysis, it was taken into account given the frequency of fog in METAR [4] messages in 2010-2016. The analysis shows that the phenomenon of fog was the least frequent in March and December (about 4), and most often the fog occurred in the following months: September, October and November (above 9). However, it should be taken into account that this phenomenon may last longer than one day or may occur more than once on a given day, therefore there are discrepancies in the presented data. Analysis of METAR messages also showed that in the cold months (January-March, November, December) fixed hours cannot be determined, while with the increase of ambient temperature, this phenomenon is usually recorded from 16:00 to 08:00 and in the summer months (from May to August) from 20:00 to 07:00. It is a radiation mist created as a result of strong cooling of the earth's surface at night. Radiation fog quickly disappears after sunrise as the air temperature increases. The fog can also turn into a stratus cloud. The fog can reach up to several dozen meters in height. This has a major impact on the approach of the aircraft to landing. In the fog, landing may not be possible due to insufficient decision height.

We cannot forget about the freezing fog that also reduces visibility, however, its much worse feature is the sticking to the surface of the airframe, which can disrupt the profile of the wing, as well as increase its mass, which can be very dangerous in consequence. Fortunately, the phenomenon appears extremely rarely (in the winter months on average 4 times and in the remaining ones about 1 time) and from May to September it does not occur at all.

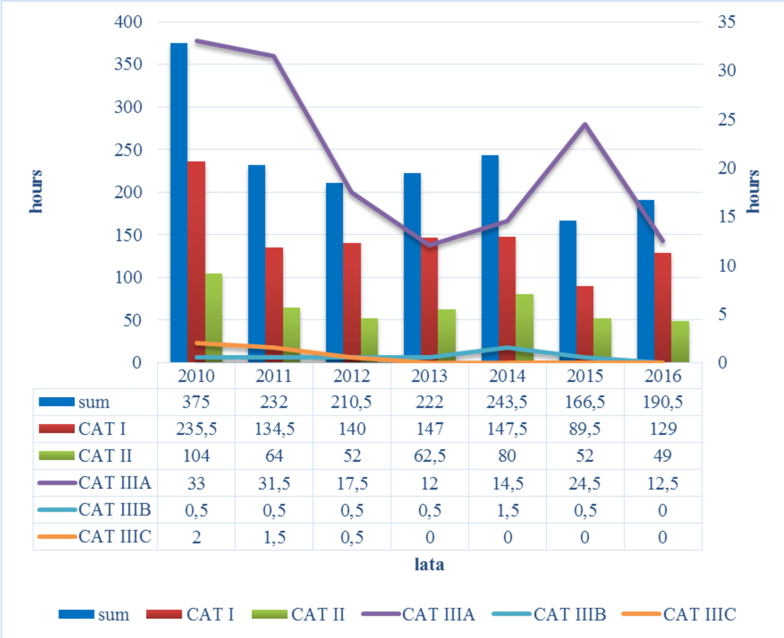
4. Analysis of RVR

In addition to atmospheric phenomena, the runway visibility (RVR) was also compiled, based on data from METAR messages from 2010 to 2016. Only the RVR given for the runway, which has the ILS system (RWY 29), was taken into consideration. Information on the RVR is given only when the runway visibility is 1500 m or less. Each year was analyzed due to the number of hours in which the RVR was reported, amounting to 1500 or less. Next, the number of hours in which there were restrictions related to RVR for individual ILS categories was determined.

Analysis of METAR messages also allowed to notice a certain dependence. The largest number of visibility

restrictions occurs in cold months (January, February, November, December). As the air temperature rises, the number of restrictions decreases and from May to September limitations appear in a small amount, mainly from midnight to morning hours. Based on the measured climatic values and data from METAR messages, one can notice a certain relationship between RVR and fog, especially in the last quarter of the year (Fig. 5).

In the graph made on the basis of the collected data, you can see that the number of hours with the RVR values in question significantly decreased after 2010. The lowest number of hours took place in 2015, but then also a large number of hours with CAT IIIA limitations was noted. As you can see, the limitation for all ILS CAT III sub-categories represents, a small percentage of the analyzed RVR restrictions, with the limitations for ILS CAT IIIB and ILS CAT IIIC being a small percentage of all restrictions (Fig. 5).



	2010	2011	2012	2013	2014	2015	2016
sum	375	232	210,5	222	243,5	166,5	190,5
CAT I	235,5	134,5	140	147	147,5	89,5	129
CAT II	104	64	52	62,5	80	52	49
CAT IIIA	33	31,5	17,5	12	14,5	24,5	12,5
CAT IIIB	0,5	0,5	0,5	0,5	1,5	0,5	0
CAT IIIC	2	1,5	0,5	0	0	0	0

Fig. 5 Number of hours with RVR for individual ILS categories (2010-2016) [1]

On an annual basis, assuming that the airport operates around the clock, 365 days a year, the RVR of 1500 m or less is, in the worst case (2010) around 4.3%, and the best (2015) around 1.9%. In all analyzed years, ILLS CAT I limits range from 54% to 68% of all RVR considered values. The number of hours with limitations for ILS CAT II is about a half lower, while the limitations for ILS CAT III constitute no more than 15% of all considered restrictions.

The number of RVR hours was compared with other six airports located in Poland (Krakow-Balice, Poznan-Lawica, Szczecin-Goleniow, Warsaw Chopin, Wroclaw-Strachowice, Rzeszow-Jesionka). The RYR values equal to or less than 1500 m for the runway, which is equipped with ILS, were taken into the calculation. In Warsaw Chopin airport, two runways were considered, as take-off and landing operations take place simultaneously from two runways. If two RVR values (range of visibility) were given in the message, a lower value was considered.

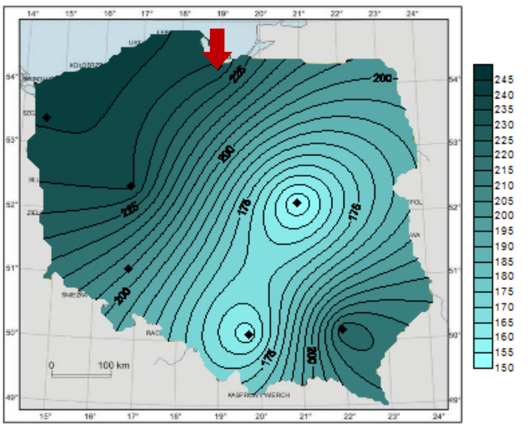


Fig. 6 Average number of hours with RVR equal to or less than 1500 m (2010-2016), [1]

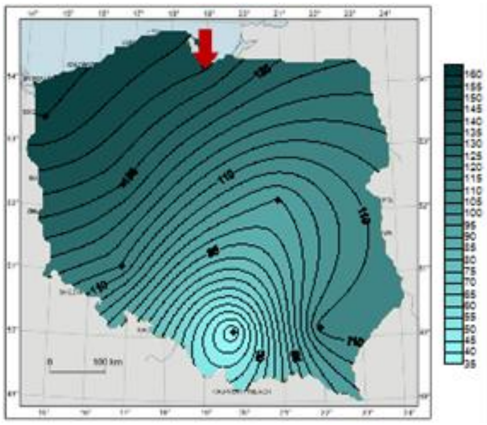


Fig. 7 Average number of hours with RVR for ILS CAT I (2010-2016), [1]

The first map contains the average number of hours in which there was an RVR equal to or less than 1500 m, in the entire analyzed period (2010-2016), (Fig. 6). It can be seen that the average number of hours of all RVR cases studied in years 2010-2016 range from 150 in Krakow and Warsaw to 245 in the vicinity of Szczecin. The next maps show the average number of hours of RVR for individual categories of operations according to ILS. The illustrated

values show that individual restrictions do not have to be related to the same extent with individual airports, e. g. at the Gdansk Lech Walesa airport, in comparison to other airports, often has limitations for ILS CAT I and ILS CAT II, while the limitations for ILS CAT IIIA, ILS CAT IIIB, and ILS CAT IIIC are more frequent at other airports located in south-western Poland (Fig. 7-11).

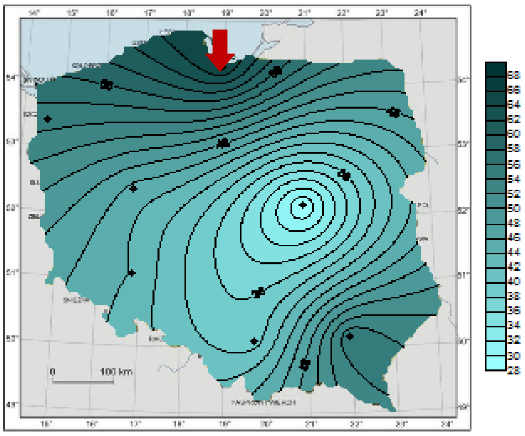


Fig. 8 Average number of hours with RVR for ILS CAT II (2010-2016), [1]

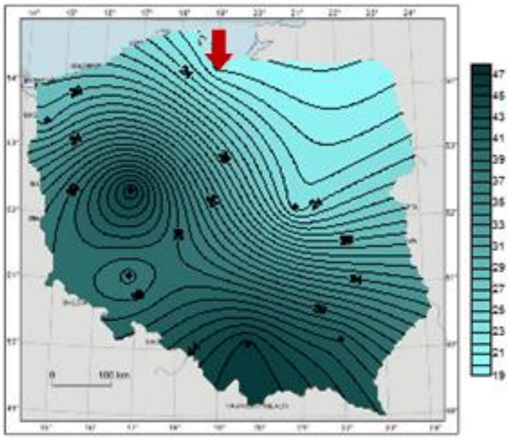


Fig. 9 Average number of hours with RVR for ILS CAT IIIA (2010-2016), [1]

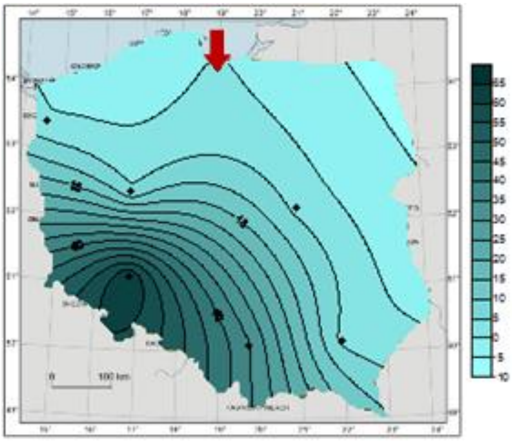


Fig. 10 Average number of hours with RVR for ILS CAT IIIB (2010-2016) [1]

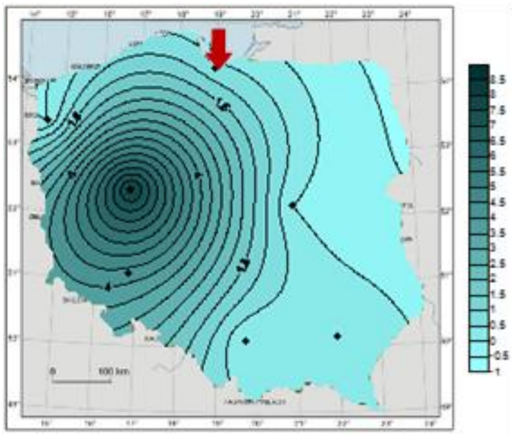


Fig. 11 Average number of hours with RVR for ILS CAT IIIC (2010-2016) [1]

5. Conclusions

On the basis of the conducted research it was possible to determine the amount of visibility limitation in the course of a year and in a multi-year course. The average visibility, about 8 km in the course of many years (in the course of an annual fluctuation from 4 km in the cold period to 10 km in the warm period of the year) allowed to make both IFR (Instrument Flight Rules) and VFR (Visual Flight Rules) flights, with the downward trend suggesting that in the coming years visibility conditions may deteriorate. The trend of occurrence of the fog phenomenon, which is decreasing, allows us to suppose that the conditions related to visibility in the next years will be much better than at the beginning of the analyzed period (2010).

The analysis of the frequency of the fog phenomenon as well as current precise approach system allowing for the second category operations would be sufficient in the flights only took place during the day. Due to significant RVR restrictions at night, especially in the cool-half year, as well as fog in the warm-half year, whose trend is increasing, which may have a great impact on visibility restrictions in the future, installation of a higher category system seems necessary if the airport further plans to develop are at a similar or higher level than at present.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Using the Self-Braking Method when the Post-Overhaul Diagnostics of Diesel-Hydraulic Locomotives

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Abstract

A large number of diesel-hydraulic locomotives are operated at industrial enterprises. Reliability of diesel locomotives in operation directly depends on the quality of the conducted acceptance testing of the hydro-transmission after repair. Test procedures presuppose running-in and testing the hydraulic transmission in all modes of its operation. Run-in time is established by normative and technical documentation. During the running-in, the technical condition of the hydraulic transmission is determined on the base of the control of input and output parameters (shafts speed, temperature and oil pressure).
The authors propose to improve the running-in process by introduction of tools and techniques of technical diagnostics. With this aim features of post-overhaul diagnostics of diesel-hydraulic locomotive were analyzed. The article deals with the diagnostics the condition of the mechanical part of the hydraulic transmission UGP (UHT- unified hydraulic transmission) 750/120 after a major overhaul. Choosing the diagnostic parameters of the mechanical part of the hydraulic transmission was carried out. We proposed to use free path (self-braking) mode to determine the mechanical losses at bench tests.
As the criteria, determining the technical state of the mechanical part of the diesel-hydraulic locomotive during the tests in the self-braking mode, the following values are proposed: run-down time of shafts; change in the braking torque and the power of mechanical losses depending on the angular velocity. Diagnostics of the hydraulic transmission according to the above criteria allows reducing the time of receive/running-in tests and significantly increasing the technical condition accuracy and characteristics of the technical condition.
KEY WORDS *diesel locomotive, hydrodynamic power transmission, diagnostics, technical condition, mechanical losses, self-braking mode, run-down mode*

1. Introduction

A large number of diesel-hydraulic locomotives are operated at industrial enterprises. Also the railways use a rolling stock, in which the hydraulic transmission is used as the main power transmission. They are diesel trains, rail buses, rail trolleys and railcars. Operational reliability of traction rolling stock directly depends on the quality of the conducted hydro-transmission receive/running-in tests of hydraulic transmission after repair. The test procedure for hydraulic transmission is established by normative documents [16]. Condition monitoring of hydraulic transmission after major overhaul presuppose running-in and testing of hydraulic transmission in all modes of its operation. Post-repair tests are carried out with the aim of running-in the hydraulic transmission nodes and verifying the compliance of technical characteristics that correspond to the values regulated by normative and technical documentation.

2. Analysis of Research and Publications

The papers of both Ukrainian and foreign scientists are devoted to improving the tests of diesel locomotives with hydraulic transmission. Almost all of them are related to optimization of diagnostic features and are aimed at increasing the level of automation of the diagnosing hydraulic transmissions, the accuracy of measuring parameters, the possibility of their analysis and long-term storage.

Typical benches are used for testing hydraulic transmissions. Principles of constructing test benches were developed in the late 70's and early 80's [7-9, 16]. At present, bench modernization provides the following directions: improving the system of drive and loading machines and mechanisms [5 - 6], increasing the energy efficiency of the testing process [2], introduction of information-measuring systems and diagnostic devices into the testing process [1, 3-4, 15].

One of the problems, which arise when testing hydraulic transmissions of diesel locomotives and other heavy vehicles in the entire range of passport loads, is the need to use special high-power equipment for the drive of input shaft. This leads to high energy consumption and increased costs for testing. The problem can be solved using energy recovery means [2]. Another way is to use mathematical and simulation models to determine the parameters of hydraulic transmissions when it operates in a range of small loads. The results of theoretical and experimental studies of determining the technical condition of hydraulic transmissions in the process of testing are presented in the works

[9-12]. According to the requirements of the normative documentation [16], efficiency of hydraulic transmission is determined during bench tests. In order to determine the technical condition of hydraulic transmission more accurately, the places where increased power losses arise are to be determined. The papers [13-14] consider the methods of indirect determination of energy losses in the hydraulic transmission nodes. One of the methods for improving bench testing of hydraulic transmissions after major overhaul is the introduction of diagnostic devices. The authors performed a number of works to improve the methods and testing means for hydraulic transmissions [1-4, 7]. Improvement involves increasing the number of control parameters and increasing the accuracy of measurements, introduction of indirect methods for determining losses in hydraulic transmission.

During the tests, the typical stand for post-repair tests of hydraulic transmission, type UHT 750-1200 is used. They are installed on the diesel locomotives TGM4, TGM6 and TGM8. Hydraulic transmission UHT 750-1200 produced by the Kaluga machine-building plant is the single-loop, three-circulating one. To transfer power in hydraulic transmission, one of the two single-stage torque converter of the type TP1000M and one hydraulic coupling, type M56 with radial blades is used alternately together with increasing the movement speed of locomotive. Pump wheels of hydraulic units receive rotation from main drive shaft through a step-up gear. The hydraulic fluid filling the hydraulic units transmits its kinetic energy to the turbine wheels, which are rigidly connected to the gear wheels of the I and II degrees. At this, the gear wheel of the II degree is located on the same shaft with the turbine wheels of the second converter and the hydraulic coupling. The hydraulic units are switched on by alternately filling with hydraulic fluid, and switched off with emptying.

The mechanical part of hydraulic transmission includes the following gears: the step-up one, transmission of the I and II degrees and reverse-mode transmission of rotation. The gear wheels of the reverse-mode and dispensing shafts are switched on in accordance with the motion direction and the operating mode of coupling. Couplings are activated by double-acting servo-cylinders through a lever system. The hydraulic and mechanical parts of the hydraulic transmission are located in a common corpus, which consists of five detachable parts, connected by screws.

In the process of running-in and testing, the drive motor simulates operation of the diesel engine. The generator, whose energy is extinguished on the water rheostat, simulates loading from the wheel sets. Separately excited DC machines are used as a drive motor and load generator. The bench makes it possible to measure the temperature and pressure of the oil in the hydraulic units, the current strength, voltage, rotation frequency of the drive motor and load generator.

The bench for testing unified hydraulic transmission of lower power of the type UHT 230 [5] produced by the specialized equipment plant "Standard" is similar in design, but less computerized one. The bench is designed to conduct acceptance testing of hydraulic transmission after its major overhaul in order to check and adjust the main technical characteristics.

For post-repair testing and running-in of hydromechanical transmission, the LLC "Scientific and Technical Center "Technical Diagnostics and Precision Measurements" created a computerized bench for diagnosing the hydrotransmission of quarry dump trucks, aircraft tow tractors, slag cars, trucks, wheel dozers Belarusian Autoworks, tractors and low power diesel locomotives [6]. Unlike the previously discussed benches, in this bench the input shaft of the hydraulic transmission is rotated by asynchronous electric motor that has feedback with the computer through a rate-of-turn transducer, which makes it possible to regulate rotation frequency of the engine programmatically in accordance with predetermined running-in modes. The parameters to be registered, such as rotational moment, rotation frequency of the input and output shafts, temperature and fluid flow in the cooling system, pressure in the oil systems of hydromechanical transmission (major road, torque converter, lubrication system, channel of blocking clutch engagement) are transmitted from sensors to a computer through an analogue-digital convertor with fixation of testing time. The main disadvantage of diagnosing hydromechanical transmission at this bench is the impossibility of loading the transmission because of the absence of loading device. Thus, the tests on this bench are limited only to the idling and running-in of hydraulic transmission units, which makes it practically impossible to obtain the necessary external characteristics.

3. Purpose

The article aims to improve the running-in tests, taking into account the features of post-repair diagnostics of hydraulic transmission of the locomotive. Also, it is aimed at selection of the criteria determining the technical condition of mechanical part of the hydraulic transmission of diesel locomotive in self-braking mode.

4. Methodology

Determining the technical condition of hydraulic transmission is a difficult task. Hydrodynamic transmission has the following types of losses: mechanical, hydraulic and power losses for own needs [8, 9]. The article deals with determination of mechanical losses in hydraulic transmission during its bench tests. The main mechanical losses occur in the following hydraulic transmission nodes:

- in bearings;
- in gear wheels;
- disc friction in the circle of circulation of hydraulic units.

One of the ways to determine the mechanical losses is the method of free path (self-braking). This method is

used to determine the mechanical losses in electric machines and other aggregates. The essence of self-braking method is to determine the negative acceleration of self-braking. Acceleration is determined either by acceleration sensors or indirectly, for example, by the chord method. When using the chord method, the time interval t during which the rotation frequency of the braking rotating part varies from the value n_1 up to n_2 is measured. The ratio of the change in rotation frequency $\Delta n = n_1 - n_2$ to the time interval t is close to the value of the rotation frequency derivative with respect to time [15].

To carry out hydraulic transmission tests (Fig. 1) in the self-braking mode, both movable couplings of reverse-mode mechanism are manually set to neutral position. When the drive motor 1 is operating, one of the hydraulic units is filled with hydraulic fluid. The turbine wheel of hydraulic unit released from connection with the output shaft is accelerated to the rotation frequency, regulated by the design of blading system of the hydraulic unit. After stabilizing the rotation frequency of turbine wheel, the power supply of drive motor 1 is turned off and emptied from the hydraulic unit. After that, the shafts of hydraulic transmission go into free path mode and the process of self-braking begins. Braking occurs solely due to internal frictional forces and fan losses in the hydraulic units. In more detail, the methodology for testing and studying the shafts movement of hydraulic transmission after stopping the diesel engine is expounded in the paper [7].

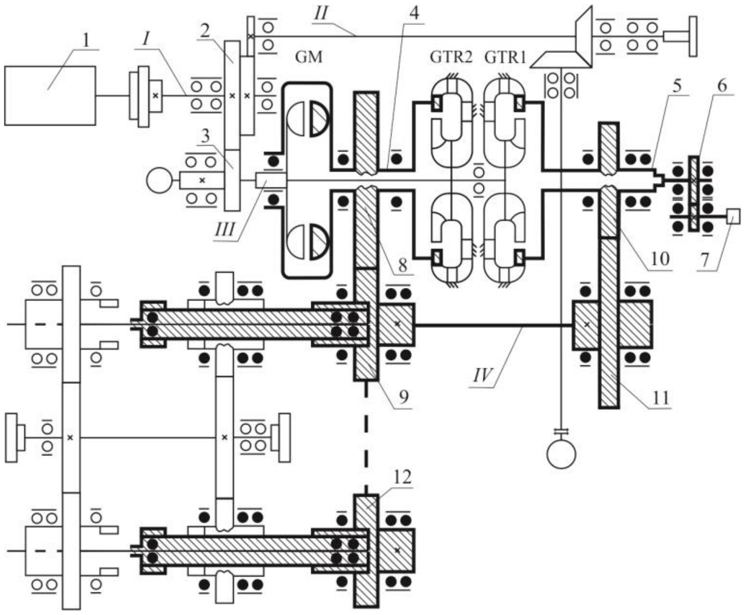

Fig. 1 Kinematic diagram for connection of hydraulic transmission UHT 750/1200 shafts: *I* – drive shaft; *II* – power-takeoff shaft; *III* – pump wheel shaft; *IV* – output shaft part; *1* – drive motor; *2* – pinion gear of correcting cogged pair; *3* – gear wheel of correcting cogged pair; *4* – turbine wheels shaft of the second degree; *5* – turbine wheels shaft of the first degree; *6* – gearhead of tachometer generator; *7* – tachometer generator; *8* – turbine shaft pinion gear of the second degree; *9* – output shaft gear wheel of the second degree; *10* – turbine shaft gear of the first degree; *11* – output shaft gear wheel of the first degree; *12* – reverse shaft gear

In general terms, when the hydraulic transmission is operating on the starting torque converter, the shaft movement equation in the neutral position of the reverse-mode reducer couplings can be represented as:

$$J_1 \frac{d\omega_1}{dt} + J_{21} \frac{d\omega_{21}}{dt} + J_{22} \frac{d\omega_{22}}{dt} + J_{31} \frac{d\omega_{31}}{dt} + J_{41} \frac{d\omega_{41}}{dt} = M_1 - M_2 - M_3 - M_4 - M_{O2} - M_{O3} - M_{O4} - M'_{Ofan}, \tag{1}$$

where J_1 – inertia of the pump wheels shaft; J_{21} – inertia of turbine wheels and shaft GTR1; J_{22} – inertia of turbine wheels and shaft GTR2 and liquid coupling; J_{31} – inertia of secondary shaft; J_{41} – inertia of reverser shaft; ω_i – angular speed of the corresponding shaft; t – time; M_1 – effective moment developed by the pump wheel; M_2 – the torque/moment consumed by the turbine wheel of the operating hydraulic unit; M_3 – torque loss in the guiding device when operating on the torque converter; M_4 – torque loss when the hydraulic fluid flows on the wheels; M_{O2} – torque loss for overcoming the mechanical resistance of turbine shafts; M_{O3} – torque loss for overcoming the mechanical resistance of the secondary shafts rotation; M_{O4} – torque loss for overcoming the mechanical resistance of the reverse shaft rotation; M'_{Ofan} – torque loss for overcoming the air resistance of turbine wheels rotation of the non-working hydraulic units (fan losses).

After disconnecting the drive motor, rotation frequency of its shaft is reduced to a full stop. In this case, rotation frequency of the power take-off shaft, the drive shaft and the pump wheels shaft is reduced, therefore, the moments M_1, M_2, M_3, M_4 are equal to zero.

Based on the kinematic diagram of the hydraulic transmission UHT 750/1200 (see Fig. 1), after the drive motor

has stopped, the turbine wheel shafts of the starting and marching torque convertor (GTR1 and GTR2) and the hydraulic coupling (HC) continue rotating under the action of inertia forces. The equation describing their movement has the following form:

$$J_{21}\frac{d\omega_{21}}{dt}+J_{22}\frac{d\omega_{22}}{dt}+J_{31}\frac{d\omega_{31}}{dt}+J_{41}\frac{d\omega_{41}}{dt}=M_{O2}+M_{O3}+M_{O4}+M'_{Ofan}. \quad (2)$$

Determining the components of the torque losses of each shaft, without disrupting the kinematic relationships between the shafts is difficult, so we will represent them as a total braking torque equal to:

$$M_b=M_{O2}+M_{O3}+M_{O4}+M'_{Ofan}. \quad (3)$$

Correspondingly:

$$J_{21}\frac{d\omega_{21}}{dt}+J_{22}\frac{d\omega_{22}}{dt}+J_{31}\frac{d\omega_{31}}{dt}+J_{41}\frac{d\omega_{41}}{dt}=M_b. \quad (4)$$

Thus, kinematic energy of the moving masses of the hydraulic transmission shafts in the free rotation mode is completely spent on overcoming frictional forces.

Expressing the angular velocity through rotation frequency $\omega=2\pi n$ and substituting (4) into equation, we obtainЖ

$$2\pi\left(J_{21}\frac{dn_{21}}{dt}+J_{22}\frac{dn_{22}}{dt}+J_{31}\frac{dn_{31}}{dt}+J_{41}\frac{dn_{41}}{dt}\right)=M_b. \quad (5)$$

To measure the rotational speed of the hydraulic transmission shafts, a modernized speed sensor [3, 15] is used. Since the speed sensor is installed on the turbine shaft GTR1, it is necessary to bring the inertia moments J_{22}, J_{31} and J_{41} to the turbine shaft of the first degree using the formula:

$$J_{red}=J_i\cdot i_{mech}, \quad (6)$$

where J_i – is inertia moment of rotating masses; i_{mech} – is gear box ratio.

Then Eq. (5) can be written in the form:

$$2\pi J_{red}\frac{dn_{red}}{dt}=M_b. \quad (7)$$

Knowing the braking torque, we determine mechanical losses P''_{mech} using the formula:

$$P''_{mech}=M_b\cdot\omega=2\pi\cdot n_{21}\cdot M_b. \quad (8)$$

Time curves of the shafts running-out obtained in this way, changes in braking torque and power of mechanical losses depending on the angular velocity and rotational speed characterize the value of mechanical losses. These relationships can be used to assess the quality of hydraulic transmission assembly.

5. Findings

To determine the dependence of the mechanical losses value in hydraulic transmission, they were tested on the modernized bench.

The curves of shafts running-out obtained as a result of testing are shown in Fig. 2.

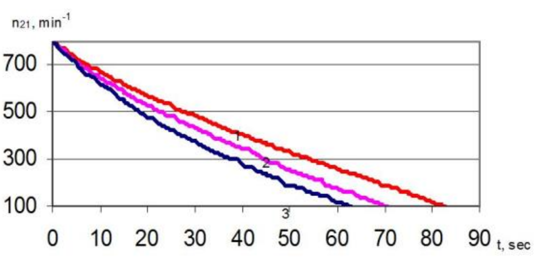

Fig. 2 Curve diagram for shafts running-out of hydraulic transmission HTU 750/202PR (mode and reverse couplings in neutral position): *1* - at the oil temperature of 51°C; *2* - at the oil temperature of 68°C; *3* - at the oil temperature of 80°C

On the basis of inertia moment values obtained as a result of investigations [7], the expression for determining the braking torque in accordance with formulas (6) and (7) can be represented in the form:

$$M_{\text{г}} = 11{,}832 \frac{dn_{21}}{dt}. \quad (9)$$

After curve transformation in Fig. 2 and expressions (8) and (9) using the chord method, the dependence of the braking torque value on the angular velocity shown in Fig. 3, and the curve of change in the power of mechanical losses – Fig. 4 were obtained.

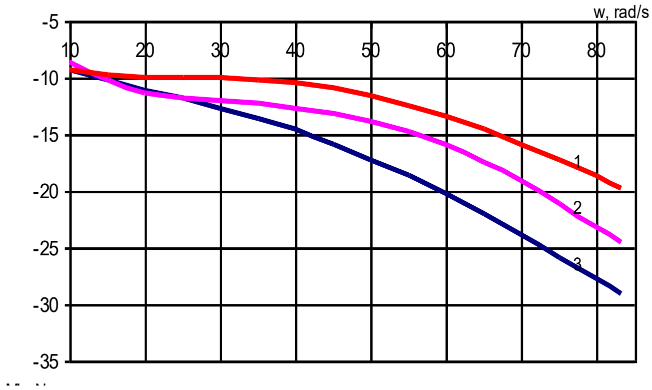

Fig. 3 Dependence graph of braking torque M_b on the angular velocity of the turbine shaft rotation: *1* - at the oil temperature of 51 C; *2* - at the oil temperature of 68 C; *3*- at the oil temperature of 80 C

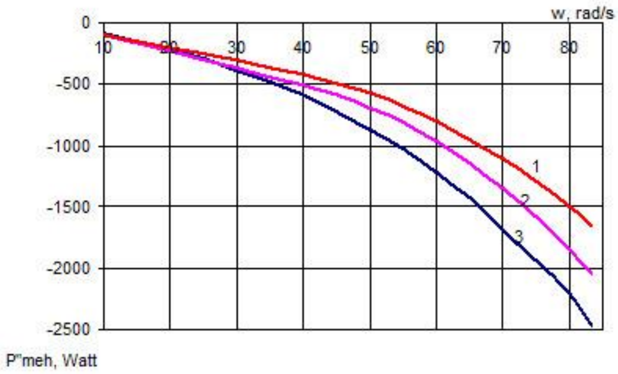

Fig. 4 Dependence graph of mechanical losses power for hydraulic transmission on the angular speed of turbine wheels: *1* - at the oil temperature of 51°C; *2* - at the oil temperature of 68 C; *3* - at the oil temperature of 80 C

6. Originality and Practical Value

As diagnostic parameters determining technical condition of mechanical part for hydraulic transmission of the locomotive when testing in the self-braking mode, we propose such parameters as the time of shaft running-out, dependence of braking torque and power of mechanical losses on the angular velocity. Diagnosis of hydraulic transmission according to the above criteria makes it possible to reduce the time of acceptance tests. The accuracy of determining the technical state of hydraulic transmission under conditions of limited or insufficient power of drive motor is also significantly improved. The obtained experimental curves can be used to estimate the value of mechanical losses in hydraulic transmission in further studies.

7. Conclusions

The methodology, which allows estimating general technical condition of mechanical part for hydraulic transmission after major repair is offered. To determine certain location and type of failure and evaluate the failures impact in hydraulic transmission units for the time of main shaft running-out, change in braking torque and the power of mechanical losses, it is necessary to carry out further experimental and theoretical studies.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

A Concept of Diagnosis of Railway Automation Systems

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Abstract

A basic functionality of railway automation systems is assuring efficient and safe rail traffic. Along with technical progress these systems have undergone a gradual evolution: from mechanical and electromechanical solutions, through transmitter ones, to computer solutions. Regardless of the constant development, as in other technical solutions, also railway traffic control systems tend to break. Because of the fact that these systems belong to safety-critical systems, they need to fulfil specific requirements concerning reliability and safety. One of the ways of fulfilling these requirements is systems diagnosis. Automatic assessment of technical condition of a railway traffic control system, the cause of this condition, its evolution and possible consequences may significantly influence improvement of its reliability and safety. In this article, the authors have presented a concept of a diagnostic system dedicated to railway automation systems. That is why an own software, based on the SNMP (Simple Network Management Protocol) technology, being a modern diagnostic system platform, has been developed. The research has been conducted for a chosen group of systems which are level-crossing protection systems. Gathered, in this manner, results, have proven a great usefulness of the SNMP standard in railway traffic control systems diagnostics; that is why the authors plan to broaden the research to other types of systems.
KEY WORDS: *diagnosis, SNMP, railway automation systems*

1. Introduction

Railway automation systems serve for assuring efficient and safe railway traffic [3, 14, 16-17]. Along with the technical progress, the railway automation systems are constantly being improved [4-5, 10]. The development process of these systems is influenced by the modern information technology, that is why the contemporary railway automation systems are computer systems [2, 15]. They allow a remote control of the railway traffic on many train service stations from one place, which is Operation Control Centre (OCC). This subject is also related to the centralization of the railway automation systems technical diagnosis in Maintenance and Diagnostics Centres (MDC). Apart from the constant technological development, there is an ongoing research concerning new diagnostic methods dedicated to railway traffic control systems. What fits into this type of research is the proposed in this article diagnostic system based on the SNMP (Simple Network Management Protocol).The research has been conducted for a chosen group of railway automation systems which are level-crossing protection systems [1, 6-7, 9, 18].

2. A Diagnostic System Dedicated to Railway Traffic Control Systems

Decisions concerning the range of repairs of railway automation devices can be made in the MDC, provided that they are equipped with modern IT systems. That is why the authors of this article have proposed using the SNMP technology, which is widely used in managing computer networks.

In the SNMP protocol one can distinguish two categories of devices: managed ones, with the SNMP agent running, and managing ones, the so called NMS (Network Management System), with the SNMP manager running [8]. The agent collects and shares information about the current status of the device, the information can be later on read or modified by the manager. Communication is based on request-response and is initiated by the manager. Additionally, there is a possibility to forward the information to the managing system without a prior request. Such messages are called traps and are sent through the agent after the occurrence of exceptional situations, e.g. failures. The UDP protocol (User Datagram Protocol) is used for the SNMP message transmission. Currently, the SNMP protocol comes in three versions, where in the versions 1 and 2c security is based on communities, which are not encrypted passwords, whereas the version 3 supports authentication and encrypted communication.

The authors of the article have assumed that every diagnosed railway automation system cooperates with a separate SNMP agent (Fig. 1). Another assumption is that the agent retrieves diagnostic data from the system with using a pre-defined for this purpose communication protocol or a system logs analysis. In the analysed case, it is the level-crossing protection system, RASP type. For each of the RASP system elements there have been developed:

– failure signatures, which are combinations of symptoms signifying breakdowns;

– failure functions, consisting in possible failure signatures.

When using the Bayes' theorem, one can calculate the probability value of failure occurrence on condition that a specific combination of symptoms is observed for each damage belonging to the failure function [13]. Calculated by the SNMP agent probability values are stored and shared upon requests coming from the SNMP manager. Additionally, the occurrence of a combination of symptoms matching the failure signature causes sending a trap to the NMS managing station, which allows informing the staff about the breakdown. Before starting servicing, one should send a request to the SNMP agent and read current probability values of the occurrence of failures described with the failure function. It will allow to shorten the time of making a correct diagnosis by choosing a failure with the highest probability rate. Additionally, the staff operating the diagnostic system receive a complete information about the symptoms (failure signatures) and all possible failures described by the failure function.

An example architecture of a diagnostic system using the SNMP technology and the presented diagnostic method for diagnosing railway traffic control systems has been presented in the Fig. 1.

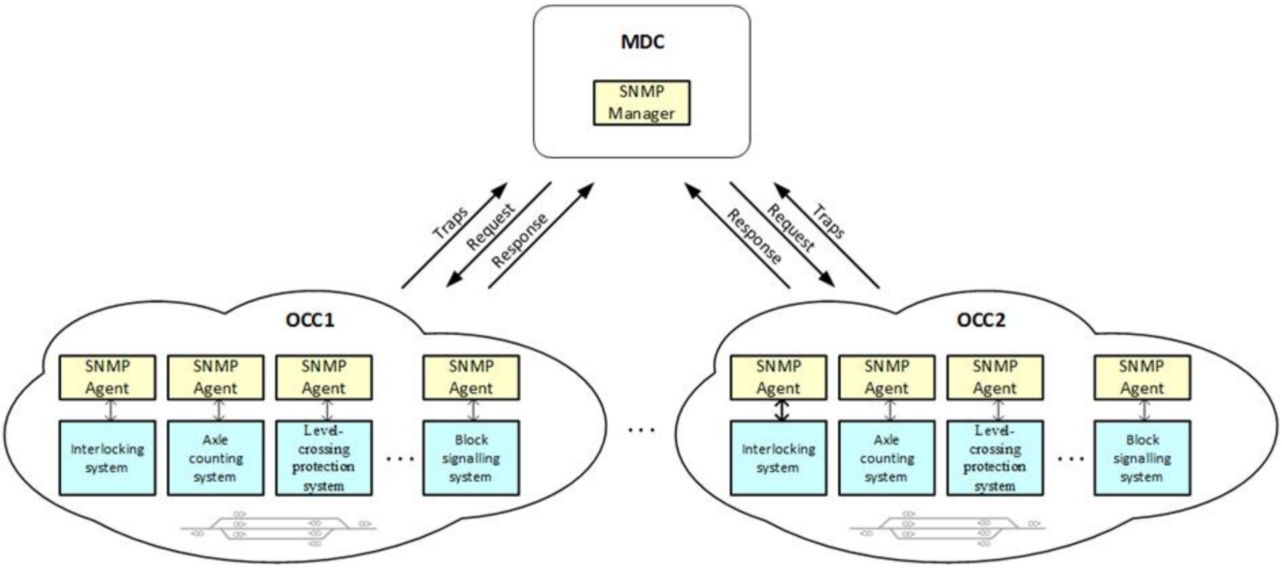

Fig. 1 Architecture of a diagnostic system dedicated to railway automation systems

Data concerning the status of the diagnosed system is stored and shared by the SNMP agent using MIB bases (Management Information Base). In order to define the structure of the MIB, the ASN.1 notation (Abstract Syntax Notation One) is used. Every object saved in the base has the object identifier, syntax and encoding rules. The objects are stored in the hierarchical structure, which is also called the tree structure. In order to get access to the object representing certain resources (diagnostic data) one needs to provide all names, separated by dots, from the root to the leaves. The names can have descriptive or numerical values, e.g. iso.org.dod.internet.private.enterprise or 1.3.6.1.4.1. ISO (International Organization for Standardization) is responsible for assigning names and numbers to nods, which ensures a unique nomenclature of the objects. An advantage of the SNMP is the ability to define new MIB bases. That is why the SNMP standard can be used in fields other than managing computer networks [11-12]. Own extensions can be added to the *private* subtree. This allows device producers to create objects supporting specific parameters of their products and ensures that these objects are seen by the managing stations. This feature was used to develop a concept of using the SNMP technology in the railway traffic control systems diagnostics with the use of the proposed diagnostic method.

In order to define the diagnosed RASP system's range of data that can be shared to the managing station by the SNMP agent, two private MIB files have been created. In the first file called "*TRAP-RASP*-MIB.mib", SNMP traps have been defined. In this case one deals with the following parameters:

– sysName, sysLocation, which are system objects, defined in RFC 1213;
– kodAwarii INTEGER type, which is a code for any errors;
– opisAwarii OCTET STRING type, which is a short description of an error.

The correctness of the MIB has been checked in the process of compilation in the "MG-SOFT MIB Browser" environment.

In the second file, "RASP-MIB.mib", variables describing the RASP system that the managing station may inquire about have been defined. Among them are:

– kategoria OCTET STRING type, category of level crossing;
– liczbarogatek INTEGER type, number of half barriers;
– liczbatorow INTEGER type, number of track lines;
– uzk INTEGER type, support the RCP (Remote Control Panel);

and the status board for each diagnosed system element. For example, for the *C*1 wheel sensor it contains the following objects:

– c1Index INTEGER type, running number;
– c1Akt INTEGER type, failure occurrence;
– c1Syg OCTET STRING type, failure signature;
– c1f1, c1f2, c1f3, c1f4, c1f5, c1f6, c1f7, c1f8, c1f9 OCTET STRING type, the probability of failure occurrence is respectively: f1, f2, f3, f4, f5, f6, f7, f8, f9.

Similarly as in the previous case, the MIB correctness has been checked by performing its compilation in the “MG-SOFT MIB Browser” environment.

3. The SNMP Agent

In accordance with the established concept, for each type of the diagnosed railway automation system it is necessary to develop software that will be the SNMP agent (Fig. 1). The first functionality of the SNMP agent which should be taken into account is the cooperation with the diagnosed railway traffic control system. Next, each of the diagnosed system element needs to be ensured detection of combinations of symptoms corresponding with failures. For every signature, on the other hand, one needs to ensure possibility of calculating probability of the occurrence of all failures included in the failure function. This data needs to be stored by the agent and shared upon the SNMP manager’s request. Another functionality of the SNMP agent is notifying the SNMP manager about every occurrence of combination of symptoms corresponding with the damage in the form of the SNMP trap. In order to confirm the assumption the authors of this article have developed an SNMP agent simulator for the RASP type system which main screen has been shown in the Fig. 2.

A difference between the operation of the simulator and a real agent consists in the necessity to manually update the “RASP state” board, in which information about failure signatures and probability of the occurrence of each failure included in the failure function are stored (Fig. 3). It results from the fact that currently the simulator does not have the function to download data from the real RASP system implemented.

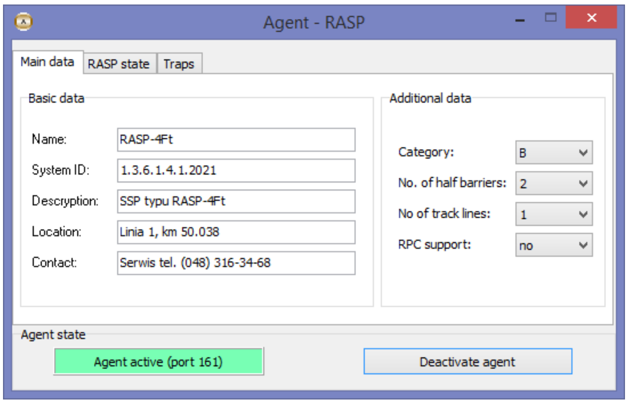

Fig. 2 The main screen of the SNMP agent simulator of the RASP system

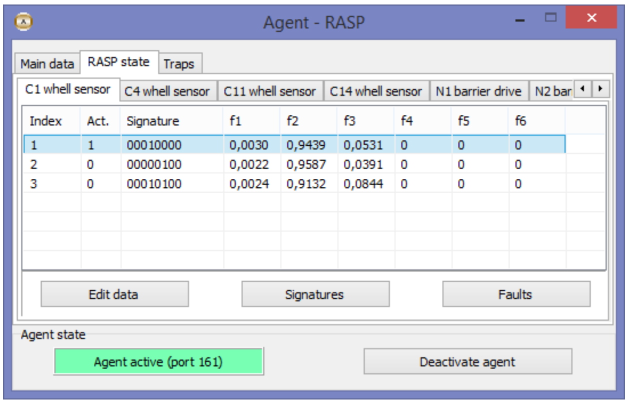

Fig. 3 An example “RASP state” board of the SNMP agent simulator of the RASP system

Data stored in the “RASP state” board are shared upon the SNMP manager’s request, localized in the MDC. For example, before starting servicing, one can send a request to the SNMP agent and read current probability values of the occurrence of failures assigned to an active signature. Thanks to this, the diagnostician not only receives complete information about the symptoms for each failure signature and about probable damages, but also suggestions which failure is most likely to occur, which will allow to shorten service time. The RASP system simulator agent allows to forward, in the form of traps, information about the damage occurrence (Fig. 4).

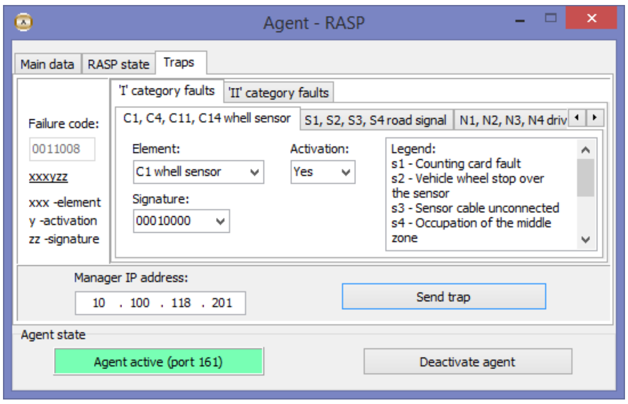

Fig. 4 The “Traps” tab of the SNMP agent simulator of the RASP system

In the trap received by the SNMP manager the following information are included: name and system location, failure code and a short failure description. The failure code consists in the element number, information about activity or inactivity of the fault and the signature number. The whole communication between the agent simulator and the SNMP manager is accomplished in accordance with the SNMP protocol, taking into account pre-defined for this purpose objects in the MIB bases.

4. The SNMP Manager

The NMS managing station uses the SNMP manager, which is a software allowing a remote diagnostics of railway traffic control systems. The cooperation between the manager and the agent requires developing MIB bases, where each type of a railway automation system has its own MIB bases. After compiling MIB files one can start the SNMP manager parametrization. The first step is scanning the network in order to detect all SNMP agents. The scanning can be conducted in the broadcast mode or in the chosen IP address ranges. As a result of the scanning, a list of active SNMP agents is obtained. After the scanning one should start creating a network map. For each device the user needs to indicate its type so that the program uses correct graphic symbols. When the symbols are put on the map, the user should combine them creating the network topology. The map editor screen with an example visualization has been presented in the Fig. 5.

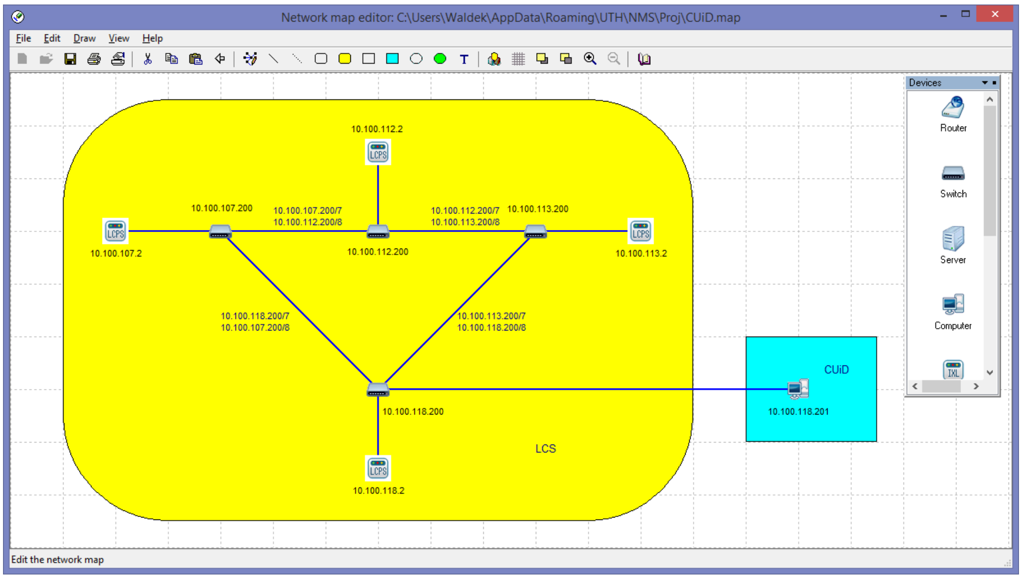

Fig. 5 The network map editor of the SNMP manager

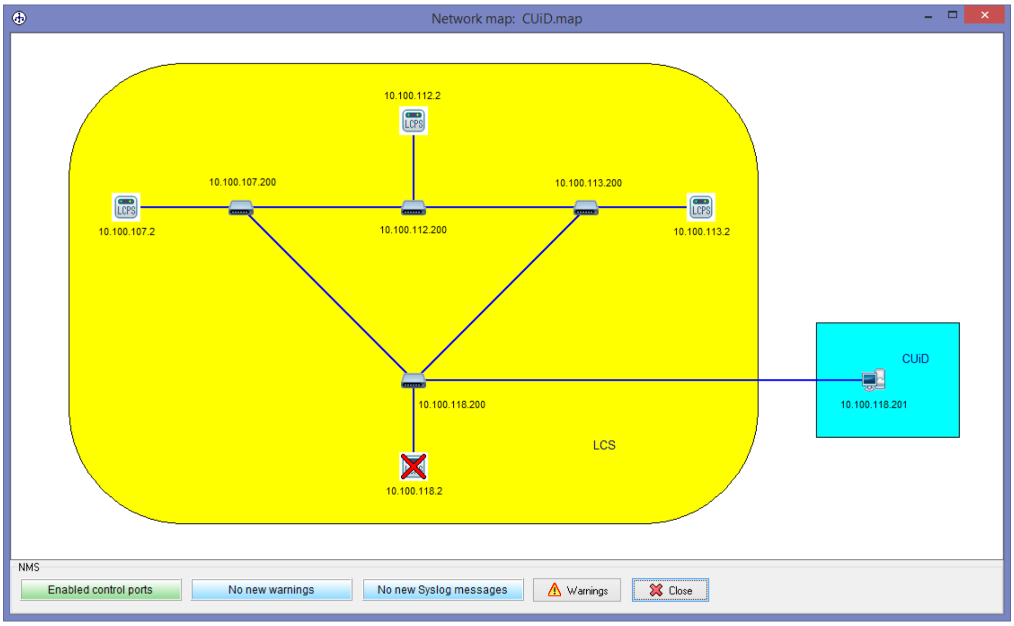

Fig. 6 An SNMP manager’s failure visualization on the network map

After saving the network map, the program is ready to automatically monitor the SNMP agents. In case of error occurrence in the controlled by the SNMP agent railway traffic control system, the agent notifies the manager in the

form of an SNMP trap. The error is then registered by the SNMP manager as a new warning. Failure occurrence is visualized on the network map in the form of the red “X” mark, which has been shown in the Fig. 6.

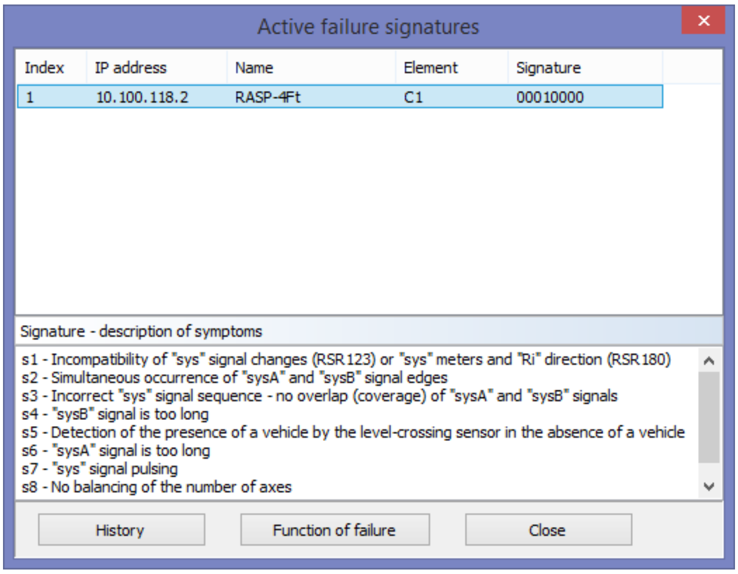

Fig. 7 An example list of active failure signatures

The user can then choose on the network map the graphic symbol of the device and, by opening the pop-up menu gain access to the list of active failure signatures (Fig. 7). By choosing the right position on the list and then the “Function of failure” option, one gets the up-to-date list of all possible failures along with their occurrence likelihood, which has been presented in the Fig. 8.

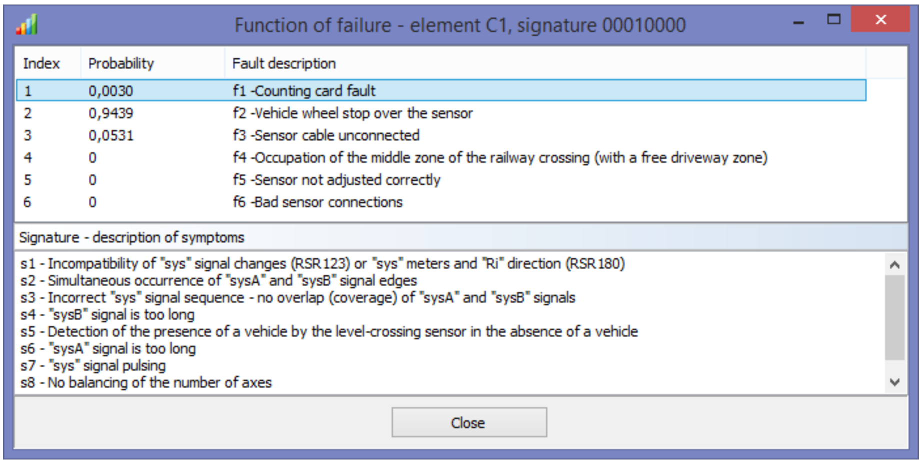

Fig. 8 An example failure of function for a chosen element and signature

The SNMP manager software also allows to notify the user about failures of the diagnosed railway automation systems in the form of emails or text messages.

5. Conclusions

Railway automation systems serve an important role in assuring safety in transporting people and cargo. That is why it is necessary for them to assure a high level of reliability, which is keeping its usability, and safety, understood as a lack of unacceptable risk. Unfortunately, despite the constant technological development, railway traffic control devices and systems tend to break. In such cases an important issue is their repair process in which a crucial role is played by the adopted diagnostic methods. Additionally, due to their purpose, the railway automation systems need to obtain the appropriate security level.

This article has presented a railway automation system diagnostic method using the Bayes’ theorem in cases of uncertain inference and the concept of using the SNMP standard in implementing this method. Verification has been conducted for a chosen group of railway traffic control systems which are level-crossing protection systems. Gathered results have motivated the authors to continue research in this matter, particularly broadening it on other types of railway automation systems.

Acknowledgment

This material is based upon work supported by National Centre for Research and Development under Grant No. PBS3/A6/29/2015 entitled „The system for maintenance data acquisition and analysis of reliability and safety of traffic control systems".

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Optimization of Railway Transition Curves For Large Circular Arc Radii

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Abstract

This article relates to the assessment of dynamical properties and the shape optimization of railway polynomial transition curves (TCs) for the large circular arc radii – 3000 m and 4000 m. The search for a proper shape means here evaluation of the curve properties based on chosen dynamical quantities and generation of a such shape with use of mathematically understood optimization methods. As a transition curve in the studies performed the authors of current work adopted polynomial of *n*-th degree, where $n = 11$. In the study one model of rail vehicle was used. The model represented 2-axle freight car of average values of parameters. The authors also used so-called standard polynomial transition curve of 11th degree and 3rd degree parabola as an initial polynomial transition curves in the optimization processes. As the quality function (evaluation criterion) the authors adopted one function concerning lateral dynamics of the vehicle. In this work the results of the optimization – the types of optimum transition curves of 11th degrees – were presented.
KEY WORDS: *railway transition curves, rail vehicle, optimization*

1. Introduction

The subject of the research done by the authors of the current work before and focusing their attention now is the assessment of the dynamical properties and shape optimisation of railway transition curves. The search for the proper shape means the evaluation of the curve properties based on chosen dynamical quantities and generation of a such shape with use of mathematically understood optimisation methods. As a transition curve in the studies performed so far the authors adopted a polynomial of *n* degree, where $n = 5 – 11$. For all degrees formulas for curve lateral co-ordinate, curvature, superelevation, and inclination of superelevation ramp as well as ranges of polynomial terms number were determined ([1-2]). Authors took into account basic and advanced boundary conditions, which the transition curve must (corresponding values of curvature and superelevation ramp in first and last point of curve) and can (tangence of curvature function and superelevation ramp function in the first and last point of curve to courses of these functions in a straight track and a circular arc) satisfy, respectively. Number of terms of the polynomial for basic condition was $n – 2$, whereas for advanced condition $n – 3$.

2. The Aim of the Work

In the context of the motivation given above, the detailed aim of this work is the optimization of railway polynomial transition curves of 11th degrees through the use of one non-traditional optimization criterion. Mentioned non-traditional assessment criterion (quality function, *QF*) concerned the lateral rail vehicle dynamics. It was as follows:

$$QF_1 = L_C^{-1} \int_0^{L_C} \left|\ddot{y}_b\right| dl \,, \tag{1}$$

where L_C – length of whole transition curve and the adjacent 100 m of circular arc; $\ddot{y}_b$ – lateral acceleration.

3. Transition Curve Assumed

The optimization problem, which was solved in the current studies aimed to find the optimum polynomial coefficients A_i, that define TC's shape. Type of a TC chosen for optimization is the polynomial TC of degree $n = 11$, as mentioned. It was defined by Eq. (2), that was related to space curve parametric equation:

$$y = \frac{1}{R}\left(\frac{A_n l^n}{l_0^{\,n-2}} + \frac{A_{n-1} l^{n-1}}{l_0^{\,n-3}} + \frac{A_{n-2} l^{n-2}}{l_0^{\,n-4}} + \frac{A_{n-3} l^{n-3}}{l_0^{\,n-5}} + ... + \frac{A_4 l^4}{l_0^{\,2}} + \frac{A_3 l^3}{l_0^{\,1}} \right), \tag{2}$$

where *y*, *R*, l_0, and *l* define curve lateral coordinate, curve minimum radius (at its end), total curve length, and curve current length, respectively. In [4] the authors presented formulas for curvature *k*, superelevation ramp *H* (being the

scaled curvature), and inclination of superelevation ramp i. The A_i are polynomial coefficients ($i = n, n-1, \dots, 4, 3$), while n is polynomial degree. Number of the polynomial terms (terms in Eq. (2)) must not be smaller than 2. Such definition of the curves gives possibility of proper k and h values at TCs terminal points. They should equal 0 in the initial point and to $1/R$ and H in the end point [1]. Note, that values for both always equal 0 for $l = 0$. In order to ensure $1/R$ and H values for length $l = l_0$, normalisation of the coefficients is necessary, such as in [4].

In all optimization processes one standard transition curve of 11th degree [2] was used as initial one:

$$y = \frac{1}{R}\left(\frac{7}{11}\frac{l^{11}}{l_0^9} - \frac{7}{2}\frac{l^{10}}{l_0^8} + \frac{15}{2}\frac{l^9}{l_0^7} - \frac{15}{2}\frac{l^8}{l_0^6} + 3\frac{l^7}{l_0^5}\right). \tag{3}$$

Additionally, the authors used 3rd degree parabola – the transition curve traditionally used in railway engineering. This curve was used by the authors only in 2 cases:

1) when standard curve appeared to be a local minimum and optimization procedure was not able to find an another solution;

2) for transition curves with lengths not greater than 100 m, if optimum curve had the curvature different than linear.

4. Vehicle Model

The scheme of the software used in optimization of TCs shape was shown in Fig. 1. The major objects within this scheme were two iteration loops visible there. The first loop was the integration loop. This loop was stopped, when distance l_{lim}, being the length of route, is reached by the model. The second one is the optimization process loop. It is stopped, when number of iterations reaches limit value i_{lim}. This value means, that i_{lim} simulations of vehicle motion have to be performed in order to stop optimization process. In the calculations done so far $i_{lim} = 100$ was used as standard value. If the optimum solution is reached earlier, i.e. for $i < i_{lim}$, then the optimization process stops automatically and the corresponding results are recorded. When no optimum solution is reached for $i_{lim} = 100$, then this value has to be increased manually, while the optimization process has to be repeated.

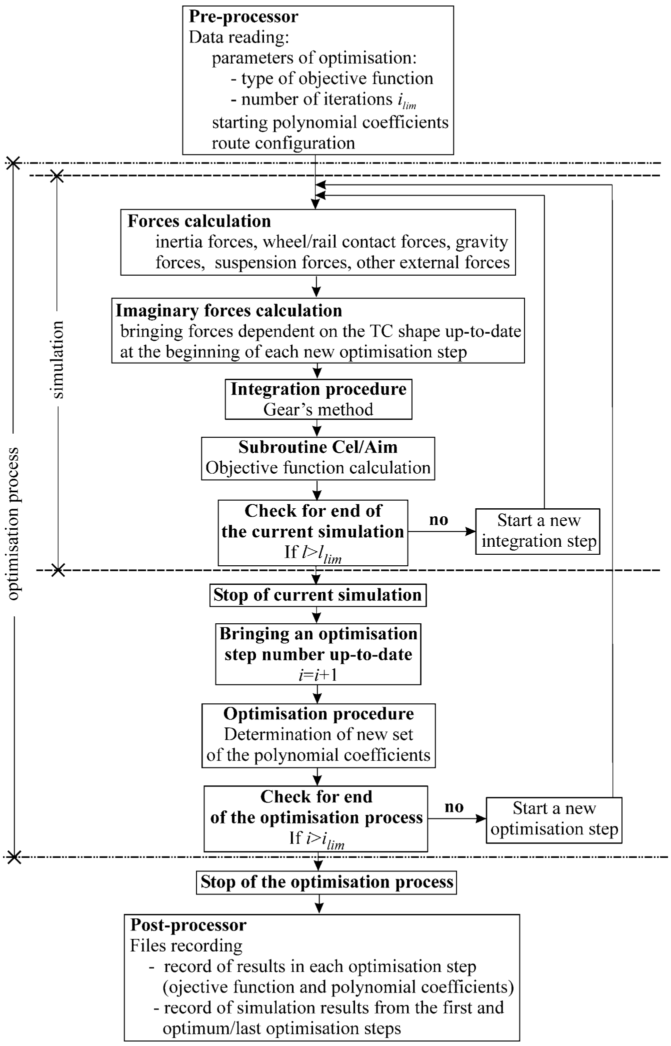

Fig. 1 The scheme of the software used

5. The Results of Optimization and Dynamical Simulations

Generally each polynomial transition curve obtained during optmization process had the curvature (and also superelevation ramp), which may be qualified to one of 5 groupes. These mentioned 5 groupes (types) of TCs are as follows:

1) type 1 – curvature (superelevation ramp) is in practice very similar to the curvature of standard TC of 11th degree;

2) type 2 – curvature (superelevation ramp) is something between standard TC of 11th degree and 3rd degree parabola,

3) type 3 – linear curvature (superelevation ramp) of 3rd degree parabola,

4) type 4 – curvature (superelevation ramp) has convex character. It has slope subtype (4a) or G_1 continuity subtype (4b) at the beginning of TC and it has slope at the end,

5) type 5 – curvature (superelevation ramp) has a concave character.

All types of the curvatures are presented in Fig. 1.

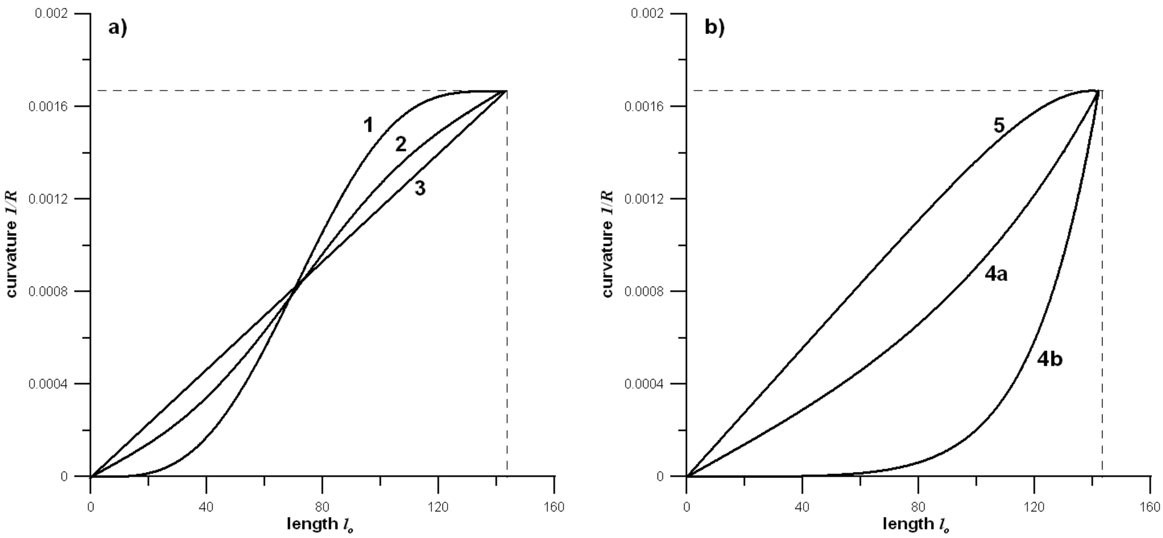

Fig. 2 Types of curvatures: a - 1, 2, 3; b - 4, 5

In Tables 1 and 2 the authors of the work presented the results of the optimization – the types of the optimum transition curves obtained in the study. The values of parameteres:

- curve radii R;
- cant H;
- TC length l_0;
- vehicle velocity v;
- lateral unbalanced acceleration in circular arc a_{lim};

applied in the optimization are presented in mentioned tables. The vehicle velocity v in majority cases were very close to 30 m/s, whereas cant H ranged between 20 mm and 135 mm. It resulted in different resultant values of a_{lim} in circular arc.

Table 1

Results of the optimization – R = 3000 m

	a_{lim}, m/s^2	v, m/s	H, mm	l_0, m	QF_1
1.	-0.6	29.10	135	172.57	3
2.	-0.3	29.40	90	116.23	3
3.	0	31.30	50	68.74	3
4.	0.15	30.66	25	33.67	3

Table 2

Results of the optimization – R = 4000 m

	a_{lim}, m/s^2	v, m/s	H, mm	l_0, m	QF_1
1.	-0.6	29.45	125	161.71	3
2.	-0.3	29.85	80	104.90	3
3.	0	30.24	35	46.49	3
4.	0.15	33.50	20	29.43	3

Going to the analysis of the types of transition curves presented in Tables 1 and 2, we see that generally program has found only one optimum shape of curve – type 3 – having linear curvature (superelevation ramp). In such case any other transition curve (due to non-linear curvature) is treated by the program as the curve, which gives greater values of *QF* assumed. Linear curvature of 3rd degree parabola, due to its nature, has no the inflection point in their middle part. The curvature of standard transition curve of 11th degree has the inflection point in central zone. The existance of a such point have bigger weight (importance) on vehicle dynamics, than the existance of G^0 continuity in terminal point of a curvature.

Fig. 3 presents dynamical characteristics - lateral accelerations of vehicle body mass centre for 11th degree. The authors used here one case for circular arc R = 4000 m and l_0 = length 29.43 m. In this case the inflection point makes the vehicle dynamics extremely sharp for the whole length of transition curve and circular arc, when we compare it with the dynamics for 3rd deegree parabola.

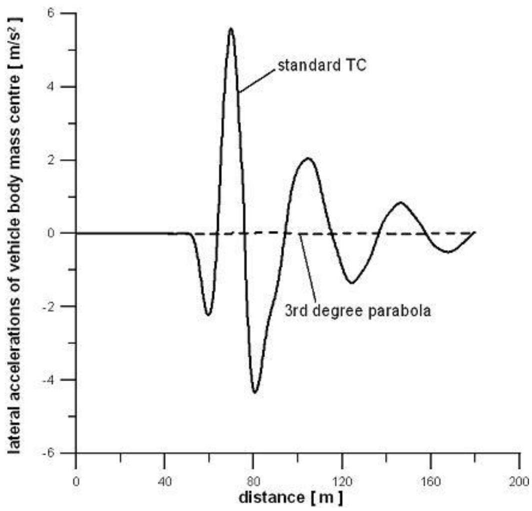

Fig. 3 Dynamical characteristics - lateral accelerations for 3rd degree parabola and standard TC of 11th degree for case: l_0 = 29.43 m, R = 4000 m

6. Conclusions

In the current study their authors showed that for different conditions of optimizations the use of criterion for assessment of the shape of the railway transition curves concerning the vehicle dynamics generally resulted in one shape of transition curve and its curvature. The adoption of more than one starting points (transition curves) in the shape optimization process enabled to, wider than before (e.g. work [3]), look at the transition curves of higher – 11th degree – in the context of their dynamical properties.

This work showed, as mentioned, that the existance of the inflection point in the middle of the curve part has bigger weight (importance) on vehicle dynamics, than the existance of G^0 continuity in terminal point of a curvature. The 3rd degree parabola is presented as the good transition curve, which can be used in the engineering practice for large circular arc radii.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Technological Process of Logistic and Transport Provision of Hospital Evacuation

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Abstract

The article mentions possible threats to the hospital, which are the reason for its evacuation. There are two basic ways of evacuation - evacuation inside the building and evacuation outside the hospital. The method of network analysis is described for processing the evacuation technological process from a logistic point of view and especially for its transport provision. Specifically, Microsoft Project software is used. In addition to a general solution, the procedure is applied to a particular hospital.
KEY WORDS: *evacuation, evacuation plan, hospital, network analysis, MS Project, patients*

1. Introduction

Evacuation is one of the basic ways of the population protection. It is a set of measures that ensure the relocation of persons, animals and things, especially from the affected areas, but also from the vulnerable areas to safe places. Evacuation plans are made for evacuation. The application of deterministic or stochastic modelling of scenarios for evacuation plans in the field of fire safety deals with [1]. From the transport point of view, evacuation planning, evacuation times and identification of critical points on the transport network are dealt with [2]. Evacuation is massive when the crowd moves. The proposal for a method to improve the evacuation of the crowd, which identifies and evaluates critical points on the transport network, deals with [3]. Human behaviour and modelling of crowd behaviour evacuation deal with [4]. Pedestrian movement behaviour and behaviour modelling in corridors is described in [5]. The capacity calculation for evacuating the station and determining the evacuation routes is given in [6]. The issue of evacuation and its modelling is dealt with consulting and SW firms. One of them is AF-CITYPLAN s.r.o. It is a VISWALK SW product, which realistically simulates and analyses pedestrian behaviour. Its use is also suitable for creating evacuation plans [7]. A complicated case of evacuation is to ensure the evacuation of people with mobility impairment. An example of this type of evacuation is solved in [8]. A specific evacuation area is therefore the evacuation of the hospital. During planning, special requirements arising from the size and character of the hospital must be taken into account. Also, the number of people who are in hospitalization, on a medical examination or on a visit. It is also necessary to come up with the number and composition of medical and other staff. As a result, there may be different procedures used to evacuate individual departments within one hospital.

Evacuation of the hospital is object-oriented in terms of structure, but it can also be a part of the area evacuation. Additionally, it may be a short-term evacuation (eg a reported explosive system) and a long-term (eg extensive fire). However, with regard to health care establishment, it must always be a managed evacuation. Evacuation of the hospital is related to logistical ensuring in providing emergency health care.

2. Possible Threats to the Hospital and an Evacuation Plan

The first for planning the evacuation is to evaluate the risk analysis (potential threats) that may occur inside the hospital or in the hospital area. Here, especially, these emergencies can occur:

- object fire;
- crash of grids and problems of backup sources (water supply, electrical wiring, gas leakage);
- finding suspicious items;
- reported explosive warning system;
- other socially violent phenomena (eg violence in the building);
- floods;
- storms and wind gusts;
- and more.

When planning the evacuation, consideration must be given to the existence of a direct dependency between the magnitude of the threat and the extent of the action to be taken. The result of planning is "Object evacuation plan".

In addition to the evacuation plan for the building are processed for the hospital:

- evacuation implementation guidelines - the task is to extend the basic evacuation system, ways of its management and safe realization at the level of middle and lower management (eg for individual hospital departments);
- written instructions on evacuation - there is a clear way to evacuate subordinate employees, how to prepare

and carry out the evacuation of selected documentation and important medical equipment.

3. Basic Types of Hospital Evacuation

At the hospital, it is necessary to distinguish whether people are evacuated inside or outside the building, or even further, outside the hospital area to another health care establishment.

Evacuation Inside the Building

This could be the case, for example, if a suspect object was found in a building. Alternatively, if it were a fire involving a minor part of the facility, and if the responsible staff (the hospital director, doctors in coordination with the intervention commander) decided that the evacuation of patients out of the building was unnecessary or if the risk of transferring patients with regard to their medical condition is higher than the risk arising from the source of the threat itself. There are two options for evacuating inside the building:

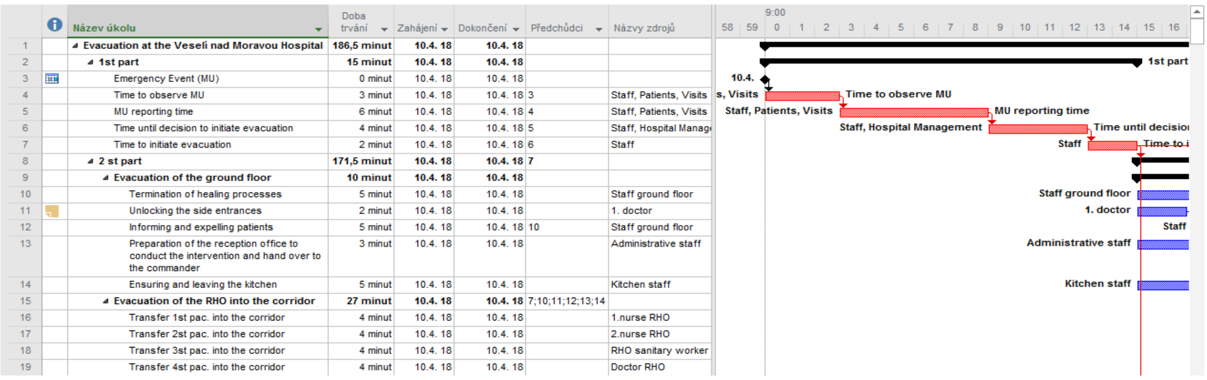
- evacuate patients within the department - the most difficult is the case for immobile patients, in addition to the devices. For these, it is necessary to ensure transport to another room or a place where there is no danger;
- evacuate patients to another department within a building.

The evacuation time inside the building can be determined by a simple relation 1.

$$t_{VE1} = t_{PR} + t_{PO} + t_{OP}, \tag{1}$$

here t_{VE1} - time of evacuation inside the building [minutes]; t_{PR} - arrival of staff to the room [minutes]; t_{PO} - removing the patient on the bed [minutes]; t_{OP} - securing the bed in the new place [minutes].

The evacuation time inside the building is linked to the pre-evacuation period, which is listed in the chapter “Evacuation outside the building”. The pre-evacuation period is determined by relation 2. Fig. 1 is marked as 1st part and in the Gantt diagram its individual steps are marked in red.



	Název úkolu	Doba trvání	Zahájení	Dokončení	Předchůdci	Názvy zdrojů
1	**Evacuation at the Veselí nad Moravou Hospital**	**186,5 minut**	**10.4. 18**	**10.4. 18**		
2	**1st part**	**15 minut**	**10.4. 18**	**10.4. 18**		
3	Emergency Event (MU)	0 minut	10.4. 18	10.4. 18		
4	Time to observe MU	3 minut	10.4. 18	10.4. 18	3	Staff, Patients, Visits
5	MU reporting time	6 minut	10.4. 18	10.4. 18	4	Staff, Patients, Visits
6	Time until decision to initiate evacuation	4 minut	10.4. 18	10.4. 18	5	Staff, Hospital Manag
7	Time to initiate evacuation	2 minut	10.4. 18	10.4. 18	6	Staff
8	**2 st part**	**171,5 minut**	**10.4. 18**	**10.4. 18**	**7**	
9	**Evacuation of the ground floor**	**10 minut**	**10.4. 18**	**10.4. 18**		
10	Termination of healing processes	5 minut	10.4. 18	10.4. 18		Staff ground floor
11	Unlocking the side entrances	2 minut	10.4. 18	10.4. 18		1. doctor
12	Informing and expelling patients	5 minut	10.4. 18	10.4. 18	10	Staff ground floor
13	Preparation of the reception office to conduct the intervention and hand over to the commander	3 minut	10.4. 18	10.4. 18		Administrative staff
14	Ensuring and leaving the kitchen	5 minut	10.4. 18	10.4. 18		Kitchen staff
15	**Evacuation of the RHO into the corridor**	**27 minut**	**10.4. 18**	**10.4. 18**	7;10;11;12;13;14	
16	Transfer 1st pac. into the corridor	4 minut	10.4. 18	10.4. 18		1.nurse RHO
17	Transfer 2st pac. into the corridor	4 minut	10.4. 18	10.4. 18		2.nurse RHO
18	Transfer 3st pac. into the corridor	4 minut	10.4. 18	10.4. 18		RHO sanitary worker
19	Transfer 4st pac. into the corridor	4 minut	10.4. 18	10.4. 18		Doctor RHO

Fig. 1 The segment of the hospital evacuation project - Pre-evacuation period in MS Project software

Evacuation Outside the Building

Evacuation outside the building involves two cases. It is only possible to evacuate people outside the building and, after passing the danger, return those persons to the department. Immediately evacuate people to other premises within the hospital area or transfer them to other health care establishments.

The evacuation can be divided into two basic parts:

- the pre-evacuation part, which is the time from the onset of an extraordinary event to the beginning of the evacuation. The duration of this section is expressed by relation 2.
- custom evacuation. It is a time from the very beginning of the evacuation to relocating the last patient to another building or another, alternative health care establishment. The duration of this section is expressed in relation 3.

$$t_{PE} = t_{VZ} + t_{ZO} + t_{OR} + t_{RZ}, \tag{2}$$

here t_{PE} – the pre-evacuation time [minutes]; t_{VZ} – the time from the occurrence of an extraordinary event to its observation [minutes]; t_{ZO} – the time from the observation of the extraordinary event to the announcement [minutes]; t_{OR} – the time from the announcement to the decision to initiate the evacuation [minutes]; t_{RZ} – the time from decision to start to the actual start of evacuation [minutes].

The size of component t_{VZ} of relation 2 can be reduced by security features (fire detectors, safety cameras) and by human factor (awareness of staff, patients, and visits).

The size of the t_{ZO} of the relation 2 affects the same elements as the first component and the availability of the means of communication and especially the knowledge of whom to inform.

The size of the t_{OR} of relation 2 depends on the capabilities, experience and resolve of managers to analyze the degree of danger.

The size of the last component of relation 2, t_{RZ}, affects the staff's readiness for these events. It can be greatly reduced by regular training and by practical exercises. Another factor is good access to evacuation plans, guidelines and written instructions, as well as marking evacuation routes.

The Evacuation

In the article will be presented the actual implementation of the evacuation for one of the most demanding procedures, namely the provision of transfer bedridden patients to another health care establishment. An even more complicated case of evacuation would be to transport patients whose basic life functions are provided by means of devices.

It is necessary to know the following basics:

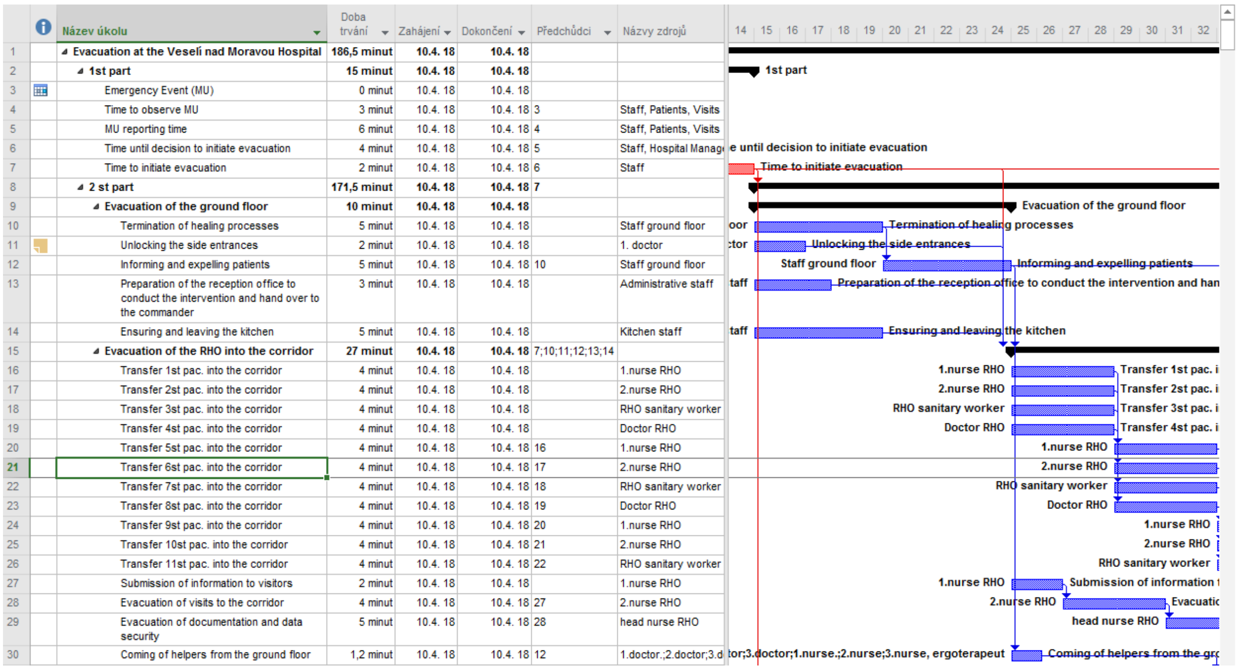
- the time of initiation evacuation that follows to the pre-evacuation period;
- the period of delivery the ambulance to the place of loading the first lying patient;
- the time of transferring the patient from the room (or the gathering place) to the ambulance;
- the time of loading the patient into the ambulance;
- distance between health care establishments;
- average speed of transport;
- the time of unloading a lying patient from an ambulance;
- the time of transporting the patient from the ambulance to the room;
- 1 ambulance transports 1 patient per bed;
- the number of ambulances available;
- the number, or the provision of ambulance drivers;
- the number of personnel to relocate patients;
- the existence (functionality) of the elevator in the building.

$$t_{VE2} = t_{PS} + t_{NS} + t_p + t_{VS} + t_{SP} + t_{JZ}\,, \tag{3}$$

here t_{VE2} – the time of evacuation outside the building [minutes]; t_{PS} – the time of transporting the patient from the room to the ambulance [minutes]; t_{NS} – the time of loading the patient into the ambulance [minutes]; t_P – the transport time from the place of loading to the place of unloading in health care establishment [minutes]; t_{VS} – the time of unloading the patient from the ambulance [minutes]; t_{SP} – the transport time of the lying patient from the ambulance to the room [minutes]; t_{JZ} – the ambulance time back [minutes].

4. Using Network Analysis to Solve the Evacuation

To solve the evacuation of the hospital, it is appropriate to use the selected network analysis method. Specifically, MS Project uses Critical Path Method (CPM). This allows you to process individual evacuation activities (partial steps), assign resources (who, what, how long will it perform), and calculate the total evacuation time with critical travel and off-road activities. The benefit is also the possibility of monitoring the use of resources (individual evacuation workers, evacuation vehicles). The evacuation of the ground floor and the rehabilitation department of the hospital is marked as 2nd part in Fig. 2 and in the Gantt diagram the steps are marked in blue.



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18	Transfer 3st pac. into the corridor	4 minut	10.4. 18	10.4. 18		RHO sanitary worker
19	Transfer 4st pac. into the corridor	4 minut	10.4. 18	10.4. 18		Doctor RHO
20	Transfer 5st pac. into the corridor	4 minut	10.4. 18	10.4. 18	16	1.nurse RHO
21	Transfer 6st pac. into the corridor	4 minut	10.4. 18	10.4. 18	17	2.nurse RHO
22	Transfer 7st pac. into the corridor	4 minut	10.4. 18	10.4. 18	18	RHO sanitary worker
23	Transfer 8st pac. into the corridor	4 minut	10.4. 18	10.4. 18	19	Doctor RHO
24	Transfer 9st pac. into the corridor	4 minut	10.4. 18	10.4. 18	20	1.nurse RHO
25	Transfer 10st pac. into the corridor	4 minut	10.4. 18	10.4. 18	21	2.nurse RHO
26	Transfer 11st pac. into the corridor	4 minut	10.4. 18	10.4. 18	22	RHO sanitary worker
27	Submission of information to visitors	2 minut	10.4. 18	10.4. 18		1.nurse RHO
28	Evacuation of visits to the corridor	4 minut	10.4. 18	10.4. 18	27	2.nurse RHO
29	Evacuation of documentation and data security	5 minut	10.4. 18	10.4. 18	28	head nurse RHO
30	Coming of helpers from the ground floor	1,2 minut	10.4. 18	10.4. 18	12	1.doctor.;2.doctor;3.d

Fig. 2 The segment of the hospital evacuation project - the evacuation of the ground floor and the rehabilitation department (RHO) in MS Project software

Evacuation Issue Questions

The basis for efficient hospital evacuation is to resolve the following issues in particular:

- How large is the range of evacuation?
- How long is the assumption of evacuation?
- Is it the evacuation without patients or with patients (able to be released from hospitalization, mobile, immobile, device connections)?
- Where to place (temporarily, permanently) evacuated patients?
- Is the medical staff able to handle the evacuation, or needs to be strengthened, and by whom?
- How to quickly train and engage non-healthcare staff (eg administrative staff) which are in place for immediate evacuation.
- How to use transport options for patients (ambulances, cars or buses)?
- How to use transport options for the transport of medical devices and equipment?

Selected Data for Evacuation

Correct compilation of hospital evacuation procedures must be preceded by the provision of the data about the evacuated building and the area through which the evacuation will take place. Important are:

- the location of the hospital;
- the number of buildings and their interconnection;
- description of buildings - number and description of the entrances and availability of keys to them, wheelchair access, lifts;
- outdoor areas and their availability;
- garages of ambulance and other vehicles, workshops, warehouses;
- plans and placement of individual departments and their characteristics (rooms, patient numbers, patient status, number of medical and support staff, equipment, etc.);
- numbers of evacuated persons and possible distribution of patients to selected substitute hospitals;
- to determine the number of evacuees, the highest possible values is necessary to be used (such as when visitors are allowed);
- a road network, especially a road network.

Establishing a Collection of Evacuation Routes and Ensuring their Passability

As a gathering place for evacuated persons, it is advisable to choose the corridors on the ground floor of a building near the exits, in case of danger of these areas use for example the car park. Care must be taken to ensure seamless access for ambulances and at least partial protection against possible adverse weather conditions.

Since evacuation is the rate of relocation, it is important to consider whether it is not advisable to make extraordinary closures on the evacuation route, or at least at selected locations, to ensure traffic management with the preference of driving ambulances.

The article presents an example of the Veselí nad Moravou hospital evacuation. From this hospital, patients can be evacuated to the Hodonín hospital. The evacuation route between the hospital Veselí nad Moravou - and the TGM Hodonín hospital is 26.5 km long (of which 23 km is the first class road I/55), see Fig. 3.

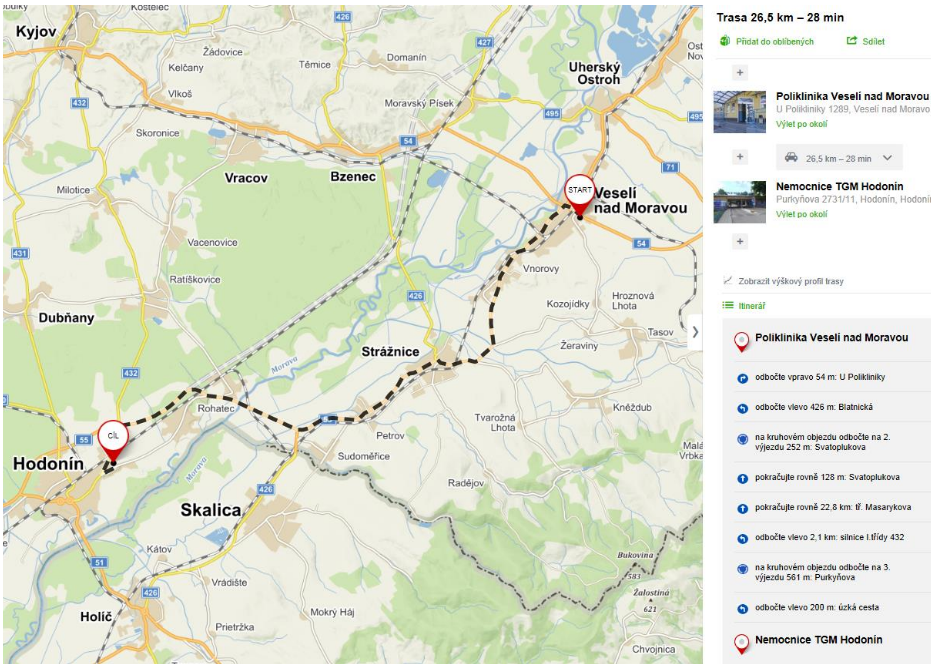

Fig. 3 Evacuation route between the hospital Veselí nad Moravou and the hospital TGM Hodonín

Determination of Type and Number of Transport Means

The type and number of vehicles will depend on the structure of evacuated people (patients and staff), selection of replacement health care establishments for each patient, the time required for their relocation to the rally, driving speed of vehicles, see Table 1, the time of transfer to an alternative health care establishments and time of vehicle turnover, see Table 2. The availability of transport means and the security of drivers will also be decisive. It is advisable to use the so-called "exit strategy" of rapid medical emergency services, including planned driving speeds, to organize the exit of ambulances with evacuated patients from the hospital.

Table 1

Travel time Veselí nad Moravou – Hodonín

Speed, kmh^{-1}	50	70	90
Driving time, minutes	32	23	18

Table 2

Turnover time Veselí nad Moravou–Hodonín (travel speed $70kmh^{-1}$)

Ambulance	Duration of action, minutes	Operation	Time, minutes	Patient	Km
1.	2	Patient loading	0 až 2,0	1.	-
	23	Route there	2,0 až 25		26,5
	2	Unloading the patient	25 až 27		-
	23	Route back	27 až 50		26,5
Sum	50	Complete turnover	0 až 50	Sum km	53,0

Driver Provision

In case of evacuation, it is necessary to have the required number of available drivers. Drivers and possibly transport managers in individual hospitals are responsible for proper coordination and provision of drivers. They will then use mobile phones to call for individual drivers.

5. Conclusion

Planning and realization of hospital evacuation is a very specific activity. This type of evacuation must take into account the special requirements arising from the size of the hospital, patient structure, medical staff and other personnel. As a result, there may be different procedures used to evacuate individual departments within a hospital, as well as different procedures in different hospitals. In the case of hospital evacuation, the evacuation must always be controlled. During the evacuation must be taken maximum respect to the health status of evacuees and to minimize evacuation time. It is advisable to use network analysis methods to determine the duration of each activity and the duration of the entire evacuation. The Microsoft Project SW can be used to solve this problem. Using it to draw up an evacuation schedule, use resources to evacuate and monitor the evacuation process, and change the duration of each activity and thus affect the overall evacuation time. This will greatly affect the time of the pre-evacuation part and especially the time of evacuation itself. The point of view is whether evacuation is inside or outside the building, or even to another health care establishment. In the case of evacuation to another health care establishment, the time of transport is significant and the longest component - the driving time. This can be shortened by selecting a suitable, above all, minimal route, regulating the traffic on this route with the preference of driving evacuation vehicles (especially ambulances).

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

RailML as a Tool for Description of Data Model in Railway Traffic Control Systems

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Abstract

RailML as one of the XML - meta-languages has been developed since 2002. This standard allows storing and exchanging data between numerous interfaces in railway systems. The current version 2.3 includes data relating to rolling stock and railway traffic management, timetables, passenger information as well as booking and selling tickets. In the upcoming version of standard, RailML 3, the interlocking subschema will be included to the RailML schema. In addition, the compliance with the object-oriented railway infrastructure data model defined in the UIC IRS 30100 (RailTopoModel, RTM) will be ensured. In the article, the authors discuss the current state of the RailML standard and its prospects. Special attention is payed to the new subschema in RailML3, which is interlocking subschema. The authors also present their own software that allows to work with RailML files.
KEY WORDS: *RailML, XML, interlocking, data exchange standards, railway IT systems*

1. Introduction

Modern railway systems commonly use information technologies [9, 14]. Although the barriers do not exist, there is still very limited number of standards in the field of data storage and exchange. It causes that system and device manufacturers implement their own solutions. This results in difficulties in the cooperation of systems from different manufacturers and requires the development of numerous interfaces [1, 4-5, 10, 11, 16]. The authors of the International Railway Standard 30100 (IRS 30100, RailTopoModel) are going to change this situation [4, 7, 18]. In the aforementioned standard, they described the topology and structure of numerous railway elements and systems in the form of UML diagrams [19]. The first practical implementation of this standard is RailML 3.1 [15, 17], which usage allows to solve many problems in the field of data storage and exchange. The previous versions of RailML allowed railway IT systems to exchange data relating to rolling stock and railway traffic management, timetables, passenger information as well as booking and selling tickets. The <interlocking> subschema is the new element of RailML, that is used to describe railway interlocking and signalling systems. In this paper, the authors using the proprietary RailML Editor software have prepared some exemplary RailML files. These files describe selected aspects of interlocking and signaling systems for a simple railway station (Fig. 2). The examples show the manner of defining the selected dependencies and signals.

2. XML and RailML

RailML (Railway Markup Language) is open standard which is being developed since 2002, initially by a group of researchers from German Fraunhofer Institute for Transportation Systems and Infrastructure in Dresden and the Swiss Federal Institute of Technology's Institute for Transportation Planning and Systems [4-5]. As a software tool aimed to solve the problem of data exchange between railway system interfaces by unifying their structures, it takes into account modern data standards used in information technologies - above all XML (Extensible Markup Language) [4 - 5, 12, 13] - another open standard, which was designed by W3C consortium (World Wide Web Consortium) and is widely used as a meta-language describing data and allowing to design and implement various XML applications. The examples of such applications include: RSS, MathML, SVG, as well as RailML. XML Schema Definition was used to define the mechanism of the language namespace, which ensures verification of the correctness of documents and the possibilities of their extension while maintaining backward compatibility. This definition specifies also the number of child element, data types and default values for elements and attributes [5]. Through features of the XML language that are inherited by all its applications, in RailML data is stored and its structure is described at the same time, which is extremely effective. A 2.3 version published in 2016 is the latest production version. The publication of the RailML 3.1 version which will consider the RailTopoModel standard developed under the auspices of UIC is scheduled on 2018, November [4, 17-18].

As with other XML documents, the hierarchical tree structure is used to define the contents of a RailML document, in which the <railml> tag is the root. It is the parent of all internal elements that can hierarchically contain

sub-elements (children). Each element can contain predefined attributes to provide a more detailed description. In the developers preview version of RailML 3.1, the root can contain four groups of sub-elements: <infrastructure>, <rollingstock>, <timetable>, and <interlocking>. Each of them defines their sub-elements and their attributes. For example, the subschema <interlocking> contains among others the following elements [2-3, 8, 17]: <signals>, <signal>, <signalAspects>, <signalAspectGroups>, <aspectSpeedDependencies>, <aspectSpeedDependency>, <routeGroups>, <routeGroup>, <routes>, <start>, <target>, <segments>, <elements>, <element>, <trackSection>, <derailerRef>, <levelCrossingRef>, <switchRef>, <switch>, <levelcrossingRef>, <levelcrossing>, <trainDetectorRef>, <trackCircuitBorder>, <flankProtection> , <flankElements>, <routePriority>, <interfaces>, <interface>.

3. RailML File Editor

To carry out the activities being considered in this paper, the authors have built their own software, RailML File Editor (Fig. 1). This software tool enables convenient viewing, editing and saving of RailML (.xml) and XML Schema Definition (.xsd) files. The files export to HTML, Rich Text Format (.rtf) as well as Adobe Portable Document Format (.pdf) is also possible. Convenient viewing of XML Schema files allows to present the document in the tree form and in case of selection of the schema element its attributes and values are shown. In the edit mode, the RailML editor colours the syntax of the document, and enables the validation of both RailML documents and XSD schemas.

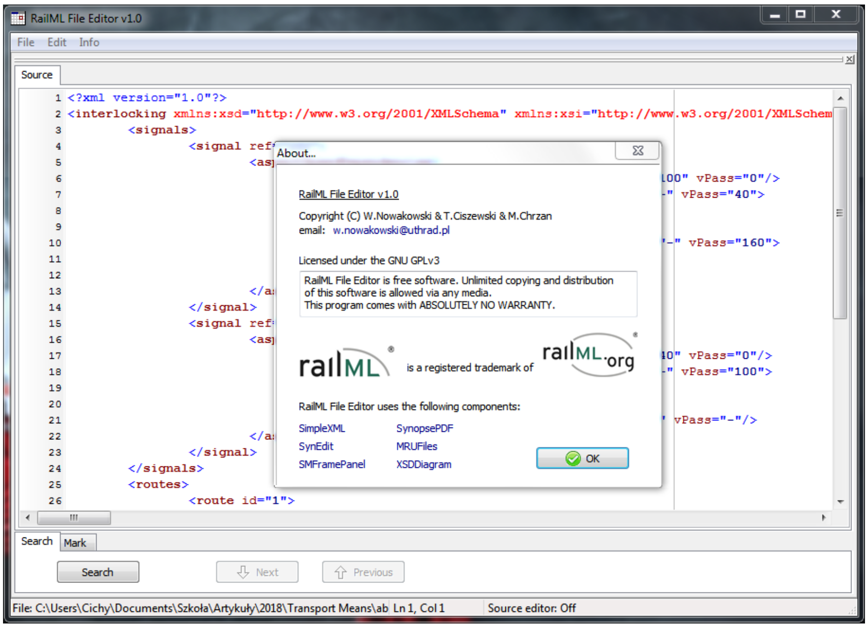


Fig. 1 RailML File Editor main window

While editing the XML Schema Definition documents, the software enables cooperation with an open source program XSDDiagram [6], which is used for graphical visualization of document structures. The built-in proprietary software is still intensively developed and has been used by the authors to prepare all RailML documents that will be presented later in this paper.

4. Interlocking

Safe movement of the train and rail vehicles is carried out using railway traffic control systems. An important group of these systems are interlocking and signalling systems that control the movement at individual signal boxes or signalling centres. Contemporary railway traffic control, interlocking and signalling systems are implemented in computer technology, that is why in the further considerations the system will mean the appropriate computer controlled system.

The railways have adopted the principle of dividing the railway network into block sections and equipping them with signalling devices, informing the engine driver of the possibility of further driving. This section is called the signal spacing distance and together with the sighting distance and overlap distance are the parts of the route (headway distance). Determining the routes at each station is very important for the railway traffic control process. The division into routes should ensure as many possible train movements as possible at the same time. If the train movements cannot take place simultaneously, it is said that are conflicting routes. This is usually the case when part of routes are overlapped or crossed. The elements of the route are usually track sections and switches, on which the rail vehicle moves as well as signalling devices. Thus, the route is understood as a set of ordered states of railway traffic control devices, in which should be the devices that control and lock the route. The railway traffic control systems, which are used for route activation, are called interlocking and signalling systems. They are responsible for meeting the following safety conditions:

- conflicting routes should be locked;
- track must be clear and not occupied or on fault state;
- route must be locked;
- all points and level crossings on track must be set and locked properly and appropriately;
- flank protection should be provided;
- other (related to block signalling, level crossing protection, etc.).

The fulfilment of these conditions is required to display the permit signal, allowing the rail vehicle to enter the prepared route. The rail vehicle, moving along the track occupies and releases further elements of the route, i.e. track sections and switch sections. The movement of the rail vehicle is controlled (and visualized) by the interlocking and signalling system.

The basic design documents of the interlocking and signalling system are:

- signalling layout plan (Fig. 2);
- locking table (Table 1).

The signalling layout plan, prepared in accordance with the rules specified in the relevant regulations is the mapping of the track layout of the station and the location of railway traffic control devices, defines the route and basic features of the elements, i.e. types and location of signalling devices, track and points numbering, etc. A layout plan is the basis for the development of the locking table, which is an essential safety component containing:

- symbols of individual routes,
- mutual relations between routes (plain locking, special locking, lack of conflict),
- ordered lists of track sections and switch sections belonging to each route including their required state.

5. Usage of the Interlocking Subschema in RailML3.1

To reflect selected RailML features in the scope of description of interlocking and signalling systems, consider the simple track layout shown in Fig. 2. The track clear detection as well as shunting movements, were omitted in the route-related locking table (Table 1), in order to preserve clarity of example. The locking table is shown in the form typically used in Polish railways, but its form can be easily adapted to formats used in other European railways.

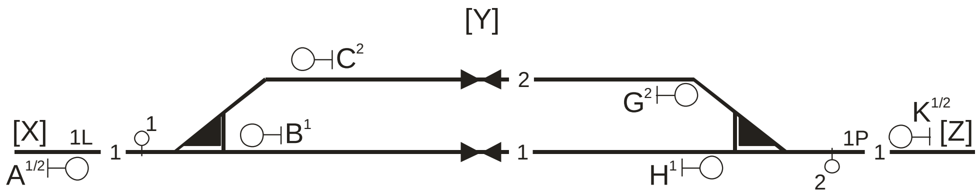


Fig. 2 An example of signalling layout plan

Table 1

Route-related locking table (for layout plan shown in Fig. 2)

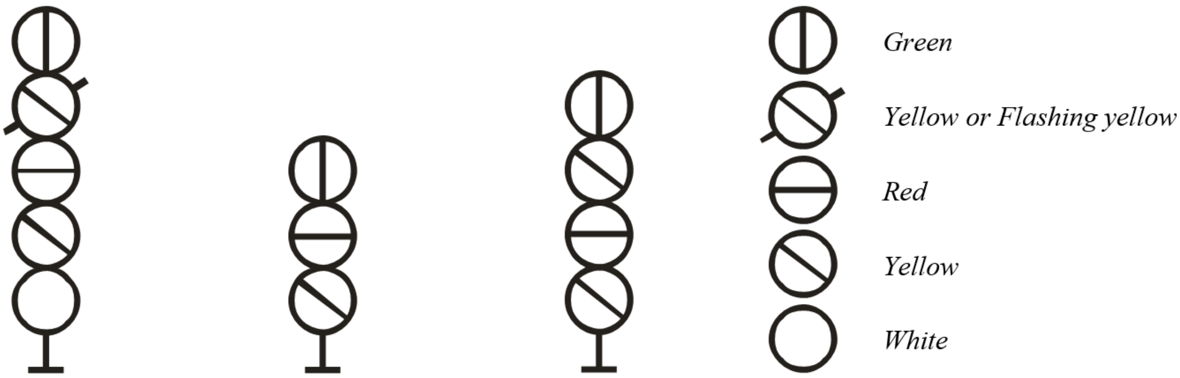
ROUTES		CONFLICTING ROUTES								POINTS
		A¹	A²	B¹	C²	G²	H¹	K¹	K²	1/2
A¹	[X] → Track 1	-	+	+	+		+	+		+
A²	[X] → Track 2	+	-	+	+	+			+	-
B¹	Track 1 → [X]	+	+	-	+			+		+
C²	Track 2 → [X]	+	+	+	-				+	-
G²	Track 2 → [Z]		+			-	+	+	+	-
H¹	Track 1 → [Z]	+				+	-	+	+	+
K¹	[Z] → Track 1	+		+		+	+	-	+	+
K²	[Z] → Track 2		+		+	+	+	+	-	-

Routes			Points		
	+	Conflicting routes locked by plain locking		+	Points locked in normal position
	+	Conflicting routes locked by special locking		-	Points locked in reverse position
	-	Main diagonal; in route matrix			

In the example, according to the regulations applied by Polish railways, the multiple aspects signaling system will require displaying one of the following signal aspects:

- signal $A^{1/2}$ i $K^{1/2}$ (Fig. 3, a)
  - speed at the first block section
    - stop,
    - V_{max} (straight, track 1),
    - 40km/h (branch-off, track 2),
  - speed at the second block section
    - stop
    - 40km/h (branch-off)
    - V_{max} (straight)
- signal B^1 i H^1 (Fig. 3, b)
  - speed at the first block section
    - stop,
    - V_{max}
  - speed at the second block section
    - Stop
    - V_{max}
- signal C^2 i G^2 (Fig. 3, c)
  - speed at the first block section
    - stop
    - 40km/h
  - speed at the second block section
    - Stop
    - V_{max}

and use signals as shown in Fig. 3.



a b c d

Fig. 3 Signals (for layout plan shown in Fig. 2): a - signals $A^{1/2}$ i $K^{1/2}$; b - signals B^1 i H^1; c - signals C^2 i G^2; d - legend

```
<signalAspects>
   <signalAspect="R" name="red" signalspeed="0" targetspeed="0"/>
   <signalAspect="YLFL" name ="yellow flashing" targetspeed="40"/>
   <signalAspect="YL" name="yellow" targetspeed="0"/>
   <signalAspect="GR" name="green" targetspeed="max"/>
   <signalAspect="YLGR" name="yellow green" signalspeed="40" targetspeed="vmax"/>
   <signalAspect="YLYLFL" name="yellow yellow flashing" signalspeed="40"
                                                        targetspeed="40"/>
   <signalAspect="YLYL" name="yellow yellow" signalspeed="40" targetspeed="0"/>
   <signalAspect="RW" name="red white" signalspeed="40"/>
</signalAspects>
<signalAspectGroups>
   <signalAspectGroup="1">
      <signalAspectRef="R"/>
      <signalAspectRef="YL"/>
      <signalAspectRef="YLFL"/>
      <signalAspectRef="GR"/>
      <signalAspectRef="YLYL"/>
      <signalAspectRef="YLYLFL"/>
      <signalAspectRef="YLGR"/>
   </signalAspectGroup>
   <signalAspectGroup="2">
      <signalAspectRef="R"/>
      <signalAspectRef="YL"/>
      <signalAspectRef="GR"/>
   </signalAspectGroup>
   <signalAspectGroup="3">
      <signalAspectRef="R"/>
      <signalAspectRef="YLGR"/>
      <signalAspectRef="YLYL"/>
   </signalAspectGroup>
</signalAspectGroups>
```

Fig. 4 Description of the signals in RailML

The RailML definition of signals is shown in Fig. 4. In this definition, in order to simplify the examples, the possibility of driving on the subsidiary signal, that is generated if it is impossible to determine the correct signal. The

example contains a list of possible signal aspects and their groups related to particular signals.

A part of RailML file defining the signal dependencies for the route based interlocking is shown in Fig. 5.

```
<interlocking>
   <signals>
      <signal refid="A1/2" Cvps="Vmax" Cvns="Vmax">
            <signalAspectDependencies>
                  <signalAspectDependency code="R" Vp="Vmax" Vg="0">
                        <targetSignalTypeRef refid="G2"/>
                        <targetSignalTypeRef refid="H1"/>
                  </signalAspectDependency>
                  <signalAspectDependency code="YL" Vp="Vmax" Vg="40">
                        <targetSignalTypeRef refid="G2">
                              &lt;segment refid="A1/2_G2"/&gt;
                              <routePriorities/>
                        </targetSignalTypeRef>
                        <targetSignalTypeRef refid="H1">
                              &lt;segment refid="A1/2_H1"/&gt;
                              <routePriorities/>
                        </targetSignalTypeRef>
                  </signalAspectDependency>

                  (...)

            </signalAspectDependencies>
      </signal>
   </signals>
   <segments>
      &lt;segment refid="A1/2_G2"&gt;
            <elements>
                  <signalRef/>
                  <trackSection/>
                  <switchRef/>
                  <crossingRef/>
                  <derailerRef/>
                  <trainDetectorRef/>
                  <levelCrossingRef/>
            </elements>
            <flankProtection/>
      &lt;/segment&gt;

      (...)

   </segments>
</interlocking>
```

Fig. 5 A part of RailML file defining the signal dependencies

6. Conclusions

Railway IT systems have been using for many years the proprietary and incompatible solutions offered by producers. The comprehensive analysis of the railway systems operation has enabled the development of an open and increasingly more complete standards for topology modeling and railway infrastructure description, such as RailML and RailTopoModel. Their subsequent versions gradually increase the number of possible applications. The quantity of practical implementations of the standard is still growing. The existence of a common data model makes easier the design of software, processes and services for the railway industry needs. By the unification of data structures, RailML, has a chance to become a universal format for data exchange in the railway business.

Inspired by this trend, the authors started developing their own software for editing and visualising RailML files. The result of this work is the RailML File Editor. It still requires intensive development, but it is already useful for users who edit RailML files and XSD schemas. The authors plan, among others, to equip the tool with the ability to generate and visually edit files for infrastructure, interlocking and signalling elements.

In this paper, the proposed RailML file editor was used to design examples of the definition of interlocking and signalling subsystems. The authors used the preview developer versions of RailML, because the version of the standard for production use is not available yet. Nevertheless, the undertaken analyses have shown that a very useful technology is emerging, which over time can revolutionize the European rail market in the next area, by facilitating the design and verification of interlocking and signalling systems.

Acknowledgment

This material is based upon work supported by National Centre for Research and Development under Grant No. PBS3/A6/29/2015 entitled „The system for maintenance data acquisition and analysis of reliability and safety of traffic control systems".

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Capacity Assessment of Railway Station Switch Area with an Emphasis on Influence of Shunting Movements

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Abstract

The article is focused on comparison of Czech and UIC methodologies for capacity assessment of switch areas within railway stations with consideration of shunting movements along the train routes. Main differences are pointed out. Part of the article is focused on shunting movements in relation to capacity of switch areas. Three different ways of time occupancy expression are mentioned in the case of shunting movements. Dependencies between individual ways of time occupancy expression and assessed switch area capacity are discussed.
KEY WORDS: *rail capacity, shunting movement, railway station, switch area, UIC 406*

1. Introduction

There are two principal methods how to assess capacity of railway stations – analytical models (formulas) and simulation models (based on simulation experiments) whether in some cases it is useful to combine them. The same approach can be applied on switch areas (usually entering and exiting parts of stations). This paper is focused only on analytical models (although that simulation is also applied in practice).

The paper considers 2 methodologies valid in the Czech Republic. Guidelines SŽDC (ČD) D24 [1] are representing a "local" point of view, methodology UIC 406 Capacity [2] an "international" point of view. Main differences in these approaches to capacity assessment of switch areas will be pointed out.

Similar "local" guidelines ŽSR D24 are valid in the case of Slovak Republic as well. The original version was issued by former Czechoslovak State Railways (ČSD) in 60's of 20th century. This methodology is sometimes named as "ČSD Methodology" as well.

Question of incorporation of shunting movements into capacity assessment will be highlighted in this article. This problem is related to all methodologies for capacity assessment of station switch areas. It is about definition what "a shunting movement" is and which parts of switch area infrastructure are occupied by this movement.

2. Literature Review

Commonly adopted method to assess railway station capacity is defined by UIC in the leaflet UIC 406 [2]. The leaflet [2] describes how to assess the capacity on a segment of infrastructure whether given timetable is compressed. In the leaflet there is no detailed information how to handle shunting movements. Most of the shunting operations are planned after the timetable is finalized so the shunting movements are adapted to fit the fixed schedule. In case of trains delays it usually leads to rearrangements of shunting movements that make it even more difficult to use the UIC 406 [2].

To help this and other problems that are relevant to calculation of station capacity, Landex et al. [3] developed methods that allow to analyse a station to gain comprehensive knowledge about the capacity. The methods are focused on platform tracks, train routes and timetable complexity. Unfortunately, shunting movements are not discussed in the suggested methods.

The capacity calculations for stations are also subject of paper [4] that focus on station capacity from the perspective of UIC 406 [2] and UK-specific measure CUI whether the aim of the paper is to enable both methodologies their application to stations. The paper is focused only on timetable and capacity planning process and shunting movements are omitted. The paper provides interesting comparison of both methodologies in case studies of Peterborough and Southampton stations.

3. Principles Based on SŽDC (ČD) D24 (Example of National Principle)

This chapter is focused on summarized (modified) short explanation of principles how to calculate capacity of station switch area according to the guidelines SŽDC (ČD) D24 [1].

This methodology is based on decomposition on switch area into elements. Each element is consisted of one

or more switch points. Maximal number of parallel routes (movements) able to be realized at one moment is minimal number of switch area elements. Number of elements can be increased when needed.

This capacity assessment is based on extent of operation as well. A list of train and shunting movements (operated in assessed time period with the length of T [min]) is necessary. This list creates a set of movements J. Occupancy time t_j must be determined to each movement $j \in J$. Relative occupancy times τ_i are calculated for each element of switch area (set of switches) $i \in I$ according to the formula (1):

$$\tau_i = \sum_{j=1}^{N} \frac{c_{ij} \cdot t_j}{N} \quad \forall i \in I \,, \tag{1}$$

here I – set of switch area elements; J – set of movements on switch area in assessed time period; N – total number of movements; c_{ij} – binary constant identifying if movement of $j \in J$ occupies the element $i \in I$ ($c_{ij} = 1$) or not ($c_{ij} = 0$); t_j – occupation time of switch area related to the movement of $j \in J$ [min].

Element with the maximal value of relative occupancy time $\tau_{max} = \max_{i \in I} \tau_i$ is considered as "limiting element". Capacity of whole switch area will be approximated by capacity of this limiting element.

Movements are divided into 2 sets now. The first set U is consisted of movements occupying limiting element. The second set V is consisted from other movements (not occupying the limiting element). This is necessary for determination of total time of probable disturbance. Table of dependence of routes (for movements) must be completed. Each row belongs to one movement occupying limiting element. Columns are for movements not occupying the limiting element.

If the movements in row $u \in U$ and column $v \in V$ are in a conflict (on another switch area element), value of $pt_y = t_v / N$ is placed in an intersection (on position of uv in the table). The value of t_v is switch area occupation time of the movement $v \in V$ (not occupying the limiting element, located in column). $N = N_{train} + N_{shunt}$ represents total number of movements operated on switch area in assessed time period.

The value of pt_v can be interpreted as partial relative occupancy time of switch area related to the movement of $v \in V$. The value of 0 is filled in the case of a pair of conflict-less movements. Each row of the Table of dependence of routes is assumed and then multiplied by the value pt_u / τ_{max}. The value $pt_u = t_u / N$ is for the movement in row $u \in U$ (occupying limiting element). Sum of all these values $\sum_{u \in U} \frac{pt_u}{\tau_{max}}$ is total time of probable disturbance $TTPD$.

Practical capacity of switch area n_p is assessed in the way of formula (2):

$$n_p = \frac{T \cdot \left(T_{closure} + T_{perm}\right)}{\tau_{max} + 0,5 \cdot c_t + \varphi \cdot TTPD} \,, \tag{2}$$

here n_p – practical capacity of switch area related to assessed time period [movements], T – length of assessed time period [min]; $T_{closure}$ – total time of closures in assessed time frame when the infrastructure is not possible to be used; T_{perm} – total time of permanent manipulations in assessed time period (occupation by movements which are not relevant for capacity assessment); τ_{max} – maximal relative occupancy time (for limiting element); c_t – transformation coefficient – ratio of train movements expressed in relation to number of all movements ($c_t = N_{train}/N$), φ – coefficient of parallelism ($\varphi = 1.00$ by 2 elements of switch area, $\varphi = 0.75$ by 3 elements and $\varphi = 0.60$ by more than 3 elements); $TTPD$ – total time of probable disturbance [min].

There are two additional important indicators as well. The first is degree of occupation providing a ratio of utilized time. It is calculated in the way of formula (3):

$$S_o = \frac{N \cdot \tau_{max}}{T - \left(T_{closure} + T_{perm}\right)} \,, \tag{3}$$

here S_o – degree of occupation [–], other symbols are noted in previous text.

The second indicator is utilization coefficient of practical capacity k_{vp}. Number of movements N is divided by value of practical capacity n_p, see formula (4):

$$k_{yp} = \frac{N}{n_p} \,, \tag{4}$$

here k_{vp} – utilization coefficient of practical capacity [–], other symbols are noted in previous text.

The methodology based on guidelines SŽDC (ČD) D24 [1] provides solution approximated by indicators (results of capacity assessment) especially made for limiting element. It could be said that capacity of this (most occupied)

element represents whole switch area.

Second problem is that this methodology considers all the route for a movement as occupied during whole time from start of preparation till release of the last part of switch area. State-of-art (relay based and electronic) interlocking systems release the routes step by step according to movement. Considered occupation times are longer than actual ones.

There is no strict rule how to involve shunting movements into consideration. It is defined as time period when shunting occupies the switch area. This is suitable for the case of switch areas with simple topology. It is required to release switch area “as soon as possible”. On the other hand, switch areas with more complicated topology and equipped with signals valid for shunting represent different situation. The most of shunting movements can be divided into several parts according to prepared (partial) routes for this shunting. It is not an exception that the shunting vehicle is staying in the field of switch area until other movements with higher priority is finished.

Possible measures of changes in capacity assessment method (involvement of shunting) reflecting these problems are in the chapter 5.

4. Principles for Capacity Assessment Based on UIC 406 (International Principle)

As already mentioned in the introduction, an international methodology UIC 406 [2] is one of the methodologies used to determine the capacity of the railway stations. This chapter only lists the main principles of the UIC 406 methodology [2]. Further details are given in the papers [5] and [6], which also deals with the alternative calculation method and the tool that can be used to the capacity calculation.

Methodology UIC 406 [2] is based on the compression method. Basic index is occupancy time rate (*OTR*) that provide ratio metric usage of a certain part of the railway station. This parameter principally corresponds to the parameter degree of occupation S_o of the SŽDC (ČD) D24 methodology [1]. Utilization rate is calculated as a proportion of occupancy time and defined time period, according the formula (5):

$$OTR[\%] = \frac{Occupancy\ \ Time}{Defined\ \ Time\ \ Period} \cdot 100\ . \tag{5}$$

Other values that are assessed are number of concatenations *K* and concatenation rate φ. Relationship between them and total number of trips (movements) is illustrated by formula (6):

$$\varphi[\%] = \frac{Number\ \ of\ \ Concatenations}{Total\ \ Number\ \ of\ \ Trips} \cdot 100\ . \tag{6}$$

Occupancy time for switch area is calculated as one value whereas individual times of occupancy are included as well as times between occupancies that might be used also for other task at switch area. Occupancy time for switch area is calculated as minimum time at which it is possible to realize all tasks according to given timetable.

To calculate capacity properly it is needed to have template for timetable that does not include any conflicts. Timetable includes individual tasks and order of the tasks as well. Basic principle is to change time stamps for individual tasks so that they follow each other in the shortest possible time. The first task is considered with its original time stamp and all other task’s time stamps are changed so that they immediately follow previous task when correct technological times are considered. It is needed to consider that individual tasks occupy infrastructure elements (tracks, switches) at switch area. Every switch can be served by one task at a time only. Element can be occupied by another task only when the element is released.

When the time stamps of tasks are changed it is named as compression – it means reduction of total time that is needed to serve all tasks.

During compression it is needed to follow these rules:

- all planned tasks must be served;
- during compression the task is moved (it’s time stamp) as a whole part on time axis;
- original order of tasks that use the same elements must be kept;
- technological times must be kept – occupancy of element by next task can start when it was already released;
- two tasks (that do not use any common element and their parallel execution is not excluded due to any other reason) can be executed in parallel or can be executed in opposite sequence.

5. Involvement Concepts of Shunting Movements

Expression of shunting movements creates such sub-problem by capacity assessment. There is no recommendation how shunting movements and their occupation times can be expressed in the case of the guidelines SŽDC (ČD) D24 [1]. There is a presumption that shunting movements are supposed to be incorporated only. State-of-art interlocking systems allow to make some another movements parallel to these shunting movements. It is possible due to stepwise releasing of route for shunting and possibility to make sojourn of vehicles in switch areas (see problem

statement of the end of the chapter 3).

The question is if it is necessary to consider one shunting operation at once or separate it into individual shunting movements (creating a sequence). Important fact is that this is not only about decomposition of shunting movement (and occupation of switch area), but also about interpretation of results. Practical switch area capacity n_p is expressed in number of movements. Question is what "a movement" is in this case, how this number will be affected by different concepts of shunting involvement.

The UIC 406 methodology [2] does not have a specific accent on shunting movements as well. It uses only terms a train and a general term road (probably as a general term for trains and shunting movements). One of the prerequisites (for the calculation according to UIC 406 methodology [2]) is a timetable which is not normally free of shunting movements. Shunting movement can be involved in the methodology as a "train". The compression method will use the complete set of all switch area movements (trains and shunting movements) to capacity calculation. The above-mentioned question on splitting a shunting movement into a several parts is also relevant for the UIC methodology [2].

Moving of a locomotive to an opposite end of a train set is one of the most typical and basic shunting operations. For that reason, this operation will be used as an example in following text. This shunting movement can be consisted of following parts (P1 – P3) in the point of view of one station switch area:

P1. a movement from station track to switch area;

P2. sojourn time (for change of direction of drive);

P3. a movement from switch area to (another) station track.

This decomposition is a base for proposal of involvement concepts. Other shunting operations (if occurred) should be assessed in similar way.

The aim of research presented in this article is to examine 3 concepts of shunting moves assessment (S1 – S3):

S1. All parts of shunting P1+P2+P3 as 1 operation together – this could be objective according to total number of shunting operations, but it should be problematic from the point of you of time occupation. Occupation times of individual switch area elements can longer than necessary and unrealistic in the most of cases.

S2. Shunting will be divided into 2 operations according to individual shunting routes set up individually. Sojourn time(s) and related occupation P2 will be added to the first movement. It means that parts P1+P2 will be assessed together as one operation and part P3 as second operation. This should be more adequate because elements occupied by P1 are released before start of P3 (drive to station track used for bypassing of train set). Inadequate is that these elements (occupied in part P1) are occupied also during sojourn time (P2) when they are usually released (by stepwise releasing of shunting route).

S3. Individual movements (P1, P3) and sojourns (P2) are considered as individual shunting operations. It means that all the parts P1, P2 and P3 are realized individually. Occupation times of sojourn (P2) are cleared of shared occupation times. Releasing time of the first shunting route belongs to P1 and preparation time of the second (new) shunting route to P3.

It is expected that the way S1 cause pessimistic capacity assessment because assessed occupation times t_j are longer than real. The way S3 is expected as the most correct way in assessment of time and spatial occupation. On the other hand, this capacity result (in number of movements in time) will be affected by rising number of assessed movements. More than one movements will be needed for one shunting operation (3 for mentioned example – the first for P1, the second for P2 and the third for P3).

Secondary, 2 concepts of topological decomposition of switch area into elements are examined as well:

E1. Standard decomposition according to the guidelines SŽDC (ČD) D24 [1]. It means that switch area elements will be determined by "cooperating" switches only (Fig. 1).

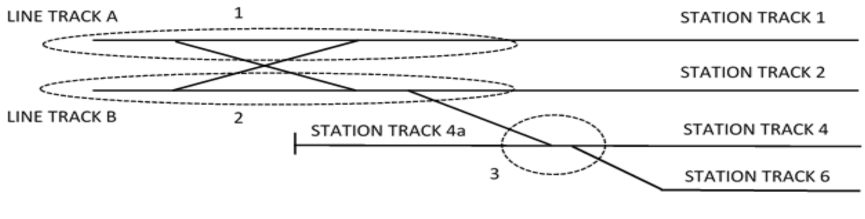

Fig. 1 Switch area elements – standard decomposition E1

There is possible to use maximally 3 parallel routes for movements (e.g. the first from station track 1 to line track A; the second from line track B to station track 2 and the third shunting movement from station track 4a to station track 4 or station track 6). 3 elements are determined due to this fact.

E2. Decomposition equipped by elements for sojourn of shunted vehicles. Another concept of decomposition will be based on an approach published by [7]. Additional elements will contain no switch. Tracks in sojourn elements must be equipped by signals valid for shunting. It is presupposed that this will be suitable especially in combination with the concept S3 of shunting moves. Sojourn can be related to specific sojourn element and other elements allowing other movements will be free during sojourn. (Fig. 2).

All the concepts of shunting involvement (S1 – S3) will be examined on the background of both concepts of switch area decomposition (E1, E2).

There are created 3 scenarios of railway operation (O1 – O3) as well. Scenarios O2 and O3 are modification of the previous one (O1 or O2).

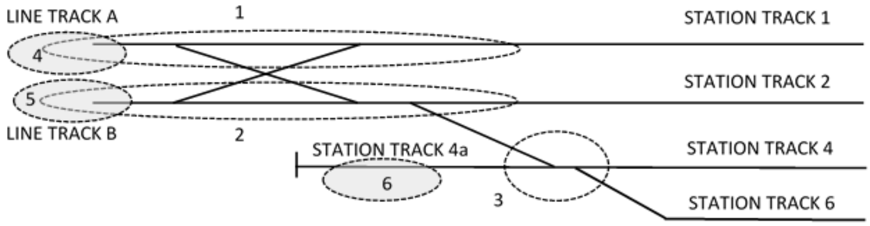

Fig. 2 Switch area elements – decomposition equipped by sojourn elements E2.

O1. Trains only, no shunting. This scenario is consisted of 10 trains passing from the station track 1 to the line track A and from 8 trains from the line track B to the station track 2. Time occupation is 4 min by each train. See Fig. 1 or Fig. 2 for illustration of these routes.

O2. Trains and 2 shunting manipulations. Extent of train operation is the same like in the scenario O1 (10 + 8 trains). 2 shunting manipulations are added. Locomotive of trains coming to the station track 6 from right side of Fig. 1 or Fig. 2 is moved to another end of train set over the station track 4. The reason is that the train will depart in reverse direction. Locomotive must go from the station track 6 to the station track 4a (part P1, see above). Occupation time of this is 3 min by this part P1. Second part (P2) is sojourn on the station track 4a related to change of drive direction. Occupation time is 5 min by P2. Third part (P3) is shunting movement from the station track 4a to the station track 4 with occupation time of 2 min. Shunting on the station track 4 and on another switch area (on the right of Fig. 1 and 2) will not be examined. In general, capacity is assessed for each station switch area individually.

O3. Is the same like the scenario O2, but the number of shunting manipulations (moved locomotives) is increased to the number of 5. This scenario O3 is designed with an effort to change maximally occupied element from element 1 to element 3 (or 6 by E2).

Operational scenarios O1 – O3 are little bit unrealistic in the operational point of view. On the other hand, these scenarios are designed with an effort to separate each examined effect. This will allow to understand to affecting effects in general case.

Also, in the UIC 406 methodology [2], these scenarios can be considered. The main difference between the methodologies is that the UIC 406 [2] does not work with the decomposition of the switch area into elements. The compression method computes a compression of occupancy times for the switch area using all switches and other parts of the station (death-end track, short station tracks, points between switch area and line track) on which a movement has been made during the assessed time period and which are assigned switch area (are marked as part of the switch area).

Using the UIC 406 methodology [2] (similar like in the case of the SŽDC (ČD) D24 methodology [1]), it is advisable to individually assess the topology of the switch area, the capabilities of the interlocking systems and the range and structure of operation on the switch area and to determine the parts of the switch area that are used almost exclusively for temporary sojourn of the shunting locomotives (vehicles). These places can be excluded from the calculation. Idea is the same as for the SŽDC (ČD) D24 methodology [1]. The other parts of the switch area are free during the shunting locomotive (vehicles) sojourn in a dedicated place.

These dedicated locations (which are not included in the calculation using the UIC 406 methodology [2]) are parallel to the sojourn elements according to the modified D24 methodology [1].

6. Evaluation of Researched Effects

Evaluation of all researched effects is made by using of the guidelines SŽDC (ČD) D24 [1] with all aspects characterized above. Capacity indicators are calculated for all possible combinations of scenarios defined in the chapter 5. Overview of results is in the Table 1.

The conclusions based on this analysis (Table 1) are mentioned below.

There is no effect, how many elements are created (if the number of elements is equal or higher than number of possible parallel routes). The results for both decompositions of switch area elements are the same (compare E1 and E2 columns in the Table 1). Question is what will happen when the limiting element will be selected in different way (chapter 7).

Results are sensitive on limiting element (element No. 1 for O1 and O2, No. 3 for O3 and E1, No. 6 for O3 and E2). Element with the highest sum $\tau_{\max}$ of relative occupation times is selected as limiting according to original guidelines SŽDC (ČD) D24 [1]. Compare practical capacity expressed in trains n_{train} = 44 trains in the case of O1 and O2 scenarios and n_{train} = 37 trains in the case of the scenario O3.

Different expression of shunting moves can change value of practical capacity n_p expressed in total number of movements (train + shunting movements) in spite of the fact that the extent of operation is the same (within each operational scenario O). Compare S1, S2 and S3 within each scenario in the Table 1. Influence of shunting involvement concepts (S1 – S3) is visible.

Another important effect should be illustrated by comparison of practical capacity n_p values within the scenario O2. These values are increasing by rising number of shunting operations (created by division) in spite of the fact that no shunting operations are occurred on the limiting element 1. It is caused by the fact that a ratio of trains c_t is decreasing (by rising number of total movements). The member $0.5c_t$ in denominator of the formula (2) will add 0.5 min reserve to

occupation for each train (using switch area, not only at element), but 0 min reserve to occupation by shunting movement. Due to this fact an "average occupation" is decreased and capacity increased in this case. Total time of probable disturbance *TTPD* is 0 min with no influence in this case of any movement sharing the same element. Recognition of this be also helpful for understanding in the common case with *TTPD* ≥ 0 min.

Table 1

Capacity assessment - comparison of concepts using SŽDC (ČD) D24 [1]

Scenario	Limiting element	Operations in time schedule		E1 3 elements according to switches				E2 6 elements, sojourn elements included			
		trains	shunt.	n_p	n_{train}	S_o	K_{vp}	n_p	n_{train}	S_o	K_{vp}
units		N_{train}	N_{shunt}	moves	trains	–	%	moves	trains	–	%
formula				(2)	$n_p \cdot c_t$	(3)	(4)	(2)	$n_p \cdot c_t$	(3)	(4)
O1		10 trains (st. track 1 → line track A) + 8 trains (line track B --> st. track 2), no shunting									
S1	1	18	0	**44**	44	0.33	40.83	**44**	44	0.33	40.83
O2		… the same extent of operation like in O1 + 2 shunting manipulations (station track 6 → 4a → 4)									
S1	1	18	2	**49**	44	0.33	40.83	**49**	44	0.33	40.83
S2	1	18	4	**54**	44	0.33	40.83	**54**	44	0.33	40.83
S3	1	18	6	**59**	44	0.33	40.83	**59**	44	0.33	40.83
O3		… the same extent of operation like in O1 + 5 shunting manipulations (station track 6 → 4a → 4)									
S1	3	18	5	**47**	37	0.42	49.17	**47**	37	0.42	49.17
S2	3	18	10	**57**	37	0.42	49.17	**57**	37	0.42	49.17
S3	3 (E1) /6 (E2)	18	15	**67**	37	0.42	49.17	**67**	37	0.42	49.17

Table 2

Capacity assessment - comparison of concepts using UIC 406 [2]

Scenario	Operations in time schedule		E1 station track 4a (sojourn point) **included** to switch area			E2 station track 4a (sojourn point) **not included** to switch area		
	trains	shunt.	*OTR*	*K*	φ	*OTR*	*K*	φ
units	N_{train}	N_{shunt}	–	moves	–	–	moves	–
O1	10 trains (st. track 1 → line track A) + 8 trains (line track B --> st. track 2), no shunting							
S1	18	0	0.333	10	55,6	0,333	10	55.6
O2	… the same extent of operation like in O1 + 2 shunting manipulations (station track 6 → 4a → 4)							
S1	18	2	0.333	10	50.0	0.333	10	50.0
S2	18	4	0.333	10	45.5	0.333	10	45.5
S3	18	6 / 4	0.333	10	41.7	0.333	10	41.7 / 45.5
O3	… the same extent of operation like in O1 + 5 shunting manipulations (station track 6 → 4a → 4)							
S1	18	5	0.417	5	21.7	0.417	5	21.7
S2	18	10	0.417	10	35.7	0.417	10	35.7
S3	18	15 / 10	0.417	15	45.5	0.333	10	30.3 / 35.7

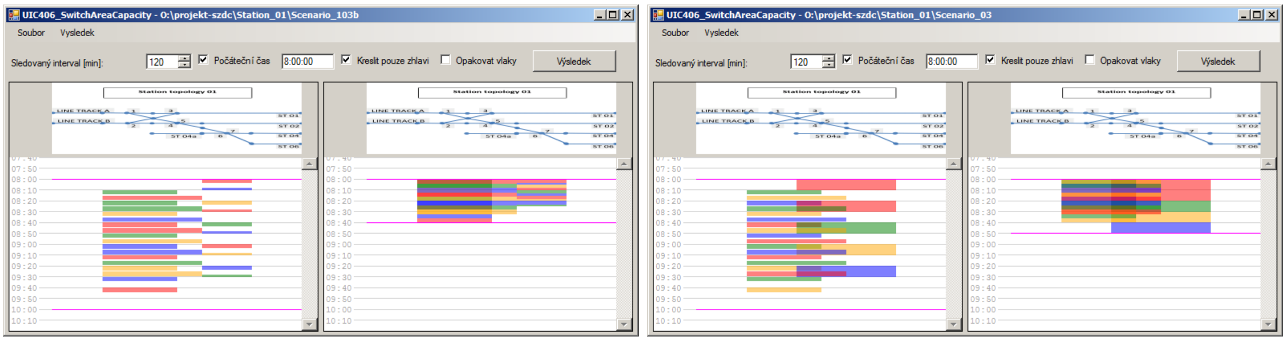

Fig. 3 Graphic representation of resulting compression for E1 / O3 / S3 and E2 / O3 / S3

Table 2 contains the resulting parameters according to the UIC 406 methodology [2]. The calculations were

made for the same scenarios as D24. The recommendations resulting from these results are listed in Chapter 7.

Fig. 3 is a sample of the software tool environment used for calculations using the UIC 406 methodology [2]. There is a comparison of two different scenarios involving shunting movements.

7. Recommended Changes in Capacity Assessment

It is interesting that some presumptions are not fulfilled in the Table 1. First of all, separating of sojourns do not lead to increase of capacity in spite of the fact that time occupancy in reduced (to smaller number of elements). This is caused by the fact that the capacity estimation is related to the most occupied limiting element. See change of limiting element in the scenario O3 between by E1 and E2 decompositions of elements for illustration. The results correspond to element with the same structure of occupation. Individual capacity assessment made for all elements seems to be a solution. Table 3 represents individualized solution for scenario O3, S3 in both variants of decomposition into elements E1 and E2. It is calculated repeatedly like each of elements will be limiting element. The values are not indicators for individual elements, but for whole switch area in total.

Table 3

Switch area capacity assessment – scenario O3, S3, E1 and E2 in detail

<table>
<tr><td rowspan="4">Switch area element assessed as limiting</td><td>Decomposition</td><td colspan="4">E1</td><td colspan="4">E2</td></tr>
<tr><td>Indicator:</td><td>n_p</td><td>n_{train}</td><td>S_o</td><td>K_{vp}</td><td>n_p</td><td>n_{train}</td><td>S_o</td><td>K_{vp}</td></tr>
<tr><td>Units:</td><td>moves</td><td>trains</td><td>–</td><td>%</td><td>moves</td><td>trains</td><td>–</td><td>%</td></tr>
<tr><td>Formula:</td><td>(2)</td><td>$n_p \cdot c_t$</td><td>(3)</td><td>(4)</td><td>(2)</td><td>$n_p \cdot c_t$</td><td>(3)</td><td>(4)</td></tr>
<tr><td>1</td><td rowspan="6"></td><td>81</td><td>44</td><td>0.333</td><td>40.8</td><td>81</td><td>44</td><td>0.333</td><td>40.8</td></tr>
<tr><td>2</td><td>97</td><td>53</td><td>0.267</td><td>34.2</td><td>97</td><td>53</td><td>0.267</td><td>34.2</td></tr>
<tr><td>3</td><td>**67**</td><td>**37**</td><td>**0.417**</td><td>**49.2**</td><td>**81**</td><td>**44**</td><td>**0.208**</td><td>**40.8**</td></tr>
<tr><td>4</td><td rowspan="3" colspan="4">-</td><td>81</td><td>44</td><td>0.333</td><td>40.8</td></tr>
<tr><td>5</td><td>97</td><td>53</td><td>0.267</td><td>34.2</td></tr>
<tr><td>6</td><td>**67**</td><td>**37**</td><td>**0.417**</td><td>**49.2**</td></tr>
</table>

The impact of clearing of sojourns is visible in the case of the element 3. Degree of occupation (valid for the whole switch area) is decreased from 0.417 to 0.208, because sojourn is removed for “active element of 3” (switch point element) to “sojourn element of 6” (station track taking part of switch area). It corresponds with the fact that the values of indicators are the same for the element 3 by E1 element decomposition and for the element 6 by E2 decomposition.

In fact it means that following recommendations could be followed:

- application of S3 concept of shunting involvement (each part assess as individual shunting operation);
- it must be supported by application of sojourn elements in switch area decomposition (E2) according to [7];
- total assessment of switch area capacity should be based on repeated assessments done for all elements in the position of limiting element with comparing of results and commentary;
- it must be not forgotten that the value of practical capacity n_p expressed in movements corresponds to a new “meaning” of 1 shunting operation containing a part of shunting manipulation only.

For UIC 406 [2], the corresponding calculations were made for the above scenarios. The calculations were made using a customized software tool [6]. The results obtained (degree of occupation, occupancy time rate) are consistent with the results obtained using the SŽDC (ČD) D24 methodology [1].

Recommendations for including shifts in the UIC 406 methodology [2] are similar to the SŽDC (ČD) D24 methodology [1]:

- splitting the shunting movement to several parts can increase the resulting rate of compression for the given switch area;
- determination and allocation of dedicated sojourn points areas on the switch area also leads, in most cases, leads to achievement greater compression and thus decreasing the resultant occupancy time rate of the switch area;
- because of the splitting of the shunting movement into several parts, the total number of movements increases and therefore the number of concatenations and concatenation rate can increase.

8. Application in General Case

Comparison of proposed shunting involvement concepts was taking part also within the project “Proposal of a new methodology for capacity assessment of railway stations” ordered by SŽDC, s.o. (Railway Infrastructure Administration, state organization) and solved by the University of Pardubice, Faculty of Electrical Engineering and Informatics. [8]

This case study is focused on the western switch area of the railway station of Zdice. This station is located on the railway lines Prague – Pilsen and Zdice – Písek providing connection of the capital with western and southwestern parts of the Czech Republic.

Specific time schedule was elaborated for this purpose. It is consisted of 4 freight, 8 long-distance passenger and

24 regional passenger trains (36 trains in total). This operation is equipped by 12 shunting manipulations (moving of locomotive to another end of train set). Length of assessed time period T is 120 min. Switch area is divided into 11 elements, including sojourn elements. Numbers of elements are related to numbers of station tracks in this case.

Occupation times t_j are determined by application of validated microscopic simulation model of this station with accuracy of 0.01 min. This allowed possibility to created hypothetical time schedule with high rate of occupation with confirmation that this time schedule is applicable. Assessed train and shunting movements are schedules as conflict-less in time, but in the switch area topology point of view these movements could be in conflict. Overview of results and comparison of examined shunting involvement concepts (for definition see the chapter 5) is in the Table 4.

Table 4

Switch area capacity assessment; station Zdice, western switch area (direction Hořovice)

Element as limiting	Involvement S1				Involvement S2				Involvement S3			
	n_p	n_{train}	S_o	K_{vp}	n_p	n_{train}	S_o	K_{vp}	n_p	n_{train}	S_o	K_{vp}
	moves	trains	–	%	moves	trains	–	%	moves	trains	–	%
	(2)	$n_p \cdot c_t$	(3)	(4)	(2)	$n_p \cdot c_t$	(3)	(4)	(2)	$n_p \cdot c_t$	(3)	(4)
1a	60	45	0.326	80.3	76	45	0.326	79.2	110	55	0.326	65.6
1b	**47**	**35**	**0.783**	**103.0**	**61**	**37**	**0.711**	**98.5**	92	46	0.508	78.3
1c	50	37	0.635	96.3	74	44	0.368	81.2	104	52	0.368	69.1
2a	92	69	0.095	51.9	139	83	0.095	43.3	232	116	0.095	31.1
2b	92	69	0.095	51.9	139	83	0.095	43.3	232	116	0.095	31.1
2c	52	39	0.552	92.3	73	44	0.408	82.5	121	61	0.204	59.4
3a	51	38	0.532	93.7	66	39	0.532	91.5	**90**	**45**	**0.532**	**79.6**
3b	51	38	0.532	93.7	66	39	0.532	91.5	91	45	0.297	79.3
3c	62	46	0.223	78.0	85	51	0.190	70.9	105	52	0.158	68.7
3d	53	40	0.508	89.9	70	42	0.463	85.2	97	48	0.416	74.4
5	59	44	0.361	81.9	74	44	0.361	81.6	100	50	0.361	71.8

9. Discussion of Results

Discussion of results is based on application in general case mentioned in the chapter 8 (Table 1). Limiting elements determined according to the guidelines SŽDC (ČD) D24 [1] (by τ_{max}) are: the element 1b in the cases of S1 and S2 and the element 3a in the case of S3.

Consideration of results for S2 in comparison with S1 can refer about an effect of division of shunting movements into parts according to individual shunting routes needed to be set by interlocking system independently. Capacity is increased in this case, because “ballast” occupation times reserved for factually another shunting route are not assessed together.

The concept S3 is focused on the most proper assessment of occupation due to the fact that possible sojourn times are assessed for sojourn elements (occupied during sojourn) only. On the other hand, more detail decomposition of switch area into elements containing sojourn elements is necessary according to [7].

There is the same extent of operation in all concepts of shunting involvement S1 – S3 in the Table 1. On the other hand, different concept of shunting involvements S1 – S3 projects this to different number of shunting movements. This can cause influence on final capacity results not only in total numbers of movements, but also in the case of capacity expressed in number of trains as well. It is caused by the coefficient of c_t expressing ratio between shunting and all movements and by the value of *TTPD* as well.

The element 3a is occupied by 38 movements from 72 in total occurred on switch area in the case of the concept S3 (using sojourn elements). This set of 38 movements occurred on the element 3a is consisted of: 8 regional passenger trains; 20 shunting movements (as a part of route for shunting) and 10 sojourns. Mentioned 10 sojourns represent the majority of sojourns at this switch area. There are only 2 other sojourns within this switch area occupying element 1b. It is visible that sojourn of vehicles as a relative time-consuming operation can attract limiting element. Occupancy times of other elements (with exceptions of 1b and 3a) are cleared of sojourn occupation times in the case of S3. These numbers are related to “core” movements.

Remaining question is which element can be considered as limiting for approximation of total capacity features of a switch area. The answer is not unambiguous. Comparison of two cases mentioned in this article could be an illustration. The volume of sojourn time can mark the sojourn element with the maximum occupation time as limiting. It is mathematically correct. On the other hand, influence on practical operation must be considered as well. In the first example (mentioned in the chapters 5 – 7) limiting element 6 is located on a death-end track. It can affect the possibilities for shunting only. It means that the impact on practical operation could be limited and it does not have to be a good approximation of features valid for all the switch area. The element 3a is representing a part of line track going to Písek in the second example (chapters 8 – 9). The results are more significant due to this and may be these results could be used as an approximation of values valid for all the switch area. The truth is somewhere between these two “extreme” variants (to exclude sojourn elements – to fully consider sojourn elements). It could be recommended to set all the elements as limiting and to assess final capacity for all switch area by individual evaluation of all these partial

results (elements). Proposal of additional capacity indicators for this individual consideration could be a scope of subsequent research works.

10. Conclusions

The question of involvement of shunting movements by estimation of capacity of railway station switch areas were discussed in this article next to comparison of an example of national SŽDC (ČD) D24 methodology [1] with an “international” UIC 406 [2]. There is made an evidence that it is necessary to select the way of shunting movement involvement very carefully. The effects on results could be significant. It is recommended to use an individualized concept of involvement when shunting manipulations are divided into more shunting movements according to individual shunting routes set by interlocking system in extension of individual assessment of sojourn in switch area. Capacity assessment should be finalized by individual evaluation of results reached individually for all switch area elements.

In the case of UIC 406 [2], it is necessary to individually compare and evaluate the results obtained by variant calculations with the inclusion or exclusion of the sojourn places in the calculation.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Selected Aspects of the Environmental Friendliness Assessment of Railway Transport Using the Indicator Method

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Abstract

Railway transport is considered as the most environmentally friendly. However, taking into account all factors (including pollution related to the production of energy necessary for the movement of electric traction vehicles), it may turn out that its position in the ranking will decrease. Therefore, it is justified to look for new indicators that will allow to assess the environmental friendliness of railway transport taking into account different points of view. The subject of the article is to assess the ecological profile of the railway transport system using the indicator method. The paper proposes five indicators according to which the assessment can be made. Three indicators are associated with the emission of harmful compounds (in the distinction between electric traction, diesel traction and steam traction), one with noise and one with valuable natural areas. The assessment of railway transport in the aspect of environmental protection for the area of Poland has been made. The emission of harmful compounds related to energy production for the needs of railway electric traction vehicles, the percentage share of people exposed to noise from railway transport, whose level is greater than or equal to 55 dB and the percentage share of the length of the railway line running through valuable natural areas was used as indicators. A summary and conclusions from the indicator analysis are presented.
KEY WORDS: *railway transport, environment friendliness, indicator method*

1. Introduction

Road transport is responsible for the majority of pollutants (80%) which generates transport in general. However, the scale of railway transport impact on the environment is many times lower. This is mainly due to the structure of transport [19]. It should be noted that in the case of railway transport, pollution of the natural environment is mainly related to the emission of noise and vibrations, pollution from locomotives and occupancy of the area [15]. In addition, it should be taken into account that the consumption of electricity for traction purposes [22] involves the need to carry out the process of burning fuel in the power plant in an amount adequate to produce energy necessary for the correct operation of electric locomotives and other electric traction vehicles. This involves the emission of harmful compounds.

Emissions of harmful substances by means of railway transport are within 1% of total transport emissions [18]. According to the European Environment Agency, EU railway transport generates 1,2% NO_2, in this 1,2% in Poland. In addition, it is much safer than road transport [3]. In railway accidents thirty times less people are killed than in road transport. In order to preserve the economic, social and ecological balance, it is postulated to shift part of the demand from road transport to railways, sea and inland waterway, as well as undertaking promotional activities for multimodal transport [9].

To assess the environmental friendliness of the transport system, appropriate indicators should be used [14]. One of the ways to reduce the negative impact of transport on the natural environment is to implement activities for the sustainable development of transport [16, 17]. The effort to formalize and define criteria for assessing the state of sustainable transport has been and continues to be undertaken by many international institutions and organizations (including OECD, World Bank, UN). Sustainable development strategy of the European Union in 2001 created the basics of the statistical information system on the state of sustainable transport. It is based on the following three levels:

- general energy consumption of transport;
- increase in transport, transport prices, social and environmental impact of transport;
- branch division in passenger transport and in freight transport [13], level of freight transport and GDP in constant prices, energy intensity of individual transport modes, deaths in road accidents in general, deaths in road accidents by age, level of nitrogen oxides emission by transport.

A reporting mechanism in the field of transport and environment (TERM), which is used to identify many aspects of EU transport policy has also been developed. Monitoring of sustainable transport indicators is monitored by Eurostat, and the European Commission presents a report every two years assessing the implementation of the EU Sustainable Development Strategy.

Therefore, it is justified to look for new indicators that will allow to assess the environmental friendliness of

railway transport taking into account different points of view. The subject of the article is to assess the ecological profile of the railway transport system using the indicator method. The paper proposes five indicators according to which the assessment can be made. Three indicators are associated with the emission of harmful compounds (in the distinction between electric traction, diesel traction and steam traction), one with noise and one with valuable natural areas. The assessment of railway transport in the aspect of environmental protection for the area of Poland has been made. The emission of harmful compounds related to energy production for the needs of railway electric traction vehicles, the percentage share of people exposed to noise from railway transport, whose level is greater than or equal to 55 dB and the percentage share of the length of the railway line running through valuable natural areas was used as indicators. A summary and conclusions from the indicator analysis are presented.

2. Selected Indicators and Measures of Railway Transport Assessment in the Aspect of Environmental Protection

Analysing railways transport in terms of its impact on the environment three issues should be considered [1]:
- emission of pollutants;
- noise emission and vibration emission (which will be omitted in this article);
- occupying the area.

Emission of pollutants in railway transport can be considered from the point of view of the type of traction that supplies a given vehicle. Therefore, another emission will characterize vehicles powered by electric traction, other diesel traction and other steam traction. In the case of electric traction it may seem that these are non-emitting vehicles. However, it is necessary to burn an appropriate amount of coal to produce electricity (for Polish conditions). As a result, pollution occurs in the place where the power plant is located. In order to be able to compare the emissions of individual tractions, the authors propose the use of indicator $WE(t,zw)$ for time period t ($t \in \boldsymbol{T}$, where $\boldsymbol{T}$ – set of time periods) and for harmful compound zw ($zw \in \boldsymbol{ZW}$, where $\boldsymbol{ZW}$ – set of harmful compounds: CO_2, SO_2, NO_x, PM) (see formula (1)).

$$\forall t \in \boldsymbol{T} \quad \forall zw \in \boldsymbol{ZW} \qquad WE(t,zw) = \frac{EME(t,zw)}{LKE(t)} \quad \left[\frac{\text{mg}}{\text{km}}\right], \tag{1}$$

where $EME(t,zw)$ – amount of harmful compound zw emission associated with the production of electricity for the transport needs in the analysed time period with the number t (where the value from the end of this period is taken into account); $LKE(t)$ – length of the electrified railway lines in a given area during the period of time with the number t (where the value from the end of this period is taken into account).

Thus indicator $WE(t,zw)$ has an interpretation of the share of the emission volume of a given harmful compound zw on kilometre of the electrified railway line. In order to obtain the emission of a harmful compound zw in time period t – $EME(t,zw)$ it is necessary to read the amount of energy produced for transport [4] and then the share of rail transport in final energy consumption [12] and the result to be converted into emission [11].

To determine the emission of harmful compounds from diesel vehicles, the authors propose using the indicator $WS(t,zw)$ for time period t ($t \in \boldsymbol{T}$, where $\boldsymbol{T}$ – set of time periods) and for harmful compound zw ($zw \in \boldsymbol{ZW}$, where $\boldsymbol{ZW}$ – set of harmful compounds) (see formula (2)).

$$\forall t \in \boldsymbol{T} \quad \forall zw \in \boldsymbol{ZW} \qquad WS(t,zw) = \frac{EMS(t,zw)}{LKS(t) + a \cdot LKE(t)} \quad \left[\frac{\text{mg}}{\text{km}}\right], \tag{2}$$

where $EMS(t,zw)$ – amount of harmful compound zw emission associated with the production of energy for the needs of diesel traction in transport in the analysed time period with the number t (where the value from the end of this period is taken into account); $LKS(t)$ – length of the non-electrified railway lines in a given area during the period of time with the number t (where the value from the end of this period is taken into account); a – share of electrified lines on which diesel vehicles run; $LKE(t)$ – length of the electrified railway lines in a given area during the period of time with the number t (where the value from the end of this period is taken into account).

Thus indicator $WS(t,zw)$ has an interpretation of the share of the emission volume of a given harmful compound zw per kilometre of the railway line on which the diesel vehicles run.

To determine the emission of harmful compounds from steam vehicles, the authors propose using the indicator $WP(t,zw)$ for time period t ($t \in \boldsymbol{T}$, where $\boldsymbol{T}$ – set of time periods) and for harmful compound zw ($zw \in \boldsymbol{ZW}$, where $\boldsymbol{ZW}$ – set of harmful compounds) (see formula (3)).

$$\forall t \in \boldsymbol{T} \quad \forall zw \in \boldsymbol{ZW} \qquad WP(t,zw) = \frac{EMP(t,zw)}{b \cdot LKS(t) + c \cdot LKE(t)} \quad \left[\frac{\text{mg}}{\text{km}}\right], \tag{3}$$

where $EMP(t,zw)$ – amount of harmful compound zw emission associated with the production of energy for the needs of steam traction in transport in the analysed time period with the number t (where the value from the end of this period is taken into account); b - share of non-electrified lines on which steam vehicles run; $LKS(t)$ – length of the non-electrified railway lines in a given area during the period of time with the number t (where the value from the end of this period is

taken into account); c – share of electrified lines on which steam vehicles run; $LKE(t)$ – length of the electrified railway lines in a given area during the period of time with the number t (where the value from the end of this period is taken into account).

Thus indicator $WP(t,zw)$ has an interpretation of the share of the emission volume of a given harmful compound zw per kilometre of the railway line on which the steam vehicles run.

The indicator presented in Directive 2002/49/EC of the European Parliament and of the Council [7] – L_{den} is used to estimate the noise emitted by means of railway transport. It describes the equivalent sound level in day, evening and night. It is expressed in decibels (dB). It can be calculated according to the formula (4).

$$L_{den} = 10\lg\frac{1}{24}\left(12\cdot 10^{\frac{L_{day}}{10}} + 4\cdot 10^{\frac{L_{evening}+5}{10}} + 8\cdot 10^{\frac{L_{night}+10}{10}}\right) \quad [\mathrm{dB}], \tag{4}$$

where L_{day} – average sound level for all day period of the year (usually 07:00 - 19:00); $L_{evening}$ – average sound level for all evening period of the year (usually 19:00 – 23:00); L_{night} – average sound level for all night period of the year (usually 23:00 – 07:00).

It should be noted that the sound level is measured at a specific point, usually in an agglomeration. Obtaining the parameter value is quite complicated, because a number of measurements have to be made. In addition, the Directive allows the use of other indicators that have been characterized in it.

The analysed sources (among others [23]) define problematic noise level at the level of 55 dB and more. Available data refers only to the number of people living in the area that are exposed to such noise levels. Therefore, for this formulated parameter, it is possible to define the indicator of the rail transport system environmental friendliness $WH(o)$ for the area with the number o ($o \in \boldsymbol{O}$, where $\boldsymbol{O}$ – set of areas) (see formula (5)):

$$\forall o \in \boldsymbol{O} \qquad WH(o) = \frac{LO_{L_{den}\geq 55[\mathrm{dB}]}(o)}{LO(o)}\cdot 100\% \quad [\%], \tag{5}$$

where $LO_{Lden\geq 55[\mathrm{dB}]}(o)$ – the number of people who are exposed to noise coming from means of railway transport with a level greater than or equal to 55 dB living in the area with the number o; $LO(o)$ – number of people living in the area with the number o.

Thus indicator $WH(o)$ has an interpretation of the percentage share of people living in a given area that are exposed to noise, which level is greater than or equal to 55 dB.

It is important that the European Commission, in order to create one coherent rail transport system across Europe, has developed Technical Specifications for Interoperability, which also deal with the issue of noise emissions [5, 6, 8]. The document mentions various types of noise. For freight wagons it is [8]: pass-by noise and stationary noise. For locomotives, traction units and passenger cars it is [8]: stationary noise, starting noise, pass-by noise and noise inside the driver's cab. For each type of transport means and for each type of noise, the Directive sets a maximum level for a continuous equivalent sound pressure level. The measurement conditions are also described. In conclusion, the Directive refers mainly to rolling stock manufacturers to produce vehicles that comply with the values presented.

When deciding whether to build a new railway line or modernizing the existing route [20] it is necessary to take into account the minimization of the impact of this investment on the environment. This impact can be considered from many points of view. One of them may be planning the route of the line through naturally valuable areas, especially Natura 2000 protected areas. Therefore, the indicator $WO(lk)$ for a section of a railway line [10] lk can be defined ($lk \in \boldsymbol{LK}$, where $\boldsymbol{LK}$ – set of railway lines) (see formula (6)):

$$\forall lk \in \boldsymbol{LK} \qquad WO(lk) = \frac{\sum_{odc\in \boldsymbol{ODC}} LLK_{chr}(lk,odc)}{LLK(lk)}\cdot 100\% \quad [\%], \tag{6}$$

where $LLK_{chr}(lk,odc)$ – sum of the length of the section parts odc ($odc \in \boldsymbol{ODC}$, where $\boldsymbol{ODC}$ – set of parts to which the section of railway line with the number lk has been divided) analysed railway line with number lk, located in protected areas (naturally valuable); $LLK(lk)$ – length of the analysed railway line with number lk.

Thus indicator $WO(lk)$ has an interpretation of the percentage share of the section of the analysed railway line running through protected areas (naturally valuable) in the length of the analysed section of the railway line. For the purposes of the article, the term railway line is to be understood as [24]: part of the railway line between junction stations or between the starting or ending point of the railway line and the nearest junction station, also [10] part of the railway line between two passenger stops and between the passenger stop and operating control point.

3. Case Study – Evaluation of Railway Transport in the Aspect of Environmental Protection

The article evaluates railway transport in the aspect of environmental protection from the point of view of the indicators discussed in point 2 of the article. The first indicator is the emission volume of individual harmful

compounds per kilometre of electrified railway lines $WE(t,zw)$. The volume of individual harmful compounds in 2016 was as follows:

– for CO_2:

$$WE\left(2016,\mathrm{CO}_2\right)=\frac{EME\left(2016,\mathrm{CO}_2\right)}{LKE\left(2016\right)}=\frac{75854}{11874}=6{,}39\quad\left[\frac{\mathrm{Mg}}{\mathrm{km}}\right]; \tag{7}$$

– for SO_2:

$$WE\left(2016,\mathrm{SO}_2\right)=\frac{EME\left(2016,\mathrm{SO}_2\right)}{LKE\left(2016\right)}=\frac{554}{11874}=0{,}05\quad\left[\frac{\mathrm{Mg}}{\mathrm{km}}\right]; \tag{8}$$

– for NO_x:

$$WE\left(2016,\mathrm{NO}_x\right)=\frac{EME\left(2016,\mathrm{NO}_x\right)}{LKE\left(2016\right)}=\frac{970}{11874}=0{,}08\quad\left[\frac{\mathrm{Mg}}{\mathrm{km}}\right]; \tag{9}$$

– for PM:

$$WE\left(2016,\mathrm{PM}\right)=\frac{EME\left(2016,\mathrm{PM}\right)}{LKE\left(2016\right)}=\frac{35}{11874}=0{,}003\quad\left[\frac{\mathrm{Mg}}{\mathrm{km}}\right]. \tag{10}$$

The values shown above refer to the entire year. Assuming that in 2016 there were 366 days, the daily emission of individual compounds were as follows: CO_2 – 17459,02 g/km, SO_2 – 136,02 g/km, NO_x – 218,58 g/km, PM – 8,2 g/km. For comparison, a petrol car engine with the EURO5 exhaust standard has a permissible NOx emission value of 0,06 g/km. he emission of nitrogen oxides for electric trains is equivalent to the emission of 3646 gasoline car engines. This corresponds to average 24-hour traffic on almost 14% of national roads in Poland. In addition, the gasoline engine with the EURO5 exhaust standard has an acceptable particulate matters emission value of 0,005 g/km. The amount of particulate matters emission for the needs of electric trains is equivalent to the emission from 1640 car engines, which corresponds to average 24-hour traffic on 2,5% of national roads in Poland.

Due to the difficulties in estimating the share of electrified lines on which the diesel and steam vehicles run, as well as the share of non-electrified lines on which steam vehicles run, the values of indicators $WS(t,zw)$ and $WP(t,zw)$ were not calculated.

Next element that can be assessed as the environmental friendliness of railway transport is the assessment of the noise level emitted by means of railway transport. As already mentioned in point 3 of the article, getting the parameter value is quite complicated, because a number of measurements have to be made. Thus, the data available on the Internet was used to implement the example [23]. Table 1 presents the values of the $WH(o)$ indicator for selected agglomerations in Poland.

Table 1

Values of the $WH(o)$ indicator for selected agglomerations in Poland (source: [21] – data from 2012)

Area ($o \in \boldsymbol{O}$)	Bialystok	Cracow	Lodz	Warsaw	Zabrze	Poland
	$o = 1$	$o = 2$	$o = 3$	$o = 4$	$o = 5$	$o = P$
$WH(o)$	0,1%	0,78%	15,41%	0,71%	26,43%	0,04%

The following conclusions can be drawn from Table 1. In Poland, the share of people living in a given area (country) that are exposed to noise with a level greater than or equal to 55 dB in the total population is 0,04%. So this problem affects 4 people per 10,000 inhabitants. This value is much lower than the indicator value for the presented agglomerations. The lowest value was obtained for Bialystok. The probable reason for this is that the number of trains running is relatively low. Low values were also obtained for Cracow and Warsaw - this is probably due to the size of the agglomeration, as the railway traffic in these regions is quite large. The value for Lodz and Zabrze is much higher than for other agglomerations. Here, the problem affects respectively 15 and 26 people per 100 inhabitants. This value is high and probably related to high density of railway traffic.

Last proposed indicator for assessing the environmental friendliness of railway transport is the indicator of the share of the length of the railway line section running through naturally valuable areas in relation to the length of this section of the railway line $WO(lk)$. As an example of determining the value of the indicator, the problem of determining the rational course of the Central Trunk Line (railway line no. 4) through the Brudzewskie forests stretching from Inowlodz to Radzice [2] will be used. These forests are located along the Strzalki - Idzikowice open line with the length $LLK(1) = 23{,}23$ km. Three variants of the route have been planned: first variant: $LLK_{chr}(1,1) = 5$ km, second variant:

$LLK_{chr}(1,1) = 7,4$ km, third variant: $LLK_{chr}(1,1) = 7,6$ km. Table 2 presents the values of the $WO(lk)$ indicator for individual variants of the route along the railway line 4.

Table 2

Values of the $WO(lk)$ indicator for individual variants of the route along the railway line 4 (source: own work)

Railway line ($lk \in \boldsymbol{LK}$)	Variant 1	Variant 2	Variant 3
	$lk = 1$	$lk = 1$	$lk = 1$
$WO(lk)$	21,52%	31,86%	32,72%

When comparing the three variants for which the indicator value is calculated in Table 2, the value of the indicator is expected to assume the lowest possible values. Therefore, the most advantageous variant is the first one because the share of the section running through naturally valuable areas is the smallest. It should be noted that variant 3 was chosen for construction, because despite the necessity to cut a large part of the forest (about 26.2 ha [2]) it did not require demolitions in households and allowed to cross the Pilica river at right angles.

4. Summary and Conclusions

The subject of the article was to assess the environmental friendliness of the railway transport system using the indicator method. Emissions of harmful compounds associated with energy production for the needs of railway electric traction vehicles, percentage share of people exposed to noise from rail transport, whose level is greater than or equal to 55 dB and the percentage share of the length of the railway line running through valuable natural areas were taken into account.

The article analyses the daily unitary emission of harmful compounds (expressed in grams per kilometre) related to the production of electricity for the needs of electric railway traffic. On the example of nitrogen oxides NO_x and particulate matter $PM_{2,5}$ and PM_{10}, it is possible to compare emission values for rail and road transport. It should be noted that in the case of nitrogen oxides, the obtained volume is equivalent to the emission made by nearly 3,7 thousand gasoline passenger cars, which can be compared to the daily traffic intensity of almost 15% of national roads in Poland. It should be noted that there is more traffic on other national roads. In the case of particulate matter, the difference is smaller - the volume of emissions from rail transport means is equivalent to emissions of 1,6 thousand gasoline passenger cars, which can be compared to the daily traffic intensity of almost 2,5% of roads in Poland. On other national roads traffic is higher. Therefore, it can be summarized that the volume of daily emission for the needs of the movement of electric traction vehicles is not high in relation to the analogous emission by means of road transport. However, it should not be overlooked in conducting analyses, as it has a significant impact on environmental pollution - especially at the point of energy production.

In large agglomerations, where the railway network is characterized by high density and there is a high demand for transport, there is a problem with noise originating from railway transport means. As indicated on the example of Lodz and Zabrze - the size of the population exposed to noise from this mode of transport above the permissible level of 55 dB is quite high (for Zabrze it is even ¼ of the population). It should also be noted that there is a significant negative effect of noise on the railways. In recent years, we can see more and more hits of outsiders passing through the tracks in places that are not designated. The manufactured rolling stock moves faster and quieter. Inattentants passing do not hear the approaching train, resulting in usually fatal effects.

The assessment of the environmental friendliness of the railway transport system using the indicator interpreting percentage share of section of analysed railway line running through valuable natural areas in length of analysed section of the railway line allows for selection of variant that has the shortest course of protected areas. It should be noted that the choice of the route variant or the modernization option should not be based solely on the value of one indicator. It is recommended that the choice should be made using multi-criteria evaluation methods, because in this decision-making problem there are many criteria whose goals are contradictory.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Remote Inventory of Computer Software in Transport Enterprises

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Abstract

Dynamic development of the IT industry causes a rise in availability of IT solutions dedicated to transport. It mainly concerns logistics: planning, processing and controlling efficient flow of goods and people. The main task of IT systems is supporting transport management, including the best use of fleet, which reduces costs of operation of a freight company. That is why IT systems are a key element of every transportation company. Because of the fact that IT technologies play an important part in transportation systems, the management of IT resources, especially including software management, is obligatory. The authors of the article have noticed this important problem and have developed software allowing remote inventory of computer systems software. Additionally, the software allows the control of discs' space and RAM. This software uses the SNMP (Simple Network Management Protocol) technology, which makes it possible to make an inventory of software running under the MS Windows and Linux operating systems. What is important is that one does not need to install any additional client software, one only needs to correctly set up the operating system. In this article, the authors have presented methodology of how to use this technology and how to implement it. The conducted research has proven a great usefulness of the SNMP standard in controlling IT resources of computer systems used in transport.
KEY WORDS: *software auditing, SNMP, transport IT systems*

1. Introduction

Contemporary transport companies commonly use IT systems when providing their services [2, 3, 13]. It causes growth of the IT infrastructure and influences the amount and gravity of the processed data [9, 11]. That is why demands concerning assuring maximum level of reliability and accessibility of IT systems constantly grow [15, 16]. Negative effects of failures leading to stoppages translate into profits or losses of the company. Apart from the direct financial losses, a transport company may also suffer reputational damage caused by unreliable services offered, which can influence its future [1, 4, 10]. A constant growth of meaning of the IT technology in efficient and failure-free running of transportation processes draws more attention to IT resources management. That is why, it is extremely important to monitor all crucial elements of the IT infrastructure [5-8]. Monitoring systems assure a prolonged failure-free operation time of the IT infrastructure, which reduces their operation cost to a great extent. One can propose a thesis that monitoring the IT infrastructure in a transport company is not only a possibility, but a requirement assuring its flawless work. Apart from avoiding failures, what is also important is knowledge concerning programs installed on the company computers. A lack of software license is a copyright breach that, in case of control, may lead to computer equipment confiscation and big financial fines. The authors of this article, noticing this significant problem, have developed the ITaudit software allowing a remote computer system software inventory, but also control of the disks and operational memory storage. This software uses the SNMP (Simple Network Management Protocol) technology that is why it is not required to install additional client software, but only to properly set up the operating system [12, 14, 17]. The implementation of the SNMP protocol for controlling IT resources of the computer systems and gathered results have proven a great usefulness of this technology and its practical usage.

2. Benefits of IT Infrastructure Monitoring

Monitoring the IT infrastructure carry a number of benefits, not only for the IT department responsible for its management, but also for the whole enterprise, which includes:

1. Assuring up-to-date information about the IT infrastructure – because of the constant technological changes and evolution of business needs of the company, knowledge regarding the current IT infrastructure status is obligatory. Such information can be delivered by the monitoring system, supporting proactive system management.

2. Predicting and solving hardware and software problems – appropriately developed monitoring and alarming system allows to avoid many problems associated with efficiency and capacity, and even if they occur, the system allows to shorten the time to restore services. Gathered data concerning the IT infrastructure allows to develop alarms,

automatic remedial actions or standard procedures.

3. Preventing breakdowns through early problems detection – supervision over individual IT service performance parameters increases chances of protection against failures. Regular monitoring of the service status allows to identify abnormalities in their operation.

4. Increasing capacity – monitoring concerns not only the control of the current capacity, but also identification of areas that need improvement consisting in adapting all elements of the IT service, in order for them to work optimally.

5. Facilitation in planning the IT infrastructure modernization – devices and software have their live span which needs to be monitored. The IT department should have the infrastructure elements records and their modernization plan.

6. Maximization of the return on investment – monitoring software efficiency allows an instant access to data, delivers information necessary in reporting to the company board and analyses trends.

7. Ensuring quality level of the provided service – monitoring guarantees collecting much information that can be analysed and used for detailed reports. A lack of system efficiency should be noticed before the quality level of provided services affects customers' and partners' trust.

8. Increasing data security level in the company – monitoring, during the times in which cybercrime is more and more frequent, can be an effective tool increasing data safety.

9. Lightening the load on the IT department – thanks to monitoring, IT workers' attention can be directed at avoiding shortages in spite of removing the effects of the failure.

3. The ITaudit Tool

The ITaudit tool is a proprietary solution developed by the authors of this article. A remote control of computer software with the use of the ITaudit software is only possible when their IP addresses are on the list of audited computers. Creating such a list takes place as a result of automatic network scanning conducted in order to detect all computers that have the SNMP service active. The scanning can also be performed in the broadcast mode or in the range of IP addresses indicated by the user in the parameterization process (Fig. 1).

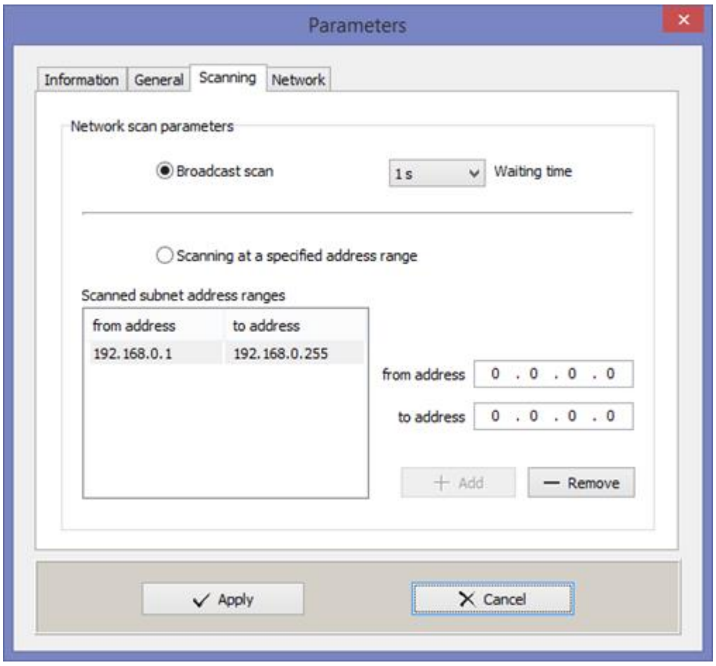

Fig. 1 The network scanning parameterization window in the ITaudit tool

ITaudit also allows to manually add an IP address of the chosen computer to the list, provided that it is an SNMP agent. Software audit can be performed later on for all these computers. After the first check-up all detected items are in the "Installed" field of the report and the "Uninstalled" field is empty (Fig. 2).

ITaudit with subsequent audits detects all changes in the range of the software used. Extracting software inventory information with the SNMP is accomplished through reading the hrSWInstalledTable object of the MIB (Management Information Base). If any software is installed or uninstalled, such information is shown in the report after the audit. It gives the computer system administrator control over software of all controlled computers. Additionally, during the software audit, the ITaudit tool provides information about the operating system and processor version through reading the sysDescr MIB object, also it checks and visualizes the occupancy of the disks and operating memory of the computer through reading the hrStorageTable MIB object. As a result of this control, one gains information about the available disk storage and RAM memory (Fig. 3).

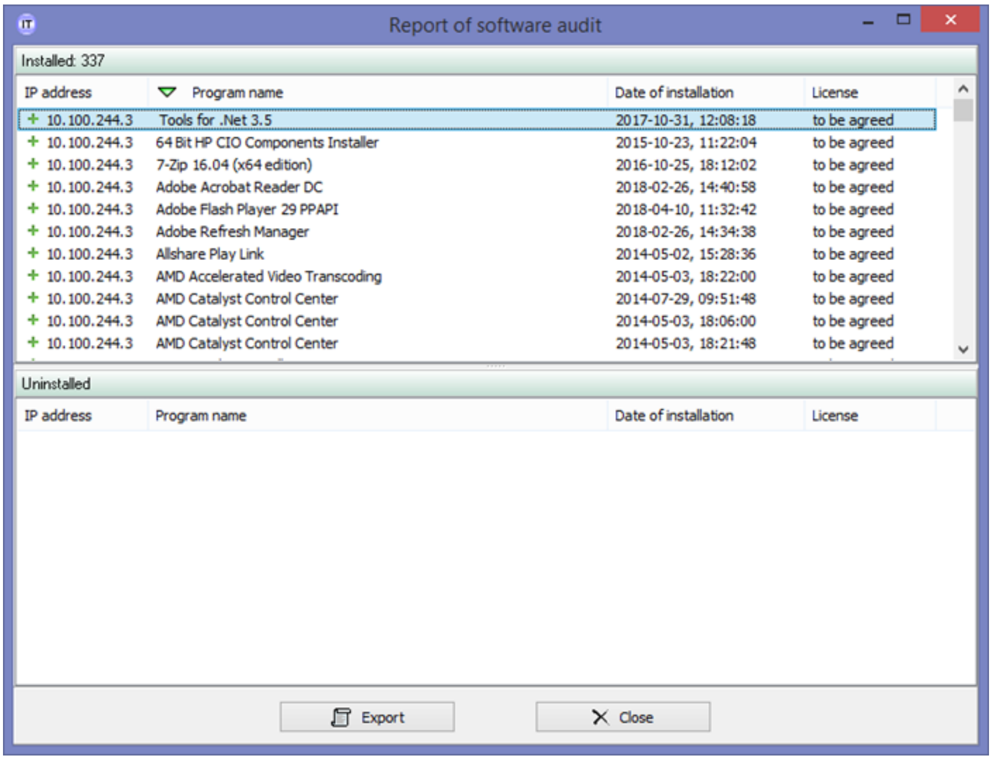

Fig. 2 A report of software audit

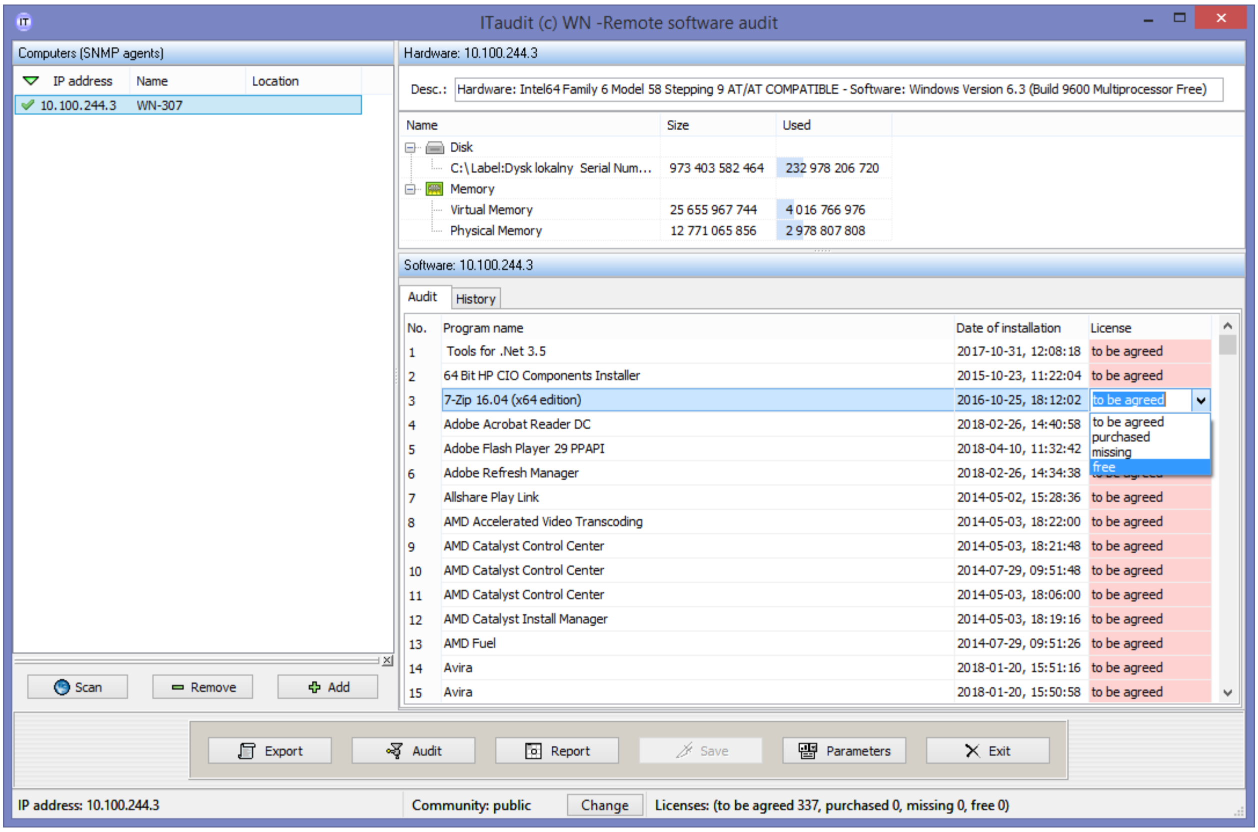

Fig. 3 The main window of the ITaudit tool

As a result of the conducted audit, the list of the installed on the computer software is updated. The ITaudit stores the software name, its installation date and license status. After performing the first audit, all items have “to be agreed” license status (Fig. 3). The computer system administrator, on the basis of the type of software and licenses owned, needs to update the “License” field. It can be done for single entries on the software list (Fig. 3) or for a chosen software group (Fig. 4). In both cases there is a possibility to change the license status to “to be agreed”, “purchased”, “missing” or “free”.

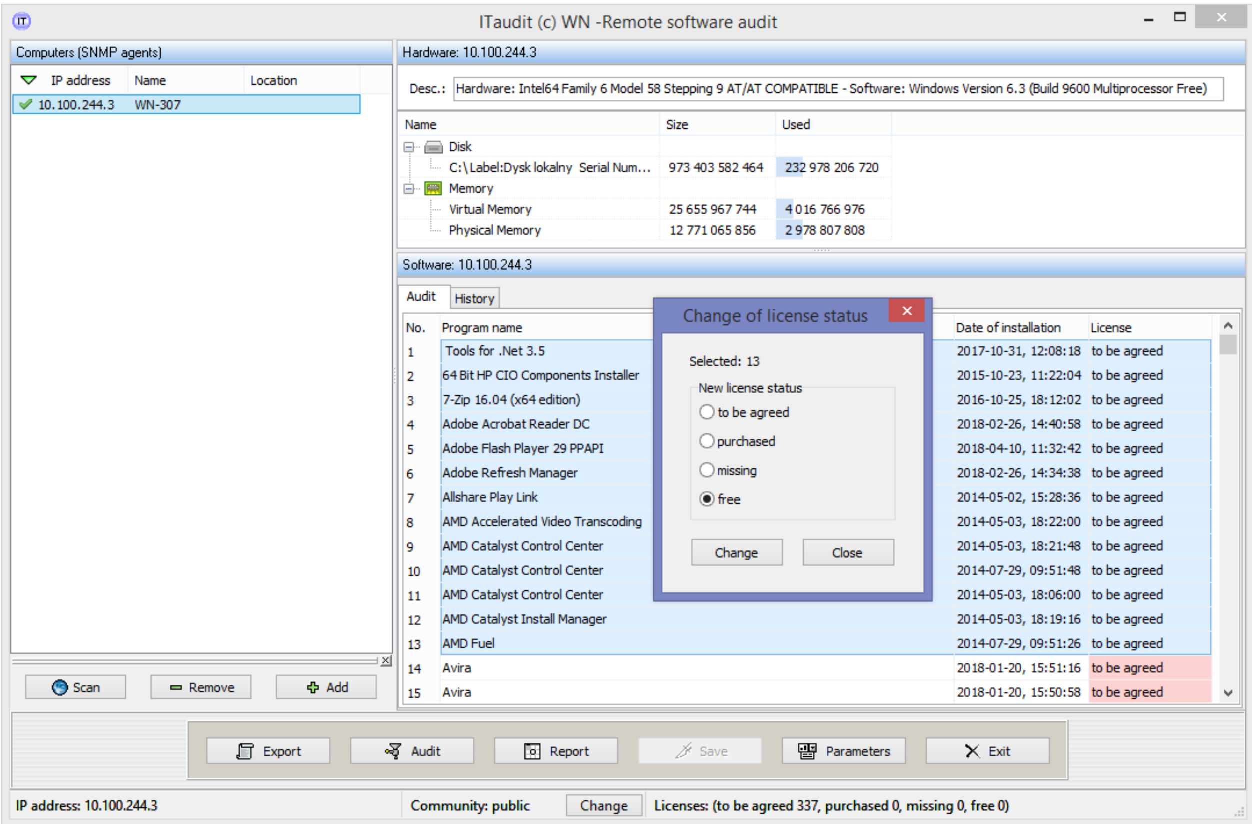

Fig. 4 A group change of software license status

After the conducted update, an organized software list with the correct license is obtained (Fig. 5). All information provided by the computer systems administrator are stored in the local SQLite data base.

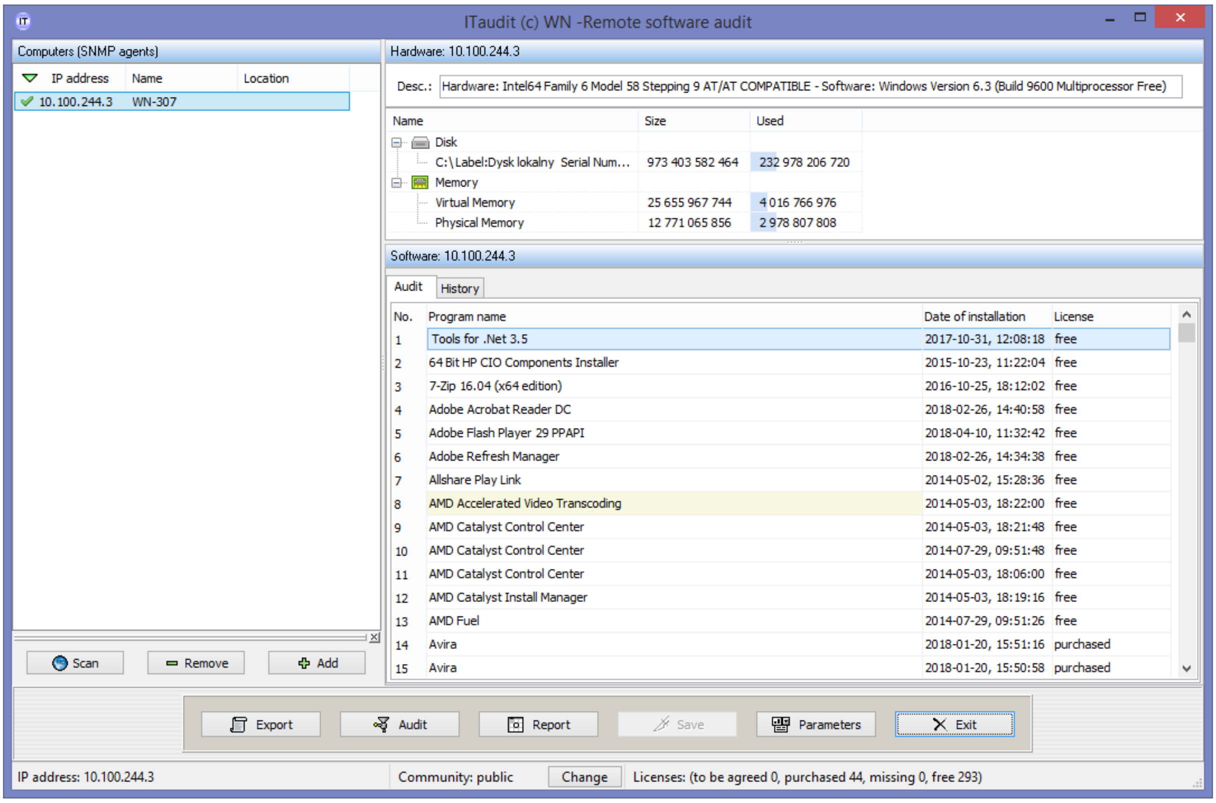

Fig. 5 The main window of the ITaudit tool after setting the license status

At any time in the ITaudit software one can create a report being the list of licenses for all computers. Then, one obtains a summary report for all audited computers containing a list of used or missing licenses (Fig. 6). It is also possible to check to which computers these licenses are ascribed (Fig. 7).

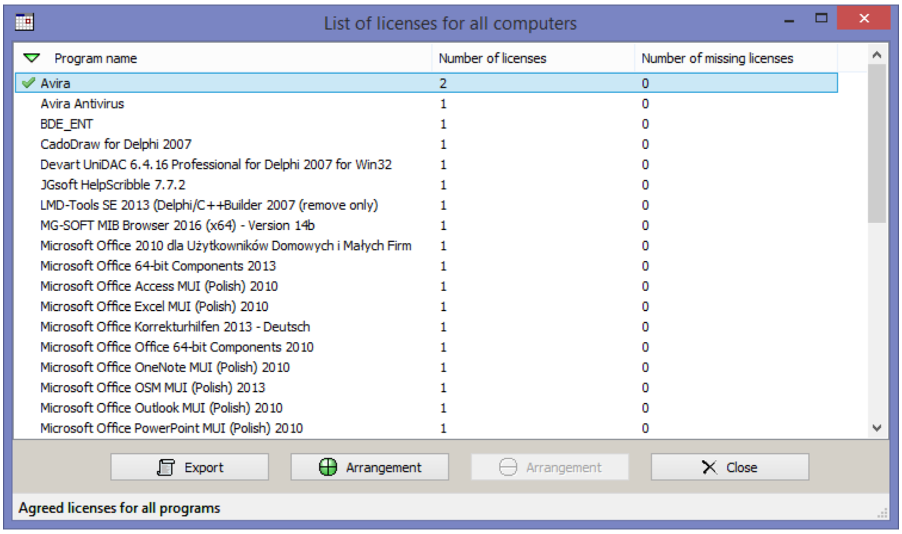

Fig. 6 A sample report with a list of licenses for all computers

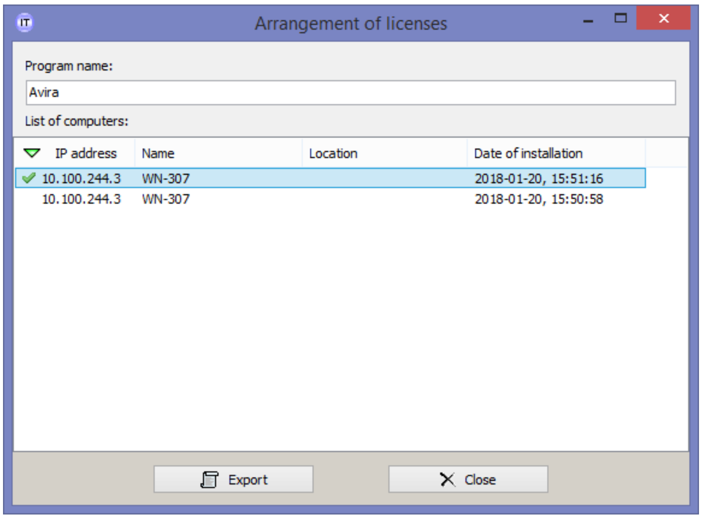

Fig. 7 A sample report with the location of licenses

All reports can be exported and then saved in the following format files: PDF, XLS or XML (Fig. 8).

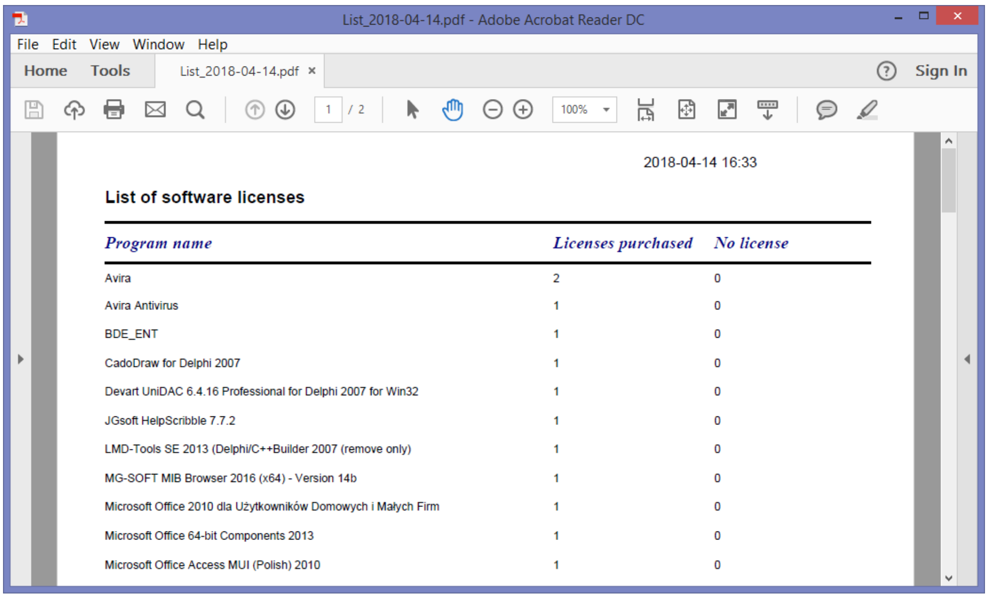

Fig. 8 A sample report created in the ITaudit tool

4. Conclusions

IT resources of a transport company constitute a significant part of the company's assets. In order to use these resources properly, it is essential to have right tools serving for their inventory and checking their level of use. Legal requirements imposing creating a detailed register of software are also of great importance. The bigger the transport company is, the more difficult it is to run IT resources audits without the proper tools. There are many paid or free tools that have such a functionality. Usually they use agents installed on the monitored computers or, in case of the Windows systems, they are based on the WMI (Windows Management Instrumentation) service. The authors of this article have proposed a tool that is based on the SNMP protocol, thanks to which an inventory of the software operating under different operating system is possible. Importantly, it is not required to install any additional software on the audited computers. Gathered results have proven a great usefulness of this technology, and the software developed by the authors can be used not only in transport companies.

Acknowledgment

This material is based upon work supported by National Centre for Research and Development under Grant No. PBS3/A6/29/2015 entitled „The system for maintenance data acquisition and analysis of reliability and safety of traffic control systems".

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Use of the Wavelet Transform for the Analysis of Irregularity of Crankshaft Angular Velocity

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Abstract

The issue of quick and qualitative receiving of reliable and complete information concerning the technical state of a diesel engine in the locomotive is relevant one, although there are already many technical solutions in this direction. Indirect methods for diesel engine diagnostics are of gain ground. Among the existing methods, the diagnostics of the diesel engine technical state occupies a special place due to the analysis of irregularity of crankshaft angular velocity.
Within the working cycle of the diesel engine, the crankshaft angular velocity of rotation is constantly changed. The mechanical inertia system of the pistons, rods and shaft receives impulses of mechanical energy from fuel combustion, as well as pulsed losses of kinetic energy on pump pistons-stroke. Thus, the value and shape of the torque of each cylinder affects the angular velocity of the shaft.
The purpose of the research is to study the various types' application for basic functions of wavelet transform to emphasize the diagnostic information from the signal of angular velocity irregularity of the diesel engine shaft. This will automate the process of diagnosing the diesel engine.
The authors conducted simulation of the working process of a shunting diesel locomotive with hydrodynamic transmission. Type of the diesel engine: six-cylinder in-line engine with turbo-charger, power 750 hp. The nominal modes of the diesel engine operation at the crankshaft speed of 1400 rpm were considered. There are simulation of the fault-free condition and two types of faults: the change of fuel injection advance angle and change of the cycle fuel injection to greater and smaller sides from the passport date. For the resulting angular-velocity vectors and acceleration we applied continuous wavelet transform with different basic functions. The obtained results are estimated by energy criteria. The most promising basic functions are separated from the point of view of the most complete estimation of the energy for the portion of the signal carrying diagnostic information.
KEY WORDS: *angular velocity irregularity, non-separable diesel diagnosis, digital signal filtering, spectral analysis, phase shift*

1. Introduction

The issue of quick and qualitative receiving of reliable and complete information concerning the technical state of a diesel engine in the locomotive is relevant one, although there are already many technical solutions in this direction [3, 4]. Indirect methods for diesel engine diagnostics are of gain ground. Among the existing methods, the diagnostics of the diesel engine technical state occupies a special place using the analysis of irregularity of crankshaft angular velocity. The method is easy to measure, but requires a rather complex analysis for receiving the diagnostic information.

Within the working cycle of the diesel engine, the crankshaft angular velocity is constantly changed. The mechanical inertia system of the pistons, rods and shaft receives impulses of mechanical energy from fuel combustion, as well as pulsed losses of kinetic energy on pump pistons-stroke. Thus, the value and shape of the torque of each cylinder affects the angular velocity of the shaft [1]. The essence of the method is to measure the crankshaft angular velocity of the diesel engine with high resolution and to determine the characteristic indicators that give evidence of the working process quality in cylinders and the technical state of the diesel engine as a whole.

For the signal analysis of the irregularity of crankshaft angular velocity for a diesel engine, the Fourier series expansion is traditionally used. However, the analysis based on infinite basic functions (sin, cos) does not provide information about the local features of the signal and adequately reflects only the stationary processes. When considering the angular velocity signal of an ideally free-fault engine, it can be considered stationary one, at any time (extent to which) the signal frequency will be the same. But in a real engine, the working processes in adjacent cylinders differ significantly (according to the passport data of the diesel engine 211D2, the difference in Pz is allowed up to 0.2 MPa), in addition, the reason code in pressure may be various, so the signal of the real engine can hardly be called stationary. A more advanced analysis tool is a wavelet transform using finite basic functions of various forms. This provides wavelet transform with wide opportunities for separation and localization of signal features. A number of works are known in which wavelet transforms are used to diagnose the technical means [5-6, 11, 14] and internal combustion engines [7-10, 12, 15].

2. Purpose

The purpose of the research is to study the various types application for basic functions of wavelet transform to emphasize the diagnostic information from the signal of irregularity of crankshaft angular velocity for a diesel engine. This will automate the process of diagnosing the diesel.

3. Methodology

Simulation of the working process of a diesel in the diesel-locomotive shunter with hydrodynamic transmission (inline six-cylinder, with turbocharger, power 750 hp) at the rated power setting of 1.400 rpm at fault-free and faulty states was carried out. For the research, two types of malfunctions are selected which can be simulated in the full-scale experiment: the change of fuel injection advance angle within the limits of +10 and -10° crankshaft angle. from the passport date of 33° and the change of the cycle fuel injection by 15% to the larger and smaller sides of the normal cyclic feed. Simulation of the working process is performed in the software product DIESEL-RK, development of Bauman N. E. MSTU. The result is detailed indicator diagrams, heat dissipation characteristics and all necessary performance indicators of the working process. Indicator diagrams are used as source data for the model of the diesel engine mechanical system. The model involves a rigid crankshaft. The result of the simulation is the graphical dependencies of the diesel engine torque, angular velocity and shaft acceleration at the listed faults in one of the diesel engine cylinders.

Table 1

Simulation data of indicator values at the change of fuel injection advance angle

Angle of injection α , °	Mean effective pressure P_e, MPa	Specific effective fuel consumption g_e, kg / (kW*h)	Maximum combustion pressure P_z, MPa	Mean indicated pressure P_i, MPa
23	1.077	0.221	10.16	1.28
33	1.083	0.219	10.91	1.29
43	0.989	0.240	8.59	1.18

Simulation is carried out in the mode of nominal load of a diesel engine at a rotational velocity of 1400 min –1 with the help of the software product DIESEL-RK, development of Bauman N. E. MSTU. Simulation data of operating parameters are presented in Tables 1 and 2 and in Figs. 1-5.

Table 2

Simulation data of indicator values at the change of fuel injection advance angle

Cyclone fuel injection q_c, g	Mean effective pressure P_e, MPa	Specific Effective fuel consumption g_e, kg / (kW*h)	Maximum combustion pressure P_z, MPa	Mean indicated pressure P_i, MPa
0.360	0.78	0.226	10.97	0.99
0.480	1.088	0.218	11.62	1.3
0.600	1.35	0.219	12.02	1.56

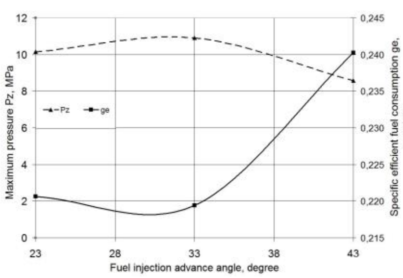


Fig. 1 Calculating dependence of indicator values P_z and g_e on the fuel injection advance angle

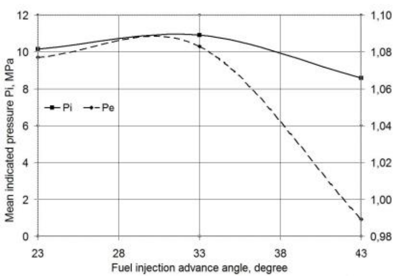


Fig. 2 Calculating dependence of indicator values P_i and P_e on the fuel injection advance angle

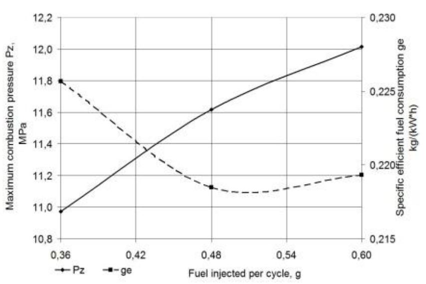


Fig. 3 Calculating dependence of indicator values P_z and g_e from cycle fuel supply

Fuel injection advance angle has a complicated mechanism of impact on indicator values.

With an increase of the advance angle, fuel injection begins at lower values of temperature and pressure, which worsens the fuel evaporation conditions and increases the delay time of self-ignition. As a result, growth rates of pressure, load on the cylinder–piston group parts increase, as well as the effective operation of the engine decreases, since a significant portion of the work of gas forces is expended on the rigid operation of the engine. When decreasing the advance angle - the effect is also negative, fuel burns out much later than TDC, which also decreases performances. When testing a diesel engine it is important to set the optimum actual advance angle, which according to the passport data has a spread of + - 3° for a particular diesel engine and even a cylinder and fuel equipment.

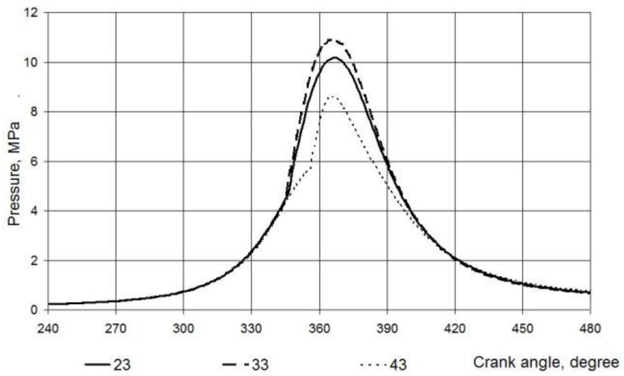


Fig. 4 Simulation results of the indicator pressure and the rate of heat dissipation at various fuel injection advance angle – 23. 33 and 43 degrees up to TDC

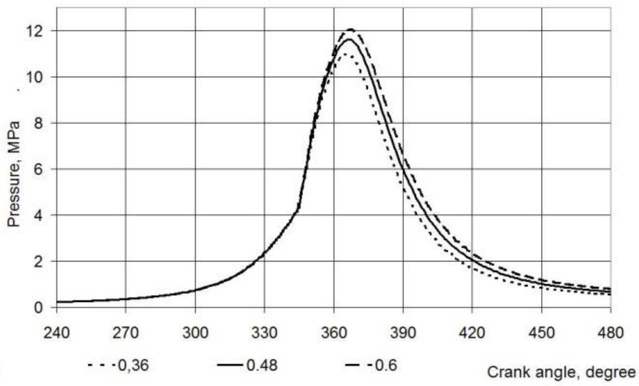


Fig. 5 Simulation results of indicator pressure and the rate of heat dissipation when changing cyclic fuel injection

Taking into account the assumptions that the engine is operating in steady state mode, and the mechanical system of the crank - connecting rod mechanism is rigid, then the dynamic model of the is based on a known equation of moment balance:

$$J\ddot{\theta}=T_e(\theta)=T_p(\theta)-T_r(\theta)-T_L(\theta), \tag{1}$$

where J - an effective moment of inertia of the rotating engine parts; θ - angular position of crankshaft and corresponding functions of time $\theta=\theta(t)$, $\dot{\theta}=d\theta/dt$, $\ddot{\theta}=d^2\theta/dt^2$; $T_e(\theta)$, $T_r(\theta)$ - the torque of inertia (or effective torque) and the moment of inertia of the reciprocating masses; $T_p(\theta)$ - indicator moment; $T_L(\theta)$ - total moment of engine resistance.

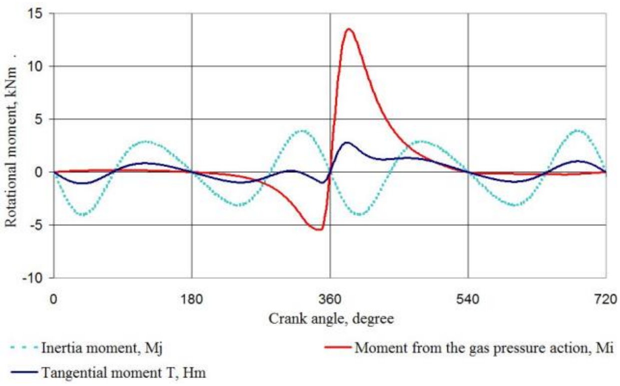


Fig. 6 Graphic dependence of moments on the action of indicator pressure and inertia force

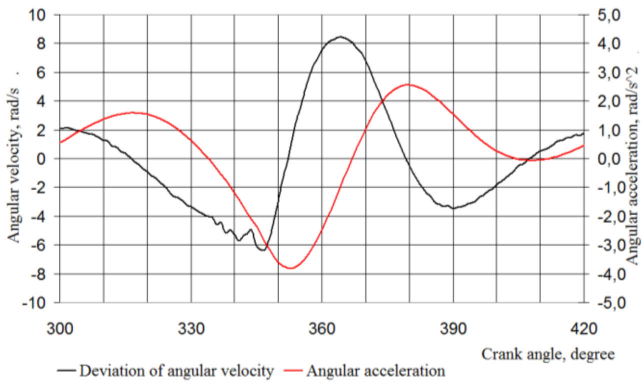


Fig. 7 Angular velocity w and acceleration ε at normal operation, the advance angle $\theta=33°$

According to the row-organized layout of the diesel engine 211D2, the working processes in adjacent cylinders are superimposed, but in the range of -60° and + 60°, according to TDC of a particular cylinder, only insignificant moments from the initial stages of the compression stroke and the final stages of the operating stroke of the adjacent cylinders affect its indicative moment (Fig. 6). In the general case, the angular acceleration graph (Fig. 7) in the specified angle range of 120° has two main extremes. The positive corresponds to the maximum of the torque during the running gear, and the negative one to the minimum torque at the compression stroke. Thus the difference between them corresponds to the positive work of the cycle.

Calculated above, the tangential forces T for each considered state of the working process are to be summed according to the operation of the cylinders in such a way that all cylinders except the third have a fault-free working process. Consequently, we have six variations of the state of the third cylinder with all other fault-free cylinders.

The wavelet transform allows interpreting the signal in frequency and time measurements and investigate each component of the decomposition, taking into account frequency and time localization. There are continuous (CWT) and discrete (DVT) wavelet transforms. The first one is used to analyze the signals and to separate its characteristic features, and the discrete transform is successfully applied in algorithms for noise filtering and compression of images and data. Moreover, the feature is the ability to perform filtration according to DWT in the FIR-filter format [2], which significantly reduces the calculation.

The wavelet transform decomposes the signal using expanded and shifted wavelets ψ :

$$\psi_{a,b}(x) = |a|^{-1/2} \psi\left(\frac{x-b}{a}\right). \tag{2}$$

As wavelet ψ has a zero mean value, wavelet transform function f:

$$W_{a,b} = |a|^{-1/2} \int f(x) \left(\frac{x \int -b}{a}\right) dx, \tag{3}$$

measures the change f in the point area b, the size of which is proportional a.

Reverse wavelet transform will be:

$$f(x) = C_{\psi}^{-1} \int W_{a,b} \psi_{a,b}(x) \frac{da\, db}{a^2}, \tag{4}$$

where

$$C_{\psi} = \int |\psi(x)|^2 \frac{d\omega}{|\omega|} = \int \left| \int \exp(-ix\omega) \psi(x) dx \right|^2 \frac{d\omega}{|\omega|}. \tag{5}$$

The primary task in wavelet analysis of a signal is to determine the wavelet basis from a wide range of basic functions. The procedure for selecting a rational basis is not formalized, and the selection criteria depend on the particular task of the analysis [13].

When selecting a wavelet basis, the criterion of distribution entropy minimum for squares of the moduli of wavelet coefficients is most often used:

$$E(x) = -\sum_{\beta=1}^{m} \sum_{j=1}^{2^{(m-\beta)}} x_j^{(\beta)} \cdot \ln\left(x_j^{(\beta)}\right) \to \min; \tag{6}$$

$$x_j^{(\beta)} = \frac{\left|c_j^{(\beta)}\right|^2}{\left\|c_j^{(\beta)}\right\|^2}, \tag{7}$$

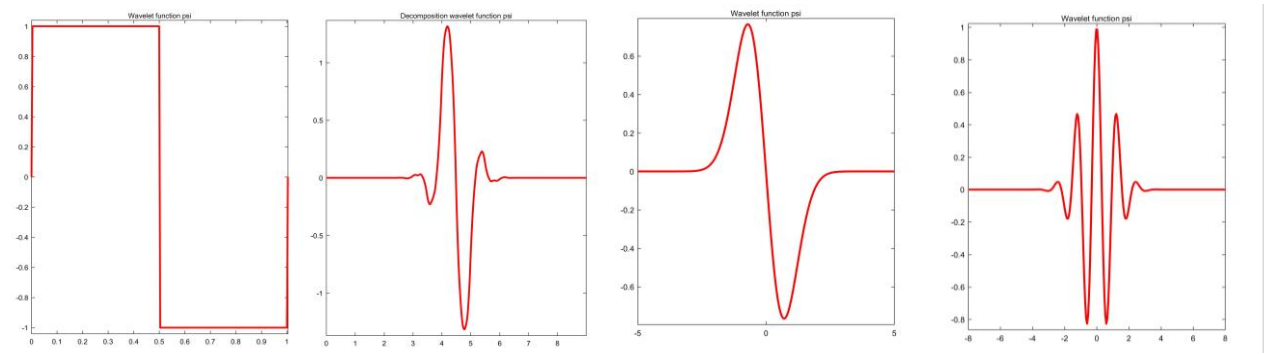
where $c_j^{(\beta)}$ - coefficients of the discrete signal decomposition; β - level of detailed decomposition.

According to this criterion for a signal being analyzed, such basis is selected in which the squares values distribution of its wavelet coefficients is maximally different from the uniform one. Due to this maximum information is concentrated in the minimum number of decomposition coefficients.

The angular acceleration signal of the crankshaft consists of a set of frequency components, each of which reflects the effect of the corresponding mechanism or device, which is mechanically connected to the crankshaft. Obtaining information about the frequency and location of the frequency component by crankshaft angle will provide an opportunity to determine its diagnostic cause.

Given the specific task, we will define additional criteria. First of all, this is a clear separation of the frequency components of the signal and their localization by the crankshaft angle. Usually, the basic function is chosen by the form that most correspond to the signal being investigated.

Selected wavelet-bases for the study correspond to the condition of the similarity to the signal being investigated and also have different central moments. We chose Haar, Gauss bases 1, 2, 3, 4, Biorthogonal 1.5 and Morle 2.8.



Haar Biorthogonal 1.5 Gauss 1 Morlet

Fig. 8 Basic wavelet function selected for consideration

4. Findings

Wavelet-spectra of the crankshaft angular acceleration accordingly to main types of basic functions are presented in Fig. 8. A result of the transformation depends on the form of the basis function, so we should select the basic function in the form of a signal that interests us.

The clear vertical structure of the spectrum makes it possible to localize the frequency components by the rotation angle.

Almost the entire energy of the spectrum according to the Gaussian basis of any order is concentrated up to the 100th scale. For other bases, energy is distributed to a much larger scale, that is, it is distributed to the low frequency zone.

The bases of Haar, Morle and biorthogonal of variuos orders demonstrate clear vertical structuring and minimal edge effects.

Basic functions are of interest, wavelet spectra of which allow separating better the frequency components by scale factors.

Figs. 9 and 10 present the result for the case of the expanded fuel injection advance angle in the 3rd cylinder (Fig. 9). It is convenient to consider the spectra together with the signal. In the angular interval of the 3rd cylinder operation there is the appearance of a low frequency component, which is displaed in cold color. The selection and processing of the vector of decomposition coefficients of the appropriate scale, at which this effect is observed will allow localizating the malfunction without significant computational costs.

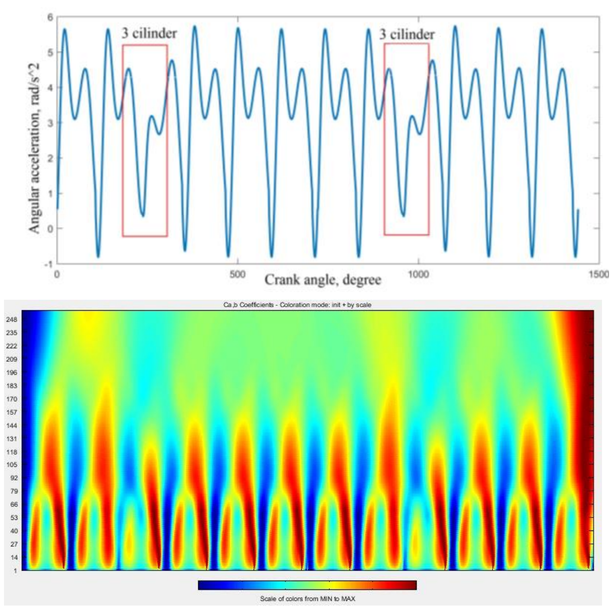


Fig. 9 The modified graph of the angular acceleration, the advance of fuel injection in cylinder No. 3 - 43 degrees and its wavelet spectrum by the biorthogonal base function with a coefficient of 1.5

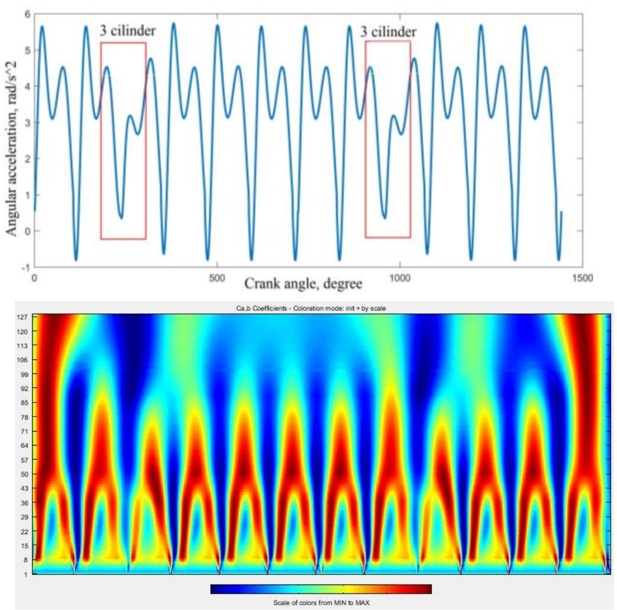


Fig. 10 The modified graph of the angular acceleration, the advance of fuel injection in cylinder No. 3 - 43 degrees and its wavelet spectrum of the angular acceleration signal by the Haar's base function

5. Originality and Practical Value

The authors researched the application of various types of basic functions for continuous wavelet transform to separate the diagnostic information from the signal of the irregularity of the crankshaft angular velocity for diesel locomotive engine. A number of basic functions with perspective applications for the diagnostic analysis of angular acceleration were determined.

6. Conclusions

The results of CWT application to the signal irregularity are presented. The basic function of Gauss showed the energy concentration in the area of high scale orders that reduces costs for computing. Basis of Haar, Biorthogonal of various orders and Gauss shown on the spectrum the clear vertical localization of frequency components. But the basis of Morle is a subject to significant impact of edge effects that deform the spectrum. Using the various types of basis wavelet functions leads to different results. This allow continuing the research in this direction and developing optimal combinations and signal analysis algorithms of irregularity of crankshaft angular velocity for the diesel locomotive engine.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Sleepy Professional Drivers, the Hidden Risk on the Roads

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Abstract

The aim of this article is presents of the problem of sleeping of the professional drivers. This is based on the research of the opinion of seven drivers in the delivery trucks under of 3,5 tons of the total mass of vehicle. They said that many of them were worked with bad sleeping. The source of this was that all owners of the trucks unless of the total mass 3,5 tons doesn't respect of maximal time of the driving by drivers and the minimal time of the rest.
KEY WORDS: *sleepy, drivers, hidden, risk, roads*

1. Introduction

Later has been prepared of the questionnaire in the two transport companies. After collection of this opinion was read of the literature of the about of source of the accidents of the trucks. In many article is presents that the main problem is the obstructive sleep apnea [1, 6]. That is the biological problem of the individual drivers. The opinion from two transport companies may help that are the other problems of the bad sleeping of professional drivers.

2. The Sleepy Problem of Drivers

The problem of the increasing of the accidents on the roads is very old. Many authors had wrote about the drunken drivers or unexpected behaviors of the drivers. Many time the death accidents had unexplained source. Also we can read the articles about the sleepy drivers. The sleepy drivers had about 3 % of accidents on the roads, nearly 25% of drivers of trucks had the sleep under time of driving [5].

This problem had been analyzed by the AAA and also and the Polish Society of the Analysis about of the Sleeping. The AAA suggest that if driver had sleeping less than the 5 hours have the its reaction similar as the drunken person with 1,9 promiles of the alcohol in the blood [6]. This may change the time of reaction in the central nervous system especially of the cognitive lapses [4].

For protection before the unsleepy night is do not use before the sleep time of the sleepy medicines, alcohol and cigarettes [7]. Many time the death accidents had unexplained source. But is possible that many accidents had different sources of the unsleepy nights. In this article has analyze this problem.

3. Methodology

For taking the another sources of bad sleeping of the drivers has been contacted with two transport companies to asking the drivers based on the anonymous opinion. The management of these two companies had agreed to do the research and also the groups oaf the drivers also agreed for it. In these two companies where working 34 drivers. 32 men and 2 women.

4. The Questionnaire

The questionnaire had 15 questions:

1) Gender	man/woman
2) Driver's age	years
3) How many years of practice in the driving	years
4) Did the driver known the law regulation about time of driving and the rest	
5) How many hours of driving may have the driver if is alone in the vehicle	
6) How many hours may have the driver in one week	
7) How many hours of rest have drover in the one week	
8) How many hours of rest must have the drover in one day	
9) How do You rest ?	
a) Still sleep	
b) Relax and sleep	
c) I prepare for next day and sleep	
d) I did many other activity and sleep	
10) How many hours of the sleeping do You have in one day	hours

11) Did the sleep has been relaxed yes/no
12) Do You had have situation that if you was sleepy You had driven on the truck yes/no
13) What is source of the bad sleeping for You
   a) Bad emotions before the sleeping
   b) Stress linked with the job
   c) Overeating at the evening
   d) Disturb of sleeping by
      − Noise (music's, loud speaking)
      − Vibrations
      − Temperature (to warm, to cold)
      − Insects (mosquitoes, bugs)
      − Other
14) What is Yours opinion about Yours conditions for job
   a) I'm rested
   b) I'm not relaxed but rested
   c) I'm not rested but I went to work
   d) I'm not rested and I'm taking a day off
   e) I felt bad but I went to work to do not loss the job
   f) I felt bad and I'm taking a day off
15) In Yours opinion the time for rest should be longer, how long and why ?

5. Results of Another Sources of Bad Sleeping of the Drivers

After collection of the questionnaires was analyzed the results. The medium age of all 34 drivers is 42 age years with 13,5 years of practice. All of them well known the law regulation about the time of working and time of rest. The most interesting is the results is how drivers used the time for rest for rest. Only 6% of them are used the time for rest only for the sleeping. Over 71% drivers had used the time for rest for preparing for the next day of work or they did another activity (Fig. 1).

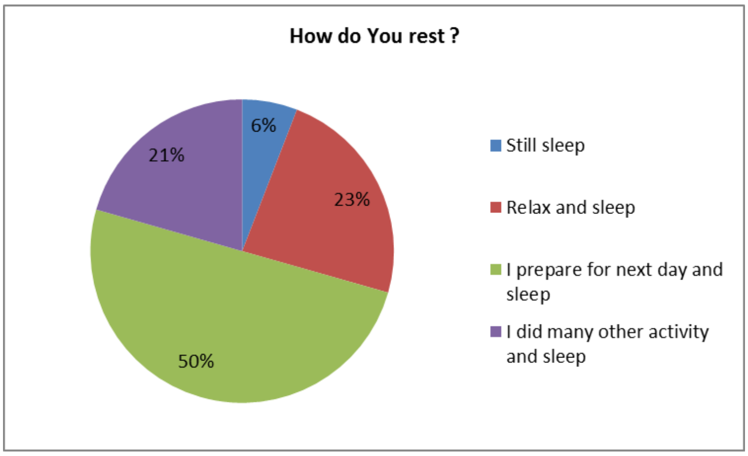

Fig. 1 Answers for question how do You rest?

The 94% of drivers wrote that the sleeping time is relaxed for them and also 41% were sleepy had driven on the trucks. Rest of them said no. The others sources of bad sleeping for drivers had the several other reasons.

The most of these reasons are linked with the stress, over 29%, and the sound background for sleeping, 25%. The another reasons are linked with the vibrations -13%, temperature-11%, and overeating at the evening -9%. It means that the construction of the drivers cabins or hotel rooms have bad noise and vibration insulation or bad condition of heat control apparatuses' or bad hygiene in the cabin od in the hotel room (Fig. 2).

The most interesting is the real time of sleeping for professional drivers. In the questionnaire was the question about this. The drivers signed the details (Fig. 3).

The results suggest that over 80% of asked drivers had sleep more than 6 hours. The most numbers of drivers had sleep 7 and more hours. That is very important for other users on the roads. The analysis of the AAA Foundation suggest that if driver had sleep less than 5 hours his body has reaction as the drinking of the alcohol. Then to do not have the reaction as the drunken man each driver must sleep ne less than 7 hours. This reduce the possibility of the accidents on the roads [6]:

− 1.3 times for six to seven hours of sleep;
− 1.9 times for five to six hours of sleep;
− 4.3 times for four to five hours of sleep;
− 11.5 times for less than four hours of sleep.

For close this part is need to see the answers of the drivers about condition for the job.

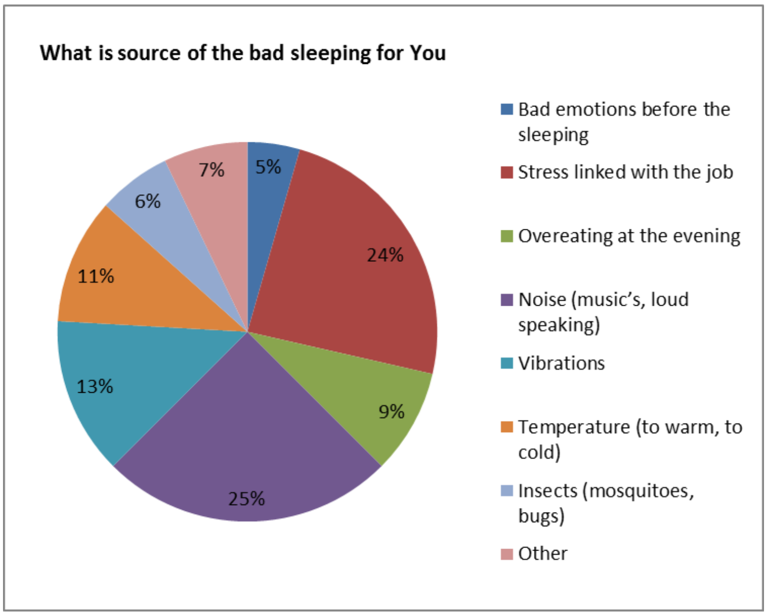

Fig. 2 Source of bad sleeping

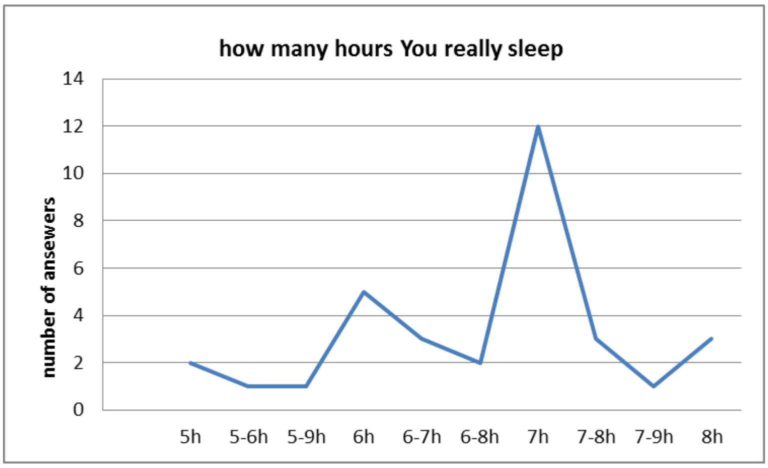

Fig. 3 Really number of hours of the sleeping

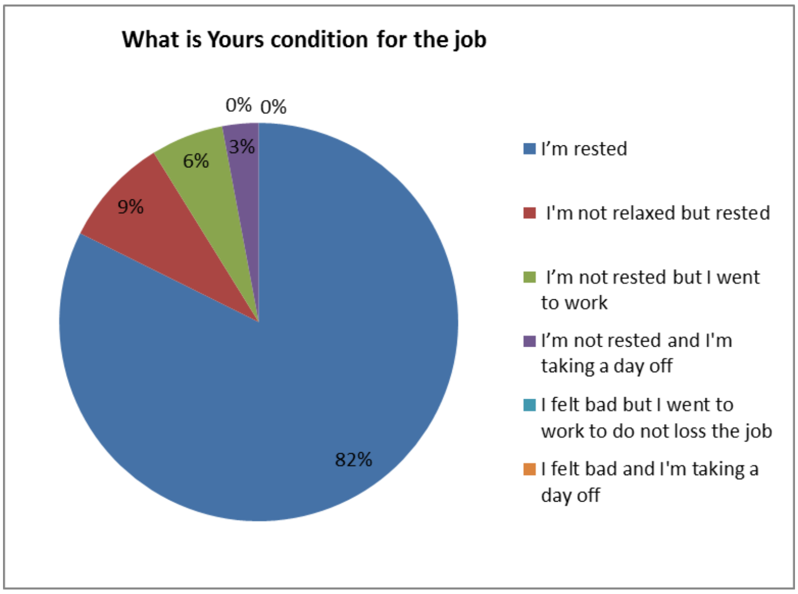

Fig. 4 Condition for the job

It seen that only 9% drivers had bad condition for the job but only 6% went to work. Then the 3% drivers were sleepy and working (Fig. 4). This may be source for hide risk of crashes on the roads. It is very important not only for

the professional drivers. Also private drivers should respect the suggestion about the minimal time for sleeping. The research of the polish Medical Center MML in Warsaw suggest that only in Poland near 10 millions of people over 30 years age had snored every night [3]. The another problem is that in 2017 in Poland had noticed 589 accidents caused by the sleep drivers. In these accidents were dead 67 persons and injured were 888 peoples [2].

6. Discussion

The initiative of the European Union to limitation of the driving licences for persons with the obstructive sleep apnea [1]:

a) In the following paragraphs, a moderate obstructive sleep apnoea syndrome corresponds to a number of apnoeas and hypopnoeas per hour (Apnoea-Hypopnoea Index) between 15 and 29 and a severe obstructive sleep apnoea syndrome corresponds to an Apnoea-Hypopnoea Index of 30 or more, both associated with excessive daytime sleepiness.

b) Applicants or drivers in whom a moderate or severe obstructive sleep apnoea syndrome is suspected shall be referred for further authorised medical advice before a driving licence is issued or renewed. They may be advised not to drive until confirmation of the diagnosis.

c) Driving licences may be issued to applicants or drivers with moderate or severe obstructive sleep apnoea syndrome who show adequate control of their condition and compliance with appropriate treatment and improvement of sleepiness, if any, confirmed by authorised medical opinion.

d) Applicants or drivers with moderate or severe obstructive sleep apnoea syndrome under treatment shall be subject to a periodic medical review, at intervals not exceeding three years for drivers of group 1 and one year for drivers of group 2, with a view to establish the level of compliance with the treatment, the need for continuing the treatment and continued good vigilance.'should be extended.

I suggest to start to construct the special apparatuses to measure of degree of enough sleeping. This should be based on observation of the eyes and dark circles under eyes. The image may be analyzed by the special software and compare with the image of this person in the official documents. This apparature should be in the equipment for police and inspection of the road transport. Thus this solution is possible to reduce the sleepy pirates on the roads.

7. Conclusion

Then the subject of the sleepy drivers is linked not only with the medical conditions of bodies of the drivers but also with the social behaviors of the drivers and external conditions for relaxing of the drivers.

As the first step should be, based on the Commission Directive 2014/85/EU, preliminary and periodic medical reviews [1].

The second is equipment of the police and inspection of road transport with the special apparatures to measure of degree of enough sleeping.

The third much more cheapest but not easy is change the proposition of the meals in the restaurants for drivers. From big and fat portions for small and thinly with difference for the time of the driving day. The restaurants should offer the different meals for drivers, one for beginning of driving day, second for the obligatory pause in the driving, and third for the end of driving day.

The subject of sleepy drivers is very important of economy of each country. Most of cargos is transported by the road transport. Then if only the 3% drivers are sleepy it is too much. The government should try to reduce any cases of possibility of accidents on the roads. The showed two another propositions may be analyzed and introduced.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Structural Analysis of Centrifugal Compressor Impellers with Different Blade Shapes

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Abstract

The stress and deformation analysis comparison of different types of impellers in centrifugal compressor, which differ by bending of blades, is discussed. Nature of blading geometry has a significant impact also on the overall characteristics and performances of the compressors. While the advantages and disadvantages of all types according to overall stiffness will be discussed in more detail. FEM stress and deformation analysis using computational software Creo Elements showed significant differences in stress fields in all compressor wheels at their maximum rotational speed.
KEY WORDS: *centrifugal compressor impeller, stress analysis, deformation*

1. Introduction

The use of centrifugal compressors for compressing air in turbocompressor engines and other types of thermal engines has its origins already in the 30's of 20th Century.

Despite the fact that they stood at the birth and boom of most jet planes, their significance has fallen due to the expansion of axial compressors with the substantial advantages of higher power dissipation of airflow and the possibility of obtaining a higher degree of compression (by installing several axial stages in succession) so necessary to increase the overall efficiency and economy of the engine. Centrifugal compressors, however the fact that in one stage they are able to create a several times higher compression ratio than the axial compressors, ultimately with less efficiency, weight and problematic sequencing, could not compete with the multistage axial compressor.

However, their usability, especially in recent decades, has begun to increase again due to their use in a mixed type of compressors, where one part is made up of several stages of the axial compressors and the other part is a centrifugal compressor which already significantly increases the compression rate of previously, partially compressed air flow. In the mixed compressor system, one passive element is also proven to improve stability. It is a Centrifugal compressor with backward blades (blades curved in opposite the direction of rotation). This type of compressor is less prone to stall, but its disadvantage is a lower compression ratio [1-2].

The content of article is a comparison of three different radial compressor wheels with regard to blade geometry both in terms of performance characteristics and strength analysis by means of the Finite Element Method (FEM).

Centrifugal compressor in aircraft engines is a device designed to compress the flowing air to the engine. Its main parts are current wheel with blades and wreath of stator vanes. In Fig. 1 are shown typical constructions of centrifugal compressors.

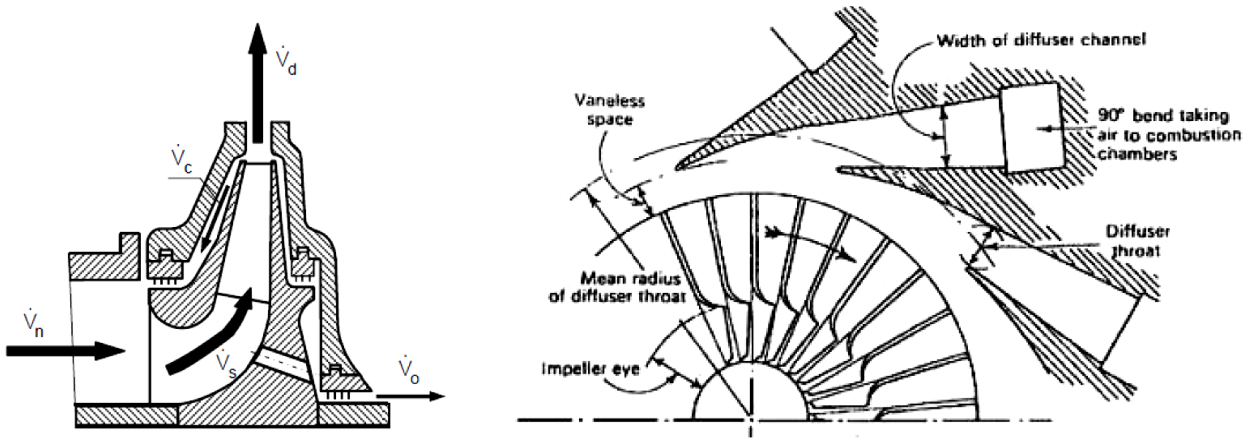


Fig. 1 Construction of various centrifugal compressors

The function of the centrifugal compressor for compressing air can be described according to [4] as follows.

Since the impeller rotates at the peripheral velocity vector u, than the absolute velocity of the gas stream vector c is given by the vector sum $c = u + w$, where w being the relative air velocity vector relative to the rotor. The absolute velocity vector of gas c_1 entering the rotor at an angle α_1 is decomposed into the velocity vectors - circumferential u_1 and relative w_1. The direction and magnitude of the relative velocity vector are given by the difference between the absolute velocity vector and the circumferential velocity vector as shown in Fig. 2. In order to achieve the vortex free input of the gas into the impeller, the blades at the inlet have to be inclined towards the tangent to a circle having a radius r_1 at the angle of the blade contact (b_1) which is identical to the relative velocity vector w_1. In order to construct the input triangle, it is necessary to know the slope angle α_1 of the absolute velocity vector c_1 to the circumferential velocity vector u_1. Due to the rotation of the impeller, the gas from the radial direction is deflected so that the current angle α_1 is slightly less than 90°. If the course of streamlines conforms to the shape of the blades (the ideal degree with an infinite number of blades), the gas will exit the wheel at a relative velocity vector w_2 at an angle β_2 equal to the inclination of the blade at the outlet. The vector sum of the relative and circumferential velocity at the exit at point 2 determines the absolute velocity vector c_2 diverging from the velocity by angle α_2. Mentioned velocity vector, similarly to the relative velocity vector, is decomposed on the circumferential part c_{u2} and meridian part c_{m2}.

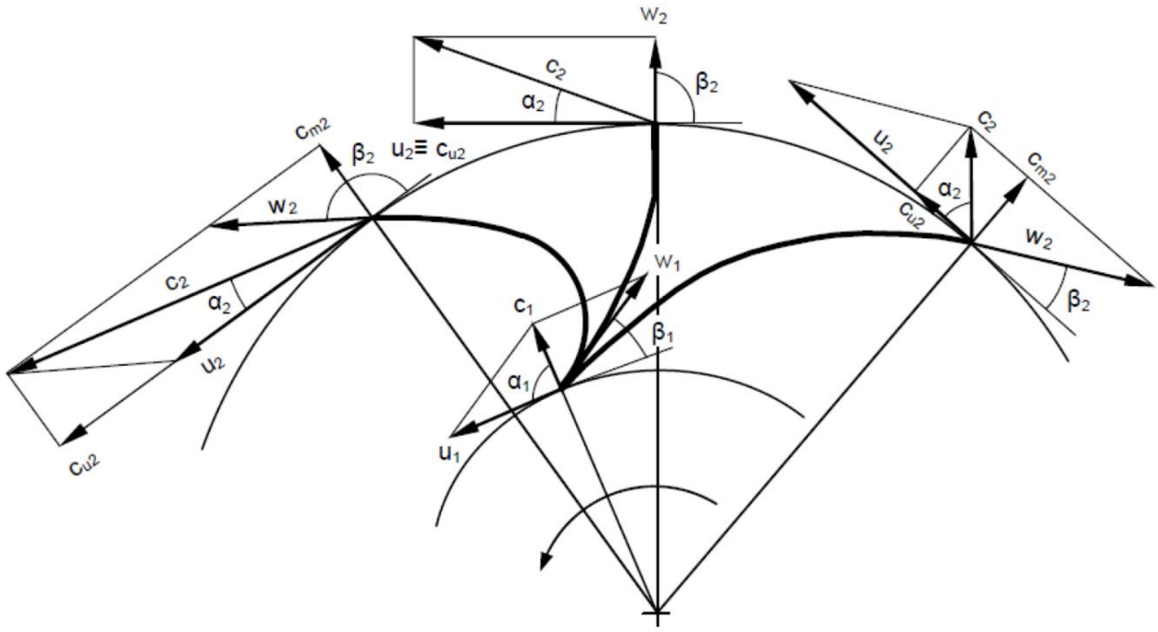


Fig. 2 Blade shapes and their velocity vectors triangles [3]

In Fig. 2, three typical shapes of the rotor blade are drawn. Forward-facing blades with $\beta_2 > 90°$, radial blades with $\beta_2 = 90°$ and blades backward angled to the circumferential velocity with $\beta_2 < 90°$.

The velocity vector triangle on the inlet is common to all of the blades. Influence of the blade shape on the energy properties of the radial stage are partly seen in Fig. 3, in dependence on the coefficient τ, providing that the circumferential speed of the rotor does not change.

Followed:

Measurable energy:

$$Y = \tau\, u_2^2 = \tau\, const \tag{1}$$

is the line that precedes the beginning,

Reaction:

$$K = 1 - \frac{\tau}{2} \tag{2}$$

is a straight line with a negative directive,

Static energy:

$$Y_{st} = K\, Y = \left(1 - \frac{\tau}{2}\right) \tau\, u_2^2 \tag{3}$$

represents the parabola with a peak at coordinate $\tau = 1$, when it is $1/2\ Y$. Zero values are at points $\tau = 0$ and $\tau = 2$.

Dynamic energy:

$$Y_d = Y - Y_{st} \, . \tag{4}$$

The principle of compressor wheels with curved blades is the same as for wheels with radial blades, except that the change in blade output angle ($\varphi \neq 90°$) greatly affects the vector velocity triangle at the wheel exit.

The relative vortex is reflected by the component of the relative velocity vector w_2, which changes the velocity distribution at the wheel exit and reduces the c_{u2} velocity vector. Slip can be determined by semi-empirical relations, but they are not accurate. The biggest influence on the slip increase is the number of the wheel blades.

The different types of wheels differ not only in the slipping factors, but also in the size of the work distributed by the wheel of the compressor to the air flow.

Obviously, at the same circumference of the wheel speed vector u_2, the circumferential component c_{u2} of the absolute velocity vector of the stream is substantially different in every type of curved blades - Fig. 2.

Euler equation is possible after fitting of:

$$c_{u2} = c_{2r} \cot \beta_2 \, , \tag{5}$$

rewrite to the shape:

$$W_{ek} = u_2 \; c_{2r} \; \cot \beta_2 - u_{1s} \; c_{1us} + w_r \, . \tag{6}$$

Hence, with the forward curved blades, the air is obtaining more work than with other types of curved blades at u_2 = *const.*, c_{2r} = *const.*, and under the same input conditions and approximately equal losses w_r. However, wheels with forward bent blades have a very unfavorable steep characteristic, and stable work has been possible only in areas with a lower effectiveness. That's why they were not used. Nevertheless, modern compressor control methods could change this. Wheels with backward curved blades have a very positive gradual characteristic. But to achieve the high degree of compression required for aviation engines, they must have high circumferential speeds. In these cases it is necessary to take into account the unfavorable strain on curved blades by centrifugal forces. These compressors are used for medium and lower compression values for stationary compressors and hydraulic pumps. Especially in aircraft engines are used wheels with radial blades, which are firmly compliant at high peripheral speeds and have an acceptable characteristic [3-5].

Rotors blades with forward curved blades reach the highest total energy, but because the degree of reaction decreases, static energy decreases too, as can be seen in Fig. 3. Extreme case is the blade wheel with extremely forward curved blades when all of the energy supplied for the drive changes to kinetic energy. Conversion of the kinetic energy to air pressure in diffuser, which is added behind current wheel, is going on with quite considerable losses. The blades are very curved and dense in number. The efficiency is low, so it is suitable for fans where their smaller radial dimensions are more important than efficiency.

The middle case are blades with the radial output reaching the maximum pressure energy and that is half of the total energy (K = 1/2). They are slightly curved and less dense. Backward curved blades convert the prevailing part of the energy input directly to the static pressure. They are relatively long and thin, showing very good efficiency. However, the achievable increase in measured energy is low. The shape of the orbital impeller blades also affects the interdependence of the main energy variables, which are the power supplied to the blades P, the measure of energy Y and the performance V_d.

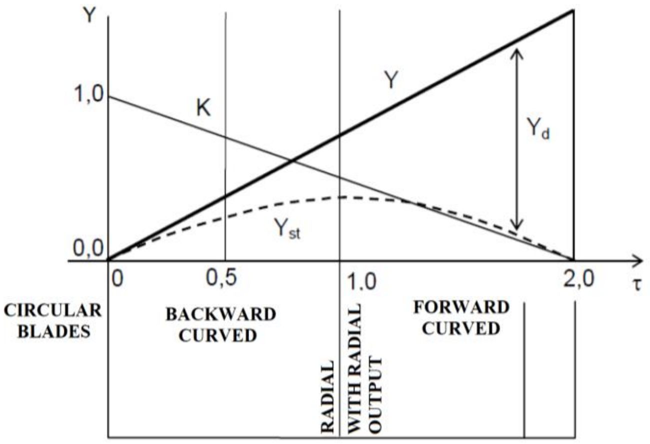


Fig. 3 The influence of the shape of the blades on the energy properties of the grade [6]

2. Methodology of the Analysis

For this analysis was used a model of a small impeller from a car turbocharger, which was created in the Creo

Parametric 3.0 software in three variants - Fig. 4.

As mentioned, variants differ by curvature of the radial blades back or forward to the direction of rotation of the wheel. Other geometric characteristics of the impellers have been retained. It is the wheel made from duraluminum with a diameter of 44 mm and overall height of 22.5 mm, the diameter of the suction throat is 32 mm. The maximum operating speed is nearly 250000 min^{-1} when it should produce compressed air at the pressure of 1.5 bar.

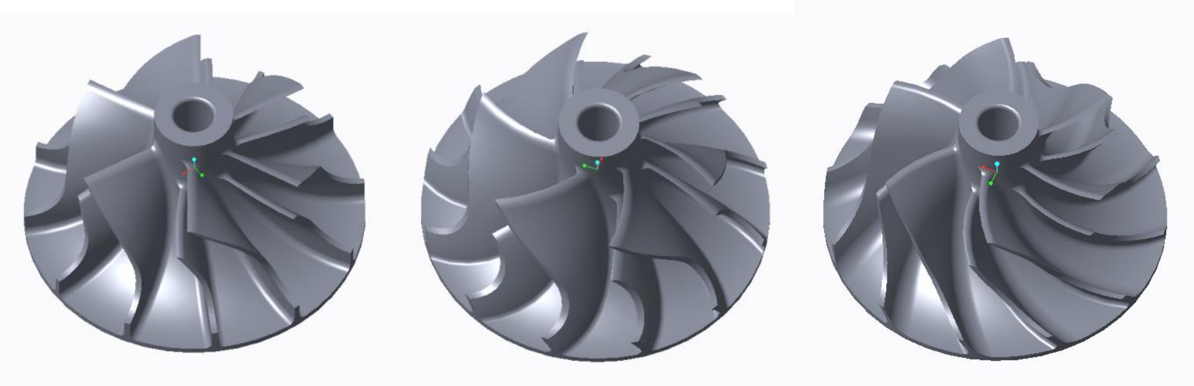


Fig. 4 3D models of three compressor impellers with different blade geometry created in Creo Parametric 3.0.

Stress and deformation analysis is based precisely on load of own material impeller mass producing the centrifugal force caused by the maximum rotational speed that are specified by the angular velocity value. According to [8] also an experimental stress measurement are possible by contactless method utilizing magnetic microwires.

After entering boundary conditions, loadings and bindings, the FEM solver in Creo 3.0 created a tetrahedral element mesh in every model (Fig. 5) the size of its elements was different in terms of wheel volume due to the location and importance of the wheel part [9].

This means that the mesh of tetrahedral elements was densified on the wheel blades, where geometric changes were assumed and less dense in a larger volume of material. Denser network guaranteed more accurate calculation of stresses and deformations.

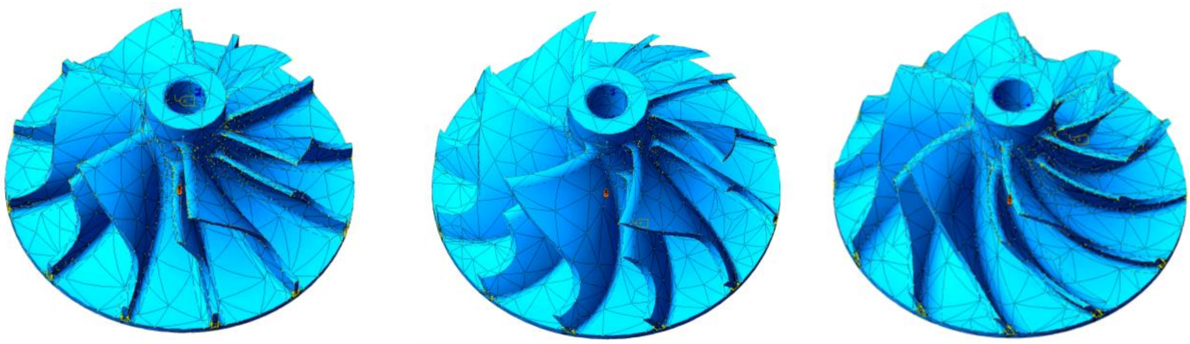


Fig. 5 Meshed 3D impeller models for FEM analysis.

Strength and deformation analyzes were performed for all types of blade curvature, and the results were shown in a contour-colored Von Mises' tension fields in the wheel, as well as contour-colored deformation fields.

3. Results and Discussion

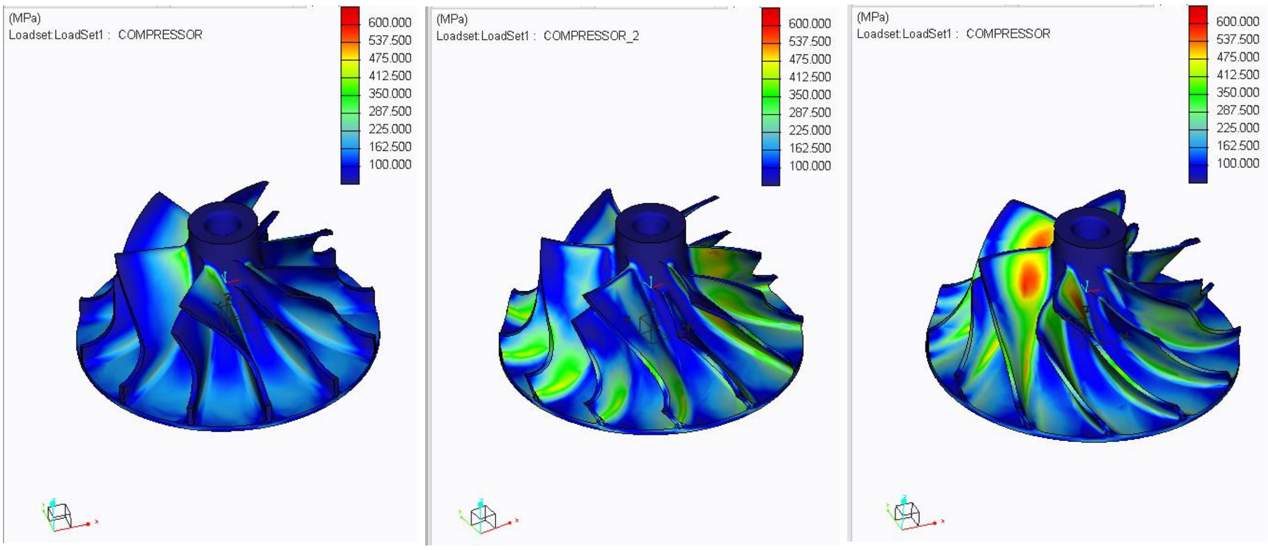
The results of stress analyzes on all of the compressor impellers are shown in Fig. 6. From the results it is clear that the blades geometry affects the distribution, concentration and maximum level of stress fields. Some of these results were already published by us in [7].

When comparing three types of wheels, it is clear that a higher stress value occurs with a wheel with backward curved blades (C) to the direction of rotation of the impeller. The maximum stress value was measured about 2494 MPa, which is about 2.7 times higher than the maximum value for the impeller with blades slightly curved in the direction of rotation of the impeller (B). The lowest value of stress reached, according to assumption, the impeller with radially shaped blades (A).

Also, there is a clear difference in the distribution of stress fields, where it can be seen that high stress levels on impeller C occur on the outer sides of the blades, unlike impeller B, where these maximum stress occur mainly on the inner sides of the blades. By radially shaped blades impeller was the stress concentration situated at roots of the impeller curved parts. This is also given by the curvature of the impeller profile. However, for impeller B, a certain concentration of tension in the root part of the blades is closer to the circumference of the impeller disk. This value

reaches only half of the maximum stress value.

From this comparison in Fig. 6, it can be seen that the impeller (B) with forward curved blades proceeds from a point of view of strength better than the impeller with backward curved blades (C), but the highest strength reaches the impeller with radially shaped blades (A).



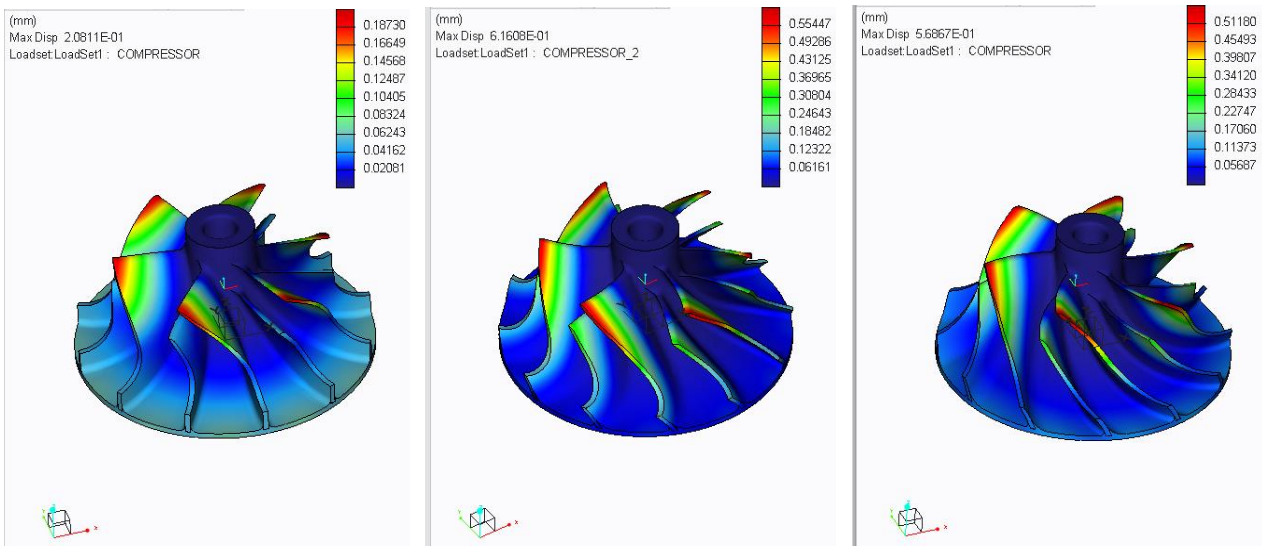
A B C

Fig. 6 Results of stress analysis of three different impellers of radial compressors [7]

The results of the impeller deformation analysis with respect to the action of centrifugal force on the impeller's material are shown in Fig. 7. It is clear from these figures that the highest deformation, unlike in the previous case, occurs at wheel B, with its blades deforming with measured value about 0.62 mm at the maximum speeds. In the case of wheel C, it is only about 0.57 mm at maximum speed. Again, the impeller with radially shaped blades (A) reaches the best results according to deformation, where its maximal deformation of tips was measured to only 0.2 mm.

It is assumed that deformation occurs most widely on the widest parts of the blades at the top of the compressor impeller. The only exception is in radially shaped impeller, where some small part of deformation occurs also in circumferential part of impeller.

From a comparison of these results in Fig. 7, it is obvious that the deformation of the compressor wheel with blades curved against the direction of rotation is better, but still not in competition to radially shaped impeller. But the difference is only at the level of millimeters (about 0.05 mm).



A B C

Fig. 7 Results of deformation analysis of three impellers of radial compressors [7]

4. Conclusions

Analyzes of Von Mises stress fields and deformations have been shown for three types of radial compressor

impellers with different blade geometry the following facts:

1. Wheel geometry has, in addition to a significant influence on the airflow nature of the impeller, also a certain effect on the layout, concentration and maximum stress level caused by centrifugal force of the rotating wheel to the mass of the compressor wheel.

2. The compressor wheel with backward curved blades showed the highest stress level in the widest parts of the outside blades areas. In this case it is the tensile stress.

3. The compressor wheel with forward curved blades showed the highest level of tension again in the widest parts of the blades, but on their inner side. Again, this is the tension stress.

4. By comparing the maximum stress values for these three types of wheels, it is clear that for wheel with blades backward curved is the maximum value of the stress von Mises almost 2.7 times higher than with the forward curved impeller. But radially shaped impeller reached far lower stress value.

5. The deformation caused by centrifugal force during rotation of the compressor impeller is to a certain extent influenced by the geometry of the impeller blade, with the greatest deformation occurring on the widest parts of the blades.

6. Comparison of the deformation in all types of impellers has shown that the wheel with forward curved blades achieves a lower deformation at the ends of the blades than is the case with the wheel with backward curved blades in the direction of rotation. It is about 0.05 mm, which is also affected by the curvature of the blade profile. Also the radially shaped blade impeller reached the lowest value of deformation.

From previous results obtained can then be concluded that in terms of strength is more convenient impeller with blades curved slightly in the direction of its rotation, deformation based on point of view is better impeller with blades bent against the direction of rotation even when is only a very small amount. In this case, have a clearly higher weight lower level of tension in the wheel, which could have a major impact on the material fatigue properties of the wheel and in some cases could be a higher level of stress cause fatal damage to the compressor impeller.

It is also necessary to consider the operating character of these types of radial compressors. Where the compressor whose blades are backward curved has a more stable operation than compressor whose blades are slightly inclined to the direction of rotation. Good stall performance has a radially shaped blade impeller used in aviation.

Such a compressor requires a sensitive control system that prevents compressor stall in its transition modes.

Due to the same dimensions and speeds, this type of compressor is able to achieve higher intake air compression than a compressor whose wheel has blades backward curved or radially curved.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Crank Train Concept Design of an In-Line Two-Cylinder Range Extender Engine

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Abstract

A range extender engine seems to be the suitable solution to meet future requirements for CO_2 emissions of passenger vehicles and simultaneous demands on an electric vehicle operating range, if acceptable weight of a vehicle powertrain should be kept.
The paper presents crank train concept design of a spark-ignition in-line two-cylinder range extender engine derived from a three-cylinder engine which is manufactured by the ŠKODA AUTO Company. The motivation for the range extender engine utilization is mentioned as well as power requirements of a drive unit. Special attention is paid to the crank train dynamics and its balancing in particular and six variants of the crank train arrangement are designed and compared by virtue of this criterion.
KEY WORDS: *torsional vibration, crank train, crankshaft, Multi-Body System*

1. Introduction

The present automotive design challenge consists in reducing depletion of fossil oil resources and decreasing fleet emissions. It can be reached by advanced vehicle power trains and drive trains, reducing aerodynamic drag, rolling resistance and vehicle lighweighting options [1].This paper is focused on advanced vehicle powertrain. Miscellaneous concepts of power train can be used for modern passenger cars. For example:

- Internal-combustion engine (ICE)
- Mild hybrid
- Hybrid
- Plug-in hybrid electric vehicle (PHEV)
- Range extender
- Electric motor

Unlike a serial hybrid, where an internal-combustion engine together with generator is the main source of electricity, the range extender is an auxiliary power supply for extending of driving range of an electric vehicle, where the battery is predominantly used as a power supply for a vehicle drive. In the case of the range extender, an internal-combustion engine is not mechanically coupled with wheels and its activation is caused by achievement of a specific value of the battery state of charge during its discharging by vehicle propulsion.

According to Roland Berger's prognoses, power train with the range extender also appears to have an interesting share at new-sold passenger cars about the year 2025 [2]. Although the internal-combustion engine will be dominant power train concept, the share of range extender should reach about 14 % in Europe [2], see Fig. 1.

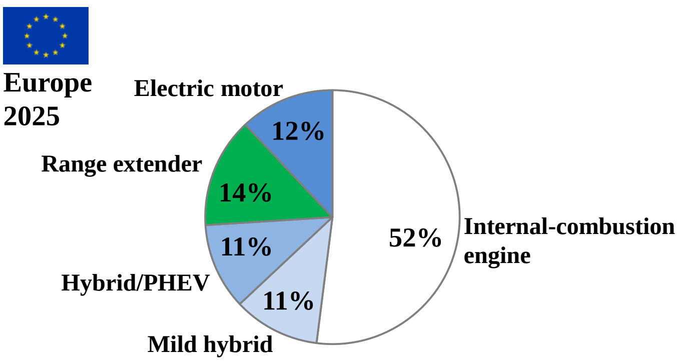

Fig. 1 Supposed share of power train concepts in the EU market at 2025 [2]

In the technical point of view, it is worth using the range extender with a small and mechanically optimized [3] internal-combustion engine for an electric vehicle from specific value of its range depending on a vehicle class and purpose.

In comparison with further range extending by increase the energy capacity of lithium-ion battery, additional

costs of the range extender are constant and a vehicle mass increase due to volume extension of a fuel tank can be nearly neglected in this case.

Fig. 2 shows additional mass (left) and additional costs (right) for the range extension of an electric vehicle from standard 150 km, if lithium-ion battery are considered. Constants, used in calculation, are based on [4].

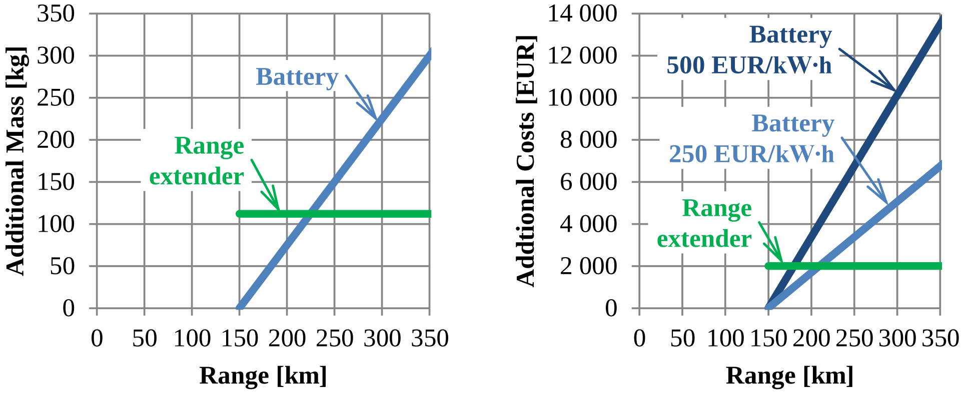

Fig. 2 Additional mass and costs for a range extension of an electric vehicle from standard 150 km

Performed analyses of potential competitors have shown that a four-stroke twin-cylinder engine concept is used in particular, although the cylinder and crankshaft arrangement are various.

2. Engine Concept

The range extender module has to meet strict requirements: low mass, compactness, high efficiency, excellent NVH parameters, low costs and sufficient power output. The dimensioning of the range extender is dependent on power output specifications resulting from the demands on minimum speed attainable by the electric vehicle with fully discharged high-voltage battery.

The minimum speed of the vehicle powered only by the range extender can work on the assumption that the vehicle's speed must be higher than speed of a heavy truck under the same driving condition.

In the Fig. 3, tractive resistance curves of considered electric vehicle for constant speed and different uphill gradient are presented. There is also marked a range of the wheels power demand.

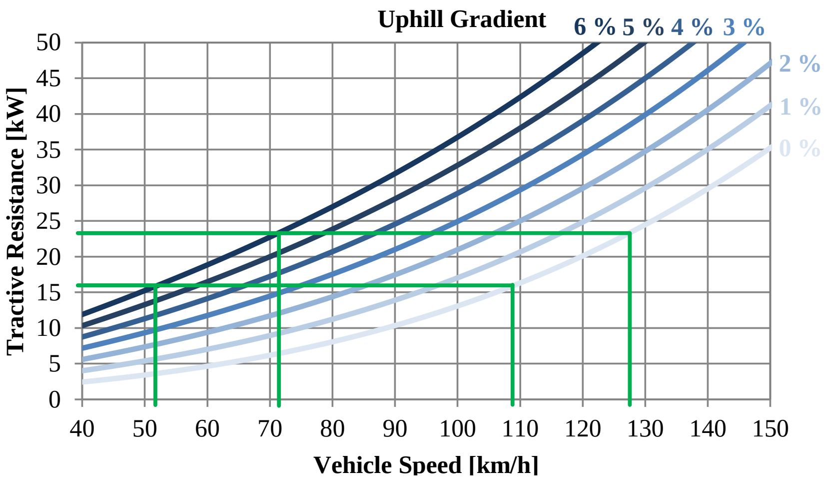

Fig. 3 Tractive resistance of considered electric vehicle (constant speed)

In order to determine the desired effective power of the internal-combustion engine, an overall efficiency of the whole drive train must be taken into account:

$$\eta_{Drive\ train} = \eta_G\ \eta_C\ \eta_C\ \eta_{TM}\ \eta_T\ , \qquad (1)$$

where η_G is generator efficiency, η_C is voltage converter efficiency, η_{TM} is traction motor efficiency and η_G is transmission efficiency. The rated output of the internal-combustion engine must reach accordingly from 20 kW to 30 kW for intended vehicle.

These values can be covered by miscellaneous engine concepts; however four-stroke spark-ignition in-line two-

cylinder engine derived from the standard three-cylinder engine of ŠKODA AUTO is chosen. It enables reduction in research and development costs, manufacturing and service costs and simultaneously satisfies requirements mentioned above. Bore of this engine is 74.5 mm and stroke is 76.4 mm and cylinder distance is of value 82 mm.

Crank train of an in-line two-cylinder engine can be designed with different angular offset of crank pins δ, see Fig. 4. Referred offset influences: crank train balancing, smoothness of engine running, NVH parameters of a power unit.

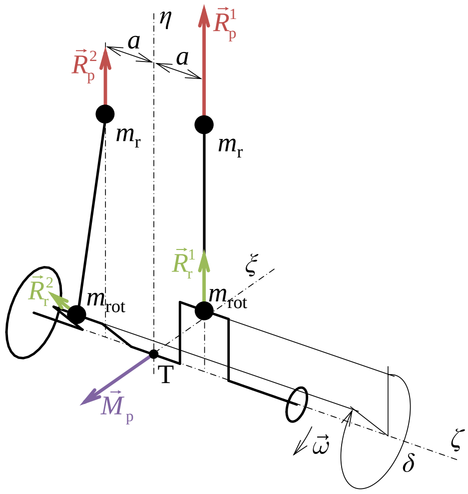

Fig. 4 Crank train scheme

For comparison purposes, three variants of crank train layout are designed: 360, 270 and 180. The number of the variant indicates the angular offset of crank pins.

The crank train design goes out from the standard three-cylinder engine, therefore piston and connecting-rod assemblies are adopted of it.

3. External Effects of the Crank Train Unbalancing and the Crank Train Dynamics

An analysis of crank train unbalancing effects is performed on the basis of definite simplifying assumptions. The effect of rotating parts is neglected because they are supposed to be fully balanced by crankshaft counterweights.

Table 1

Crank train unbalancing effects

Variant name	δ	Relative amplitude [–]			
	[°]	Primary force (R_{pI})	Secondary force (R_{pII})	Primary moment (M_{pI})	Secondary moment (M_{pII})
360	360	1	0.2634	0	0
270	270	0.7071	0	0.7071	0.2634
180	180	0	0.2634	1	0

Significant parameters of crankshaft unbalancing are inertia forces of reciprocating parts R_p (primary and secondary) and their moments M_p. In the Table 1, the crank train unbalancing effects are shown by their relative amplitudes. The angular offset of crank pins also affects time-dependent torque of the engine. Results for wide opened throttle and 4000 rpm are shown in the Fig. 5.

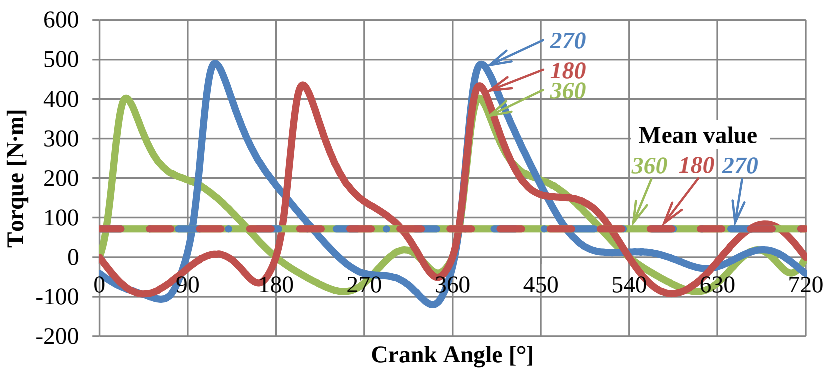

Fig. 5 Torque at crankshaft output side

The computational model has been excited by inertia effects of moving parts and gas forces are based on measurements of the original three-cylinder engine.

4. Crank Train with a Balancing Unit

The balancing unit, used for described crank train variants, consists in one contra-rotating balancing shaft and modified crankshaft counterweights which are able to eliminate primary force and moment. This balancing unit operates on the principle of contra rotating vectors and added roll moment of the crank train, caused by the arm between exciting and balancing resultant forces, is not so critical in the point of view of the engine vibration as compared with the original primary effects. Relative unbalancing effects of crank train equipped by the balancing unit are shown in Table 2.

Table 2

Unbalancing effects of the crank train equipped by the balancing unit

Variant name	δ	Relative amplitude [–]			
	[°]	Primary force (R_{pI})	Secondary force (R_{pII})	Primary moment (M_{pI})	Secondary moment (M_{pII})
360B	360	0	0.2634	0	0
270B	270	0	0	0	0.2634
180B	180	0	0.2634	0	0

Based on parameters obtained from the balancing analysis, the crank train concept design of all variants is carried out, see Fig. 6. The new design is as compatible as possible with Škoda/VW engine family EA211 MPI to reduce costs.

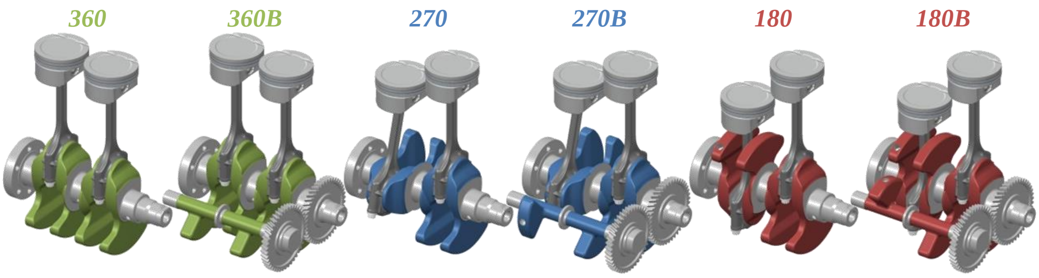

Fig. 6 The crank train concept design covering all mentioned variants

5. Conclusion

Compared with an electric vehicle equipped only by high-voltage battery, range extender can bring interesting costs and mass reduction depending on required range of the vehicle.

However, the internal combustion-engine incorporated as the main component of the range extender module can be also the source of undesired noise and vibration. Since crank train layout significantly affects the engine NVH, its design should be worked out attentively.

The first aspect in this stage of the project is the engine balancing and the second one is smoothness of the engine running.

In spite of the fact that 360 variant's balancing corresponds to a big single-cylinder engine, regular firing spacing offers the most engine smoothness. The balancing unit enables to eliminate primary force which amplitude is the biggest one among all variants otherwise.

The variant 180 shows primary moment instead of primary force compared with the 360 variant and this moment can be less unfavourable for vibration transmission to the car body; however the primary moment of the 180 can be eliminated by the balancing unit as well, moreover without added roll moment. Amplitudes of the unbalancing effects of the 270 variant can be found approximately between 360 and 180 variants.

The advantage of the 270 variant with the balancing unit is inherence of only secondary moment; nevertheless the biggest torque fluctuation accompanies the engine running.

The whole powertrain running smoothness can be evaluated also by a linear torsional computational model [5, 6], however the next stage of the project will be focused on MBS dynamics solution according to [7, 8] with regard to noise and vibration [9].

Acknowledgement

The research leading to these results has received funding from the MEYS under National Sustainability Programme I (Project LO1202) and Specific research project of the Faculty of Mechanical Engineering, Brno University of Technology (FSI-S-17-4104).

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Evaluating the Efficiency of Spacecraft Electric Thruster Operation

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Abstract

The article analyses an ideal and a real model of thrust creation in ion plasma thrusters. The correction of the ideal ion plasma thruster model is proposed to be carried out with the help of efficiency factors. Factors affecting the efficiency of thrusters are analyzed.
Thrust to power ratio, which is one of the most important indicators of ion plasma thruster perfection, is evaluated as well.
KEY WORDS: *Ion thrusters, plasma thrusters, losses, heat losses, efficiency, thrust, specific impulse*

1. Introduction

The operating principle of plasmatron (electrothermal) spacecraft electric thrusters (SET) [1] is close to the operating principle of traditional chemical rocket engines, in which jet thrust is created by a gaseous (or gasified) working fluid jet flowing out of a quasi-closed volume; the working fluid expands in a discharge chamber (an analogue of the combustion chamber of traditional engines) under the effect of heat released during arc discharge. In such SETs, the mechanism of structural element heating is similar to the mechanism of heating the combustion chamber and nozzle of traditional rocket engines.

One of the most important problems is a necessity of building a model of processes occurring in SETs in order to correctly evaluate the thermal power being generated during SET functioning. Once such a maximally accurate evaluation has been provided, it becomes possible to reduce the energy consumption, mass, dimensions and cost of the cooling system, which is important for a spacecraft.

This article analyses the processes occurring in spacecraft electric thrusters (SET); it also provides calculations of losses and describes their influence upon the total thermal power generated during SET operation. At the same time, it considers thrusters, in which the process of jet thrust creation is related to the ionization and further acceleration of working fluid ions – ion plasma thrusters (IPT) [2-4].

2. An Ideal and a Real Model of Thrust Generation in Ion Plasma Thrusters

From the equation, which connects jet power P_{jet} and ion plasma thruster (IPT) thrust T, it follows that thrust augmentation can be achieved by increasing thruster jet power without increasing the consumption of working fluid:

$$P_{jet} = \frac{T^2}{2m_i n_i}, \tag{1}$$

where n_i is the number of ions; m_i - is the mass of working fluid ion.

The energy of electric field accelerating the ion in the IPT is equal to the product of ion charge q_i and the difference of the potentials of this field (the voltage between the electrodes, the difference of potentials between which is a source of this field V_b expressed in volts). According to the law of energy conservation, after conversion to ion kinetic energy, field energy will be equal to ion kinetic energy:

$$E = V_b q_i = \frac{1}{2} m_i V_{exi}^2 . \tag{2}$$

From (2), it is possible to express ion flow velocity:

$$V_{exi} = \sqrt{\frac{2q_i V_b}{m}}. \tag{3}$$

Ion beam current I_b expressed in amperes is equal to the product of ion charge q_i and the number of ions n_i, which can be expressed through the ion mass flow:

$$I_b = q_i \cdot n_i = q_i \cdot \frac{G_i}{m_i}.$$

Whence the ion mass flow can be expressed through the ion beam current:

$$G_i = I_b \cdot \frac{m_i}{q_i} \tag{4}$$

From Eq. (1), which determines the thrust of the thruster, by substituting (3) and (4) and taking into consideration the assumption that ions in the IPT have a single degree of ionization, i.e. a single charge is qual to e, there appears the following expression for IPT thrust (in Newtons):

$$T = \sqrt{\frac{2 \cdot m}{e}} \cdot I_b \cdot \sqrt{Vb}. \tag{5}$$

Such a form of representation is convenient because the first cofactor of expression (5) $\sqrt{\frac{2 \cdot m}{e}}$ is a constant for each type of working fluid; thus, thrust is determined by the beam current intensity and by the square root of accelerating voltage value.

The value of constant $\sqrt{\frac{2 \cdot m}{e}}$ is: for hydrogen = $1.44537 \cdot 10^{-4}$; for helium = $2.88042 \cdot 10^{-4}$; for neon = $6.467598 \cdot 10^{-4}$; for argon = $9.09981 \cdot 10^{-4}$; for krypton = $1.31796 \cdot 10^{-3}$; for xenon = $1.64968 \cdot 10^{-3}$; for air = $7.75058 \cdot 10^{-4}$.

For example, the expression for the thrust of xenon thruster (in millinewtons) acquires the following form:

$$T = 1.65 \cdot I_b \cdot \sqrt{V_b}. \tag{6}$$

It is obvious that thrust is growing along with the increase of working fluid atomic weight; at the same time, the ratio of thrust constants for hydrogen and xenon pairs and for helium and xenon is 11.414 and 5.727 respectively.

Equation (5) describes the ideal model of thrust generation in the IPT – when the ion beam does not have divergence, i.e. all ions move along the trajectories that are strictly parallel to the axis passing through the thrust vector.

Besides, when forming the expression for the thrust of the thruster, it was assumed that all the ions had a single degree of ionization, though in reality the degree of ionization has probability distribution.

In a general case, the equation of ion motion in an electromagnetic field in conditions of low-density plasma takes the following form [5]:

$$m_i \cdot \frac{dV_i}{dt} = q\mathbf{x}\mathbf{E} - \frac{VP_i}{n} - \frac{qj}{\sigma} \cdot (\mathbf{v}_{exi}\ \mathbf{x}\,\mathbf{B}), \tag{7}$$

where m_i is the ion mass; $\mathbf{v}_{exi}$ is the ion flow velocity; q is the ion charge; **E** is the electric field strength; VP_i is the ion pressure gradient; n is the plasma concentration; j is the electric current density; δ is the plasma conductivity; **B** is the magnetic induction. Here and further on, **x** is a sign of vector product, while vector variables are marked in bold.

Expression (5) does not take into account positive effects of other forces described in equation (7), for example, the increase of ion kinetic energy due to electronic heating, as well as negative effects related to the inhomogeneity of IPT plasma flow, for example, ion beam dispersion at collisions with neutral atoms contained in the thruster plasma flow.

Generally, expression (5) qualitatively describes the mechanism of thrust generation based on general model (7) and can be applied as an ideal model for calculating the error-free characteristics of a thruster.

In general terms, expression (5) for real thruster characteristics can be presented as:

$$T = \gamma \cdot \sqrt{\frac{2 \cdot m}{e}} \cdot I_b \cdot \sqrt{V_b}, \tag{8}$$

where γ is the coefficient which takes into consideration the above described effects reducing the thruster efficiency:

$$\gamma = \alpha \cdot \beta \cdot \delta, \tag{9}$$

where α is the coefficient of beam dispersion taking into consideration the dispersion of ion beam; β is the ionization

coefficient taking into consideration the degree of ion beam ionization; δ is the dissipation coefficient taking into consideration heat effects, dispersion on neutral atoms, oscillatory processes in plasma, etc.

At the same time lim α = lim β = lim δ = lim γ = 1. In the ideal case, $\gamma = 1$.

In some particular cases, it is just required to create models for the calculation of the above coefficients.

For the ion beam with uniform conic divergence after exiting the thruster, with constant current density and uniform electric field, correction coefficient α is equal to the cosine of the half mean angle of beam divergence θ or to the cosine of angle θ between the generator and ion beam symmetry axis. In this case, taking into account the divergence of ion beam, Eq. (5) takes the following form:

$$T = \cos\theta \cdot \sqrt{\frac{2 \cdot m}{e}} \cdot I_b \cdot \sqrt{Vb} \; . \tag{10}$$

For example, if the angle of beam divergence is equal to 60 degrees, $\theta = 30^{\circ}$ and cos θ = 0.866, i.e. the loss of thruster thrust due to beam divergence is 13.4%.

If the source of plasma does not provide a uniform plasma flow, i.e. the above listed conditions related to current density, field and beam geometry are violated, the correction coefficients have to be integrated for the given surfaces with account of their curvatures.

In this case, for cylindrical thrusters:

$$\alpha = \frac{1}{I}\int_0^r 2\pi \cdot J(r) \cdot \cos\theta(r) dr, \tag{11}$$

where $J(r)$ is the function of ion current density depending on radius r.

When $J(r)$ = const, expression (11) transforms to (10).

In practice, the distribution of ion current can be measured during the experimental development and testing of thrusters with the help of Langmuir probes or other similar devices.

Ionization coefficient β correction takes into account the presence of multicharged ions in plasma.

If thruster plasma simultaneously contains singly charged, doubly charged and triply charged ions, the total beam current is equal to the sum of currents that correspond to the flows of singly charged, doubly charged and triply charged ions:

$$I_b = I^+ + I^{++} + I^{+++} , \tag{12}$$

where I^+, I^{++} and I^{+++} are the currents of the flows of singly charged, doubly charged and triply charged ions respectively.

In this case, the total thrust generated by the flows of singly charged, doubly charged and triply charged ions will be:

$$T = \sqrt{\frac{V_b m}{e}} \cdot I^+ \left(1 + \frac{1}{\sqrt{2}} \cdot I^{++} / I^+ + \frac{1}{\sqrt{3}} \cdot I^{+++} / I^+ \right). \tag{13}$$

Then ionization coefficient β can be expressed as follows:

$$\beta = \left(1 + \frac{1}{\sqrt{2}} \cdot I^{++} / I^+ + \frac{1}{\sqrt{3}} \cdot I^{+++} / I^+ \right). \tag{14}$$

In practice, the ion current created by singly charged, doubly charged and triply charged ions can be measured with the help of a magnetic sector charge analyzer during the experimental development of the IPT.

Dissipation coefficient δ is to a considerable extent determined by two groups of factors:

− by the ratio of the number of ionized atoms to the total number of working fluid atoms, or by the ionization coefficient;

− by the inhomogeneity of magnetic and electric field in the IPT.

The development of a reliable mathematical model for determining dissipation coefficient δ poses a difficult challenge because the reliable model has to describe various types of plasma flow inhomogeneities, the inhomogeneities of magnetic and electric fields and their fluctuations for different Volt-Ampere and thermal modes of the thruster, etc.

Such models are developed for series-produced IPTs on the basis of empirical data acquired as a result of trial operation and experimental development by measuring the spatial distribution of the electric, magnetic and thermal field of an operating thruster. In the long run, this sort of modelling reduces to determining heat losses, so this type of research is usually carried out while developing thruster thermal models based on experimental data, as for instance in

work [5].

Dissipation coefficient δ can be expressed as:

$$\delta = k_1 \cdot N_i + k_2 \,, \tag{15}$$

where k_1 is the coefficient taking into consideration the interaction of neutral atoms and ions; N_i is the degree of ionization; k_2 is the inhomogeneity coefficient.

Another method of determining dissipation coefficient δ is obtaining its value when determining the efficiency factor and utilization factors [6].

3. Conclusion

The approach proposed in the article allows to develop the mathematical models of IPT operation, determine IPT losses and efficiency, it also allows to make the equation of IPT heat balance more precise and achieve sufficient accuracy when performing calculations on IPT thermal loads and cooling system.

This approach will allow to avoid overheating and destruction of high-power spacecraft electric thrusters, increase their thrust and specific impulse as well as to optimize the cooling system in the course of development and testing.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Flexible Prediction of the Vehicle Component Damage

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Abstract

This paper presents the results of tests concerning the flexible selection of the mileage-to-damage probability distribution. The “mileage-to-damage” also referred to as “usable mileage” refers here to the mileage of the vehicle component. For a given component its usable mileage is determined from the mileage of the vehicle with this component. The unit of usable mileage is one kilometer. The tested vehicles are intensively used and have an annual mileage of 60-70 thousand km. The mileage of the vehicle and useful mileage of its components are a measure of their age. For the prediction of the probability of the component damage, we use the function of its “remaining usable mileage” (RUM). The RUM function is a conditional function dependent on the current age of the component expressed in its usable mileage. The prediction of the RUM function value is made on the basis of properly prepared statistical data. To prepare these data, access to the “operational database” (ODB) of the vehicle fleet is necessary. In the case of maintenance data, there is generally no complete data concerning mileage of a specific component of the vehicle. Therefore, in the prediction of the probability of component damage we use statistical methods for censored observations. “Flexible prediction” (FP) is a consequence of the developed method of selecting the best probability distribution for further usable mileage of the given component.
KEY WORDS: *flexible prediction, usable mileage, censored observation, sudden damage*

1. Introduction

Vehicles are complex, multi-component technical objects that require high reliability and safety levels and, on the other hand, ensure high level of quality and low cost of service. These requirements and limitations need reliable information for making reasonable decisions. Operators or users tend to use advanced information concerning daily usage, maintenance, reliability, costs, and many other aspects [6]. We assume that the measure of the age of the vehicle and its components is their mileage expressed in kilometres. Component damages can be divided into two groups. The first group are component damages that may be predicted by one or several condition monitoring indicators. This damage is referred to as a “gradual damage”. It also called “soft” (or “degradation”) damage. The current research and developments in degradation models are reviewed and summarised in [4]. The second group are component damages that cannot be predicted by either condition monitoring indicators or by measuring the age of the asset. This kind of the component damage is referred to as a “sudden damage”. However, in the case of long-life systems, sudden component damage can depend on the time of its use.

Flexible prediction is a consequence of the developed method of selecting the best probability distribution, among many possible distributions for further mileage of the given component. This method consists of several steps. In the first step, statistical data on the mileage of the selected vehicle component are prepared [1]. For this purpose, access to the ODB of a fleet of homogeneous vehicles is needed. In our case, it is the ODB of a fleet of 45 trams used for five years and having mileage of approximately 300,000 km. Statistical data relates to the mileage of both already damaged components and those that still remain and are used in the vehicles [3]. In the second step, based on the prepared statistical data, the parameters of the basic probability distributions known from the reliability theory are estimated. In our case, these are the distributions available in the WEIBULL++ software [7]. In the third step, a ranking of probability distributions is carried out according to three criteria and according to the combined criterion obtained as a mixture of these three with appropriately selected weights. From the ordered distributions, we leave the top four according to the combined criterion for use in the next, i.e. the fourth step.

The aim of the developed method is to estimate the conditional probability of the usable mileage for a certain vehicle component. To achieve this goal, it is now necessary to determine condition, i.e. the current mileage of the component and the further mileage of the vehicle (mission) for which the probability of this component damage will be estimated. In the developed FP method, we assume the minimal length of 90 percentage “conditional confidence intervals” (CCI) as the criterion for selecting the best conditional probability of component failure. Details and an example of the application of the developed FP method are given in the following sections of this paper.

2. Subject of Research

The research was carried out on the basis of the ODB with data collected during the operation of the fleet of vehicles [2]. All vehicles were used under similar operating conditions and had similar daily and total mileage during

the survey period. The authors of this paper have identified the probability distribution of the usable mileage for the most expensive vehicle components. It should be noted that due to the ongoing process of operating the vehicle fleet, the so-called right-censored times [5] are used in estimation of parameters of selected distribution families. From the ODB, for the assumed period of use, the drive controller was selected as one of the most damaging and the most cost-generating tram components. The purpose of identifying the usable mileage probability distribution for drive controller is determining its distribution of the RUM and the probability of damage in the subsequent useful periods counted in weeks, months or even years of its further operation. The probability of damage of any vehicle component in the further process of its use is determined from the estimated conditional failure function, i.e.

$$\hat{F}\left(l+l_1 \mid L>l_1\right)=\Pr\left(L\le l+l_1 \mid L>l_1\right), \tag{1}$$

where Pr is probability; $\hat{F}$ is estimated unreliability function; L is the random usable mileage of the vehicle component; l_1 is a given mileage of the tested component and l is planned further mileage. On the basis on multi-criteria statistical analysis, four distributions best suited to the given data are selected. For these distributions, the probabilities of damage for driving controllers with different mileage in subsequent periods of tram usage will be calculated. As a comparative criterion of designated damage probabilities, we assumed the length of the determined 90 percent confidence intervals.

3. Preparation of ODB for the Unreliability Distribution Estimation

Identification of the best-fit unreliability distributions was made by the authors of this work on the basis of the ODB of a fleet composed of homogeneous $|J| = 45$ trams used for 5 years in comparable conditions. A hand-held drive controller is similar to a joystick and it is one of the key components of the tram. The WEIBULL++ software was used for estimation of the parameters of the best unreliability distributions and for the point and interval prediction of the probability of damage in the selected periods. During the time t_1 covered by the research, $n(t_1) = 23$ corrective maintenance were registered due to the change of the drive controller. The total costs of these services amounted to approximately 208 thousand PLN (approximately 50 thousand EUR). Using adaptation of the ODB for the needs of the conducted reliability tests, data on the drive controller's mileage for all fleet vehicles up to the day t_1 was compiled in the form of pairs $(l_i; \delta_i)$, $i = 1, 2, \dots, n(t_1) + |J|$, where l_i is expressed in kilometres of usable mileage of the i-th instance of the drive controller, $n(t_1) + |J| = 68$ is the number of data records about the controller and

$$\delta_i = \begin{cases} 1, \ if\ l_i\ is\ the\ observed\ operational\ mileage, \\ 0, \ if\ l_i\ is\ the\ censored\ operational\ mileage. \end{cases} \tag{2}$$

On the basis of ODB, mileage of vehicles for the usable mileage of individual 68 driving controllers has been recalculated in a way that developed in the paper [1]. Then, the data was coded according to the formula (2) and the final version of the data for the identification of unreliability was set up in Table 1 in the form of pairs $(l_i; \delta_i)$.

Table 1

A set of statistical data prepared for the unreliability distribution estimation

(327707; 0)	(156048; 1)	(116623; 0)	(360404; 0)	(243532; 0)	(216144; 1)	(68690; 0)
(235268; 1)	(134168; 0)	(314522; 0)	(339907; 0)	(311679; 0)	(262359; 1)	(79882; 0)
(328494; 0)	(354100; 0)	(244106; 1)	(24143; 1)	(23789; 0)	(339492; 0)	(292266; 0)
(258866; 1)	(60222; 0)	(352654; 0)	(132841; 1)	(177672; 0)	(305087; 0)	(335015; 0)
(308114; 0)	(328878; 0)	(143058; 1)	(142315; 1)	(29216; 0)	(268743; 0)	(108027; 1)
(29092; 1)	(71490; 1)	(111124; 0)	(235029; 1)	(93451; 0)	(328168; 0)	(219815; 1)
(67307; 0)	(283162; 1)	(14190; 0)	(271868; 0)	(122934; 1)	(121071; 0)	(284525; 0)
(207679; 0)	(152554; 1)	(161592; 0)	(265598; 1)	(5786; 0)	(316331; 0)	(286225; 0)
(282281; 1)	(3889; 1)	(3355; 0)	(254974; 0)	(290198; 0)	(26807; 1)	(272367; 0)
(264787; 0)	(265863; 0)	(192863; 1)	(102032; 0)	(315371; 0)		

When we have an identified unreliability distribution function that describes a component lifetime, we can use this distribution to predict its future behavior.

4. Simple and Mixed Ranking of Estimated Distributions

ReliaSoft's WEIBULL++ software can provide guidance in selecting a distribution based on statistical tests. Firstly, the maximum likelihood estimation (MLE) is used for estimating the parameters of the chosen distributions. Then, the Distribution Wizard uses three factors in order to rank the obtained distributions: the Kolmogorov-Smirnov (K-S) test, a normalized correlation coefficient and the likelihood value [7]. Table 2 summarizes the results of the ranking of available probability distributions according to three criteria of their matching to the data summarized in Table 1. In the Table 2, the second column AVGOF contains ranking values obtained using the Kolmogorov-Smirnov (K-S) test. The third column, AVPLOT, provides the ranking results of the second test, which is a normalized correlation coefficient (rho) that measures how well the plotted points fit a straight line. The fourth column, LKV,

contains the ranking of the likelihood values, based on the values of the log-likelihood function obtained for the estimated parameters of the distribution.

Table 2

Single and multi-criterial ranking of probability distributions

Distribution	AVGOF	AVPLOT	LKV	DESV	Ranking
G-Gamma	2	4	1	170	1
3P-Weibull	1	1	4	250	2
2P-Weibull	4	5	2	310	3
Gamma	6	7	3	460	4
Normal	3	2	8	540	5
Loglogistic	7	6	6	640	6
Logistic	5	3	10	730	7
2P-Exponential	10	9	5	740	8
1P-Exponential	11	10	7	890	9
Lognormal	9	11	9	920	10
Gumbel	8	8	11	950	11

As can be seen from Table 2, columns 2-4, the rankings based on the three described criteria do not match. Therefore, the DESV ranking includes these three individual rankings with the appropriate weights as a synthetic one, which allows to choose the best probability distributions for further reliability analysis. The fifth column contains the values of multi-criterial DESV statistics for individual probability distributions [7], in which these three ranking values are weighted and combined into one overall value given by:

$$\begin{aligned}\text{DESV} = {} & (\text{AVGOF Rank} \times \text{AVGOF Weight}) + (\text{AVPLOT Rank} \times \text{AVPLOT Weight}) + \\ & + (\text{LKV Rank} \times \text{LKV Weight}),\end{aligned} \tag{3}$$

where the following values were assumed: AVGOF Weight = 40, AVPLOT Weight = 10 and LKV Weight = 50. The last column shows the ranking of the 11 analyzed distributions according to the DESV value.

It should be noted, however, that all these rankings allow to order the probability distributions in an way that is unconditional from the mileage value. In the case of estimating the conditional probability of the component failure, the local ranking of distributions is more important for the remaining period of vehicle use. The question arises: How to define the criterion for local ordering of probability distributions including the DESV ranking? The best probability distribution obtained according to such an ordering criterion can be used to estimate the probability of damage of a specific component. The locality of prediction of component failure results from the assumed further mileage of the vehicle. Depending on the length of this assumed mileage, we can talk about short-, medium- or long-term prediction. Because the measure of the uncertainty of prediction of the conditional probability of damage of a vehicle component is a CCI, we propose that for the assumed significance level (sl) of 90%, the length of this interval K_{sl} should be the criterion for ordering the distributions. Of course, if the failure probability has a shorter CCI, the risk of incorrect failure prediction is smaller. Thus, for the best probability distribution among those selected we accept the one with the shortest CCI.

It is worth mentioning that in WEIBULL++ software confidence bounds method uses the Fisher Matrix. For given significance level sl, usable mileage l_1 and planned further mileage l conditional probability of damage to a specific component is equal to $\hat{F}(l + l_1 | L > l_1)$, while lower and upper limits $k_l(sl)$ and $k_u(sl)$ of the CCI are determined by values $\widehat{F_{Lower}}(l + l_1 | L > l_1)$ and $\widehat{F_{Upper}}(l + l_1 | L > l_1)$. For given significance level sl, the length K_{sl} of the CCI is the difference between its two ends, i.e. $K_{sl} = k_u(sl) - k_l(sl)$. In this way, defined K_{sl} is our criterion for ranking probability distributions. The best distribution in the sense of this criterion is proposed for estimating the probability of damage to the selected vehicle component.

5. Application of the Flexible Prediction Method

The presented flexible prediction method of finding the best distribution for estimating the conditional probability of damage to the vehicle component with the lowest risk will be applied to the already indicated drive controller. The ranking covers four out of eleven best distributions determined by the DESV method. The following distributions are compared: general gamma (G-Gamma), three-parameter Weibull distribution (3P-Weibull), two-parameter Weibull distribution (2P-Weibull) and gamma distribution (Gamma) as the best among the selected ones. The results of both estimation and rankings of probability distributions for a tram driving controller are presented in Tables 3, 4 and 5. In all tables, the estimation of conditional unreliability and 90 percentage CCI is made for the same planned vehicle mileage of 30,000 km. Such a mileage means that the prediction concerns the probability of the drive controller being damaged within the next half-year of using the tram in which it is installed.

Differences in the tables result from the prediction of damage of the drive controllers with various mileages, i.e. one relatively new with a mileage of 5,000 km, one used for almost a year with a mileage of 60,000 and one used for almost two years with a mileage of 120,000 km.

Table 3

Prediction conditional damage for $l_1 = 5{,}000$ km, $l = 30{,}000$ km and CCI ranking

Distribution	Lower limit	$\widehat{F}(35,000\|L > 5,000)$	Upper limit	Length K_{90}	CCI Ranking
G-Gamma	0.0140	0.0303	0.0640	0.0500	2
3P-Weibull	0.0090	0.0186	0.0367	0.0277	1
2P-Weibull	0.0125	0.0281	0.0628	0.0503	3
Gamma	0.0135	0.0303	0.0666	0.0531	4

Table 4

Prediction conditional damage for $l_1 = 60{,}000$ km, $l = 30{,}000$ km and CCI ranking

Distribution	Lower limit	$\widehat{F}(90,000\|L > 60,000)$	Upper limit	Length K_{90}	CCI Ranking
G-Gamma	0.0288	0.0415	0.0594	0.0306	2
3P-Weibull	0.0217	0.0364	0.0504	0.0287	1
2P-Weibull	0.0300	0.0441	0.0648	0.0348	4
Gamma	0.0320	0.0462	0.0664	0.0344	3

Table 5

Prediction conditional damage for $l_1 = 120{,}000$ km, $l = 30{,}000$ km and CCI ranking

Distribution	Lower bound	$\widehat{F}(150,000\|L > 120,000)$	Upper bound	Length K_{90}	CCI Ranking
G-Gamma	0.0371	0.0504	0.0681	0,0310	1
3P-Weibull	0.0349	0.0488	0.0682	0.0333	2
2P-Weibull	0.0381	0.0534	0.0746	0.0365	3
Gamma	0.0379	0.0536	0.0754	0.0375	4

6. Conclusions

As can be seen in Tables 3, 4 and 5, the probability distributions rankings depend on the age of the tram drive controller. Hence the conclusion that in the prediction of the conditional probability of damage to a vehicle component, we cannot use one distribution for components of different age of use. Similarly, it can be shown that the differences in rankings may also result from the planned different periods of further use of the vehicle with a given component. We believe that this short development of the FP method in a sufficient way justifies the need for flexible prediction of events for operated vehicles. However, we must remember that in the RUL analysis, the output of the analysis is always an estimate. The true value of the probability of failure, the mean life, the parameters of a distribution or any other applicable parameter is never known, and will almost certainly remain unknown to us for all practical purposes. Nevertheless, we are convinced that the application of the FP method will contribute to the development of modern tools for flexible management of the fleet of mass transport vehicles. Finally, it is worth emphasizing that the methods of optimizing the maintenance of technical systems are the subject of intense interest.

Acknowledgements

The research work financed with the means of statutory activities PUT 04/43/DSPB/0104 and DS05/51/DSPB/3551.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Rationale for Choosing the Type of Traction Rolling Stock for the Enterprise of Industrial Transport

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Abstract

Shunting locomotives are used to carry out shunting and clean-up operations on the routes of most private and state enterprises of industrial transport in various spheres of activity. In most cases, the power of these locomotives significantly exceeds the pre-determined volume of works, especially if the work has cyclical nature.
One of the options for solving the problem of transportation for owners of small industrial enterprises, grain elevators and other similar enterprises may be the presence of their own traction rolling stock. Moreover, its technical and economic characteristics must fully comply with the conditions and volumes of shunting/clean-up operations of the enterprise.
Definition of the most rational type of traction rolling stock should be carried out taking into account the available track infrastructure of the enterprise, volumes and organization of shunting and clean-up operations, organization of the system and production cost of maintenance and repair.
The authors proposed a technique of comparative analysis of technical and operational indicators for the utilization of various types of traction rolling stock using traction calculation methods and ways to organize the operational performance. This will allow the owner of the industrial enterprise to choose the type of traction rolling stock (locomotive, locotractor or steam-accumulator locomotive), which most closely comply with the conditions of a particular enterprise. At the same time, the company's cost reduction for operation of the traction rolling stock is ensured.
KEY WORDS: *shunting operation; rolling stock; locomotive; locotractor; steam-accumulator locomotive; traction calculation; technical and operational indicators*

1. Introduction

An important condition for improving the efficiency of freight transportation by railway is reduction in expenses for shunting operations performed at loading and unloading stations and on approach tracks. One of the key factors at the same time is the choice of technical means for performing shunting operations, first of all shunting locomotives. In this regard, the choice of parameters of shunting locomotives, depending on the operational aspect of major and industrial railway transport, is an urgent task.

The contemporary fleet of shunting locomotives of the PJSC Ukrzaliznytsia public carrier and industrial enterprises in Ukraine actually includes three types of diesel locomotives with an electric or hydraulic transmission, an adhesive weight 45, 90 and 100-120 tons and a power from 370, 550 and 736-883 kW, respectively. The larger part of the shunting locomotives of Ukrainian enterprises was built up to 1990, and today a significant problem is their deterioration, which reached 96%. The renovation of the locomotive fleet at the enterprises is usually carried out through the acquisition of locomotives that were in operation. In this case, small and medium-sized diesel locomotives such as TGM23 and TGM4 of different series, are replaced by more powerful diesel locomotives TGM6A, TEM2. As a result, the share of shunting locomotives with an adhesive weight of 90-100 tons and a power of 735 kW. and more exceeded 70% [3]. Also, there are cases when small-scale enterprises use diesel locomotives with electric transmission CHME3 and TEM7, which were designed for operation at the major railway stations or enterprises of the mining and metallurgical complex. Such a redistribution of the structure of the diesel locomotive fleet leads to a significant reduction in the efficiency of locomotives usage. The data of the enterprises show that at present diesel locomotives are used extremely irrationally, both by the basic parameters - adhesive weight and power, and by time-of-use. The

foregoing resulted in a significant 20-25% increase in the share of expenses for traction in the carrier cost with a significant increase in energy costs [2, 3].

It should be noted that the problem of traction shunting operation is quite typical for railway transport in different countries. The analysis given in [14] shows that in Canada, 98.7% of locomotives of industrial enterprises were manufactured before 1990, and in the United States, the share of industrial locomotives, manufactured by 1990 was 99.6%. According to [14], the main direction of increasing the efficiency of industrial locomotives in Canada and the US is the upgrading of the operational fleet. Extension of the service life and modernization of existing locomotives are widely used on major railways. This approach applies in particular on the railways of Estonia [15], which use the shunting locomotives CHME3 built before 1990.

In conditions of decrease in workload a part of the enterprises refuses to hold own traction rolling stock and uses locomotives of third-party organizations. However, this approach leads to a dependence of the operational mode at the industrial enterprise on the "third person" and, as a consequence, significant downtime of the rolling stock. At the same time, there are additional costs associated with unproductive mileages of locomotives and locomotive brigades between stations and shunting districts, the costs of which are also transferred to enterprises–users. In this regard, the question about using the own new traction rolling stock (TRS), technical and economic characteristics of which will fully meet the conditions and volumes of shunting/clean-up operations [11] is relevant for enterprises. The use of own traction rolling stock will improve the control over its technical condition by encouraging the locomotive brigades and maintenance staff.

2. Methodology and Results

The research [1, 5, 12, 13, 16] of locomotive operating conditions at transport enterprises of different industries confirms that for all operating conditions, the long-term usage of power plant of the diesel locomotive on small loads and idling is typical. Diesel locomotives of industrial transport often operate in mixed mode, performing shunting and clean-up operations. Typical features, characterizing the operating conditions of industrial diesel locomotives of different series, are the sharp changes in the train tonnage from zero to maximum; low speed, large number of reverse operations. Investigations of operational modes for diesel locomotives TGM23, TGM4 and TGM6 at enterprises of industrial railway transport showed that even in the case of intensive shunting operation they work mainly on the 1-4th positions of the locomotive throttle. The capacity utilization factor of a diesel engine at work under load on the basis of some data is 0.17-0.26, on the others – 0.16-0.20. From 50 to 70% of the time, diesel locomotives operate in idle mode, and the rest of the time - under load and, more often, on the 1-4th positions of the locomotive throttle. At this, the time of the throttle at positions is approximately the same and varies from 17 up to 34%, and diesel is accompanied by a significant number of changes in the crankshaft speed. [1]. The specified modes are the most unfavorable for the power equipment operation of the locomotive [17] and cause its considerable deterioration.

Partial solution of this problem is the use of hybrid power equipment on shunting and industrial locomotives [10, 16, 18], in which an excess of electric energy, produced by diesel locomotive power equipment for charging the batteries, whose energy is used in the operation of the locomotive in intensive modes. However, the use of hybrid equipment leads to an increase in the cost of locomotives and can lead to increased costs for shunting at enterprises with insignificant and volatile over time volumes of operation.

In papers [2, 7] the issues of the steam-accumulator locomotives usage for performance of shunting operation at the enterprises are considered. The idea of introducing the steam-accumulator locomotives is not new, since 40’s of the last century fireless locomotives were used. On such locomotives a boiler-accumulator with a working pressure of 18 to 35 kg/cm^2 is installed. Pressure in the boiler-accumulator in the course of carrying out the transport operation by the locomotive is reduced to the level of 3-4 kg/sm^2. Approximately 0.5 hours are spent on the required energy "recharging", while the conventional locomotive was equipped within 1.2-1.3 hours.

As a result of the introduction of steam-accumulator locomotive, the following positive effects are achieved [2, 7]:

a) refusal to use a significant part of the current fleet of shunting diesel locomotives by means of their equivalent replacement with the proposed traction rolling stock with a corresponding reduction in the consumption of diesel fuel;

b) reduction by 80-90% of the planned maintenance costs (technical inspections and repairs) of the proposed traction rolling stock in comparison with the conventional shunting locomotive;

c) possibility of operation in polluted, contaminated or explosive conditions without reducing the resource;

d) environmental friendliness of the steam-accumulator locomotive both per the maximum permissible emissions (only atmospheric steam is present in the escape) and by the maximum permissible concentrations of harmful emissions;

e) the lifetime of the steam-accumulator locomotive is 50 to 60 years old. According to preliminary calculations, the "life cycle" of the steam-accumulator locomotive is seven times cheaper than the "life cycle" of the diesel locomotive TGM4 and twelve times of the locomotive CHME3 [7].

To the disadvantages of a steam-accumulator locomotive it is worth mentioning [2] a relatively small (compared with a shunting diesel locomotive) worktime fund without refueling the steam-water accumulator (5-6 hours) and the need for the presence of a specific stationary source of external energy for the production of hot steam with a pressure of up to 1.5 MPa.

As an alternative to diesel locomotives, locotractors have recently been used. The lokotractor is constructed on

the basis of a wheeled tractor equipped with a combined pneumatic-rail travel. Currently, they are manufactured by a number of machine-building enterprises with a very wide range of standard sizes. Locotractors have high reliability in operation, a high degree of automation of performed operations, ease of transfer to the railway track, and from it - on the bus-bar as well as by cost-effectiveness.

Experience of operation of locotractors in different conditions has shown that the high economic effect of their application is achieved due to:

a) a complete replacement of traditional locomotives (diesel locomotives) in all types of transport operations, since the shunting locotractors on railway transport provide the specified traction, speed and braking modes of operation;

b) the possibility of performing a significant additional volume of transport works as a tractor towing vehicle on the bus-bar motion during forced breaks;

c) reduction of operating costs: fuel and lubricants (energy resources); current expenses (depreciation, maintenance and repairs); use of working and backup locomotives.

According to various sources, the cost of operating the shunting locotractors is almost 40 - 50% lower than the cost of maintaining the shunting diesel locomotive with a power of 290 - 330 kW. [4].

The advantages of these machines also include the fact that in case of their derailing from the railway track, the machine itself goes back to the track and continues to operate.

To the disadvantages one can be added and the model of motion along the rails. Contact the rubber wheel-rail and guide-rail wheels. According to calculations of experts [6] and operating experience the coefficient of coupling of a "rubber-metal" pair is incomparably better than "metal - metal" one. However, this rule operates under favorable operating conditions. In real conditions: oil, snow, rain, frost or dirt on rails, as well as dirt on tire can reduce the advantage of a "rubber - metal" pair to zero. In addition, scuffs and joints on the rails, as well as other possible obstacles, lead to increased wear of the rubber. The mechanical equipment of the locatractor is often not designed to work with cars and requires constant repairs [6].

The performed analysis shows that the problem of choosing the traction rolling stock to perform shunting operation remains unresolved and requires additional studies. The purpose of this research is to conduct a comparative analysis of technical and operational performance indicators of various types of traction vehicles and determine the area of their effective application, depending on local conditions at the enterprises.

In a comparative calculation, as a traction rolling stock that can be used at the enterprise, authors considered shunting locomotives with hydraulic transmission such as TGM23 and TGM4 and their modifications, shunting locomotive TEM2 and its modifications; locotractor MMT-3 on the basis of the tractor XTA (CHTA)-300, and steam-accumulator locomotive PAL9P. Characteristics of this traction rolling stock are shown in Table 1.

Table 1

Main characteristics of the traction rolling stock for shunting

Parameter	MMT-3	PAL9P	TGM23	TGM4	TEM2
Wheel arrangement	-	0-3-0	0-3-0	2-2	3_0-3_0
Tractive power of continuous rating, ton	-	9.0	10.2-12.5	16.4-23.0	20.4
Length, m	8.59	9.82	8.92	12.6-13.1	16.970
Power, kW (h.p.)	183.8 (250)	-	294-365 (400-500)	552 (750)	882 (1200)
Adhesive weight, ton	13.0	50	44	68-80	120
Minimum radii of ease curve, m	50	40	40	40	80

The rate of diesel fuel consumption for shunting diesel locomotives is from 15-20 kg/h, and for MMT-3 from 6.5-10 kg/h, depending on the volume of shunting/clean-up operation.

For technological calculations, it was assumed that the enterprise is located at a distance of 3 km from the connecting station, the calculated slope of this section is 8‰, the radius of curves is 80 m, the slope of the track when performing shunting for changing four-axle cars, weight 90 t between the tracks of the enterprise is 5 ‰, the speed of shunting/clean-up operation - 5 km/h.

The train capacity, which can be rearranged by the shunting traction rolling stock, is determined from the expression:

$$Q = \frac{F_p - \left(w_0' + i + w_r'\right) \cdot P_{aw} \cdot g}{\left(w_0'' + i + w_r''\right) \cdot g},$$

here P_{aw} - adhesive weight of the vehicle, ton; w_0', w_0'' - the main specific train resistance of hauling equipment and cars; w_r', w_r'' - additional specific train resistance of hauling equipment and cars in curves; i - calculating slope; g - gravitational acceleration.

In accordance with the rules of traction calculations [13] the maximum traction force is determined depending on

the adhesive weight of the traction rolling stock and the coefficient of adhesion:

$$F_p \leq 1000 \cdot P_{aw} \cdot \psi$$

here ψ - adhesive coefficient of driving wheels of traction rolling stock with rails.

For MMT-3, the curb weight with equipment is not exceeding 13.0 tons. We assume approximately 10.0 tons of adhesive weight, in view of the fact that a part of the mass will be transferred to the rails through the rollers of combined motion.

According to [8, 9], we take ψ = .75. The coefficient of adhesion for the pneumatic wheel-rail pair is higher than a metal wheel-rail pair (0.22-0.24). It is 0.68-0.85 for dry and 0.35-0.45 for wet rails. On the icy rails the coefficient of adhesion of pneumatic wheels with the rale drops to 0.15).

As a result of the calculations, we determined the permissible number of cars in the shunting train, shown in Fig. 1.

Based on the effective power of the traction rolling stock and the calculated number of cars, the zones of the most efficient application of different types of traction rolling stock were obtained. Visually, the zones of the most effective application of various types of traction rolling stock for specified conditions of shunting/clean-up operation are shown in Fig. 2.

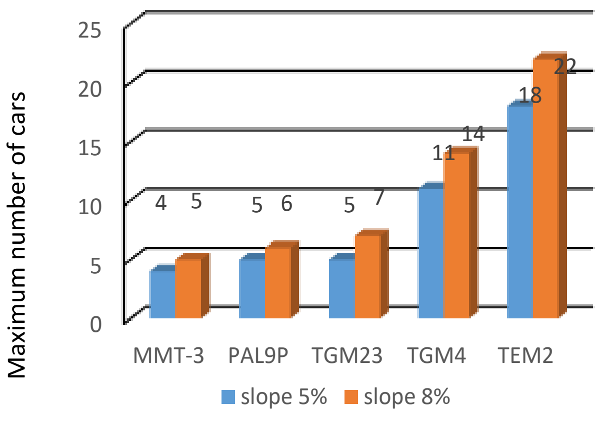

Fig. 1 Maximum number of cars when performing shunting/clean-up operation depending on the type of traction rolling stock

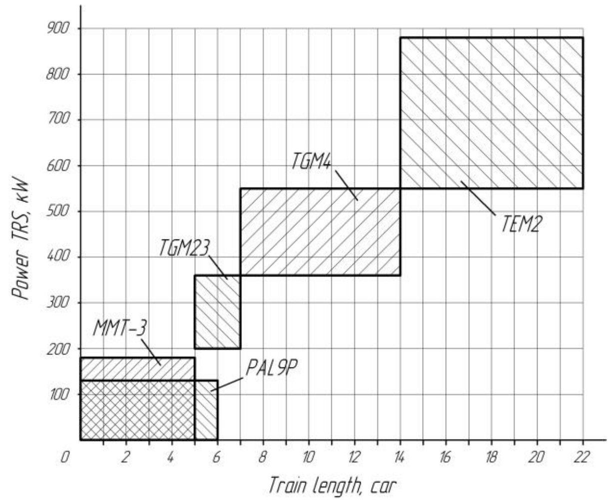

Fig. 2 Areas of the most effective application of different types of TRS for the given conditions of shunting/clean-up operation

3. Conclusions

Characteristic features of railway transport operation both in Ukraine and in the world is the aging of traction rolling stock, which provides execution of the shunting operations at loading and unloading stations and industrial enterprises. The renovation of the shunting locomotives fleet in Ukraine is usually carried out through the acquisition of locomotives of more powerful series that were in operation at other enterprises. It leads to noncompliance of their characteristics with operating conditions and increase in operating costs. In this regard, the issue of ensuring approach tracks with average and low volumes of operation by traction rolling stock is relevant.

Using the methods of traction calculations, a comparative analysis of the most common and perspective types of traction rolling stock for shunting/clean-up operations was carried out. Authors determined the areas of the most effective application of different kinds of traction rolling stock depending on the length of trains with which shunting are performed. The obtained results allow carrying out preliminary assessment of expediency for using the various types of traction rolling stock to perform shunting operation.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Impact of New Informatics Solutions Using in Railway Transport on its Safety

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Abstract

The introduction on a large scale of new informatics and telecommunications solutions (IT) and the use of microcomputer technology has contributed to the implementation of modern computer systems on railway transport. Their task is to ensure a high level of reliability and safety. Devices of railway traffic control made in computer technology belong to the family of modern multi-computer distributed systems, are based on network solutions and using control decentralization. These devices are built as redundant structures, and must work reliably, safety, and with a low failure rate irrespective of operating conditions.
The article presents technical characteristics of selected solutions for computer systems of railway traffic control used in Poland and shows their influence on improving the safety level of the transport process in the Polish railways. It is widely recognized that computer technology and telematics applications in the 21st century establish the standard and the directions of technological progress also in railway transport in Europe and around the world.
KEY WORDS: *railway transport, safety, railway traffic control, computer systems, Programmable Logic Controllers*

1. Introduction

The railway traffic control system is one of the main elements of railway transport system. The railway traffic control system significantly affects the safety and efficiency of the people and cargoes movement. The railway traffic control system should be understood as the technical means of implementing the control function in the process of moving rail vehicles as well as the methods and means of their maintenance. These systems belong to the group of modern and multi-computer distributed systems based on network technologies. The new technical solutions of railway traffic control systems enable to shorten the time of train travel on the railway routes. These solutions involve also a proper operation of safety devices at the level crossings, shorten the time and facilitate the operation of setting devices at railway stations.

In the railway transport systems responsible for railway traffic control, the *fail-safe* principle applies as the overriding safety requirement. This rule indicated the fact that a single failure (hardware, software) or a single fault cannot cause a dangerous situation. This means that a critical fault must be detected and a safe system reaction to the detected fault should be made. This is possible assuming that the likelihood of multiple damage is negligible. In practice, the principles of safe design have been defined and faults have been classified depending on their impact on the system's operation security as follow:

– non-critical (safe) failures that only limit the system functionality, causing disruptions in the train traffic but without the possibility of trains collision;

– critical (dangerous) failures that introduce an immediate threat to security and can lead to collisions.

The fail-safe principle became insufficient when the computer railway traffic control systems were launched. In addition, there is determined detection time of failure in the computer systems [6, 9].

2. The Safety of Railway Traffic Control Systems

2.1. Standards and Security Levels

The hardware and software which are used to create new systems responsible for safety must meet high quality and reliability requirements. As a result of European Committee for Electrotechnical Standardization (CENELEC) activities, there were developed standards regarding algorithms for creation, verification and operation of safe railway applications.

In Poland, CENELEC standards have become applicable: PN-EN 50126, PN-EN 50128 and PN-EN 50129. These standards represent completely different approach to the current one and they do not provide detailed solutions. They only define the criteria for their assessment and comparison. Each identified threat and risk that the control process and the control system potentially entail must be reduced to an acceptable level. This is possible by assigning them the safety function.

The PN-EN 50126 standard defines reliability, readiness, availability and safety (RAMS – Reliability,

Availability, Maintainability and Safety*)* as a process based on the system's life cycle. The individual steps of the system and approval procedures before moving on to the next stage were defined in this process (requirements specification, design, implementation, etc.). The PN-EN 50128 standard specifies the procedures and technical requirements for design of the safety electronic system software concerning control and protection on the railway. The PN-EN 50129 standard defines the requirements for the design, testing, acceptance and approval of the electronic systems, subsystems and signaling devices which are related to safety in railway applications [8, 13].

2.2. The Redundancy in New Informatics Solutions Applied in Railway Transport

The concept of safe computer systems which are used in railway transport assumes a very low faults intensity. This idea guarantees a negligible probability of a double or multiple failure to a critical (catastrophic) failure with the total independence of the processing channels. The basis of the analysis is the acceptable and permissible level of risk.

The railway system based on computer technology must consist of at least two computers associated with each other in an appropriate structure in order to meet high safety requirements. This structure will enable independent data processing and mutual control. Two independently operating channels in redundancy can be seen in: control system, power systems, I/O systems, etc. (Fig. 1, Fig. 2). The components in the railway device are allocated to both control channels regardless of their number and type. In the event of failure by one of the channels, the other one provides sufficient system protection.

The multi-channel systems, i.e. two-channel or three-channel systems, operate in the “2 out of 2” and “2 out of 3” systems, where the security is ensured by redundancy at the level of hardware and software. The requirement of safe operation of the “2 out of 2” system is the results compliance on the active channels outputs. The appearance of an error causes a safe reaction of the system. The different results in two compared channels of the “2 out of 3” system cause as turning on the additional computer. Finally, the same result from two control channels is taken into consideration [3, 5].

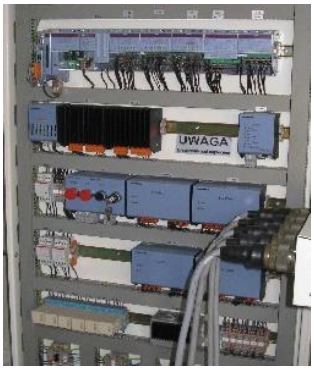


Fig. 1 Stand with the microprocessor controllers PLC in the level crossing signaling SPA-5 type with the two-channel structure [own study]

Fig. 2 Power stand with the two-channel structure in the level crossing signaling SPA-5 [own study]

The Tolerable Hazard Rate (*THR*) of damage level is the important parameter which determines the safety level of the railway traffic control system. It depends on the damage intensity and the detection time. This indicator can be calculated from relation [8-9, 13]:

$$THR = \prod_{i=1}^{n} \frac{\lambda_{ui}}{\mu_{di}} \sum_{i=1}^{n} \mu_{di} \ , \qquad (1)$$

here: λ_{ui} – the intensity of critical failures in the *i*-th control channel; μ_{di} – the intensity of error detection in the *i*-th control channel.

In accordance with the requirements of standards described in chapter 2.1 for computer systems, it is mandatory to specify the *THR* value. It should be located within the required range (Table).

Table

Safety levels of control systems in railway transport and Tolerable Hazard Rate (THR) values [8, 10, 11]

Safety level	Potential effects of damages	Examples of railway transport devices	THR [h^{-1}]
SIL-0	No effects	-	-
SIL-1	Loss of important properties	Power devices	$10^{-6} \leq$ THR $\leq 10^{-5}$
SIL-2	Environmental pollution	Diagnostic devices	$10^{-7} \leq$ THR $\leq 10^{-6}$
SIL-3	Injuries or illness of travelers	Train continuity control device	$10^{-8} \leq$ THR $\leq 10^{-7}$
SIL-4	Losing health	Railway crossing protection devices, track occupancy control	$10^{-9} \leq$ THR $\leq 10^{-8}$

In the railway systems responsible for the train traffic control, five Safety Integrity Levels have been distinguished. They are marked with the abbreviation SIL. The Table lists the valid *THR* values occurring in 1 hour per function. The safety level SIL-4 is the highest one and it assumes that the intensity of damage λ (probability of damage occurrence per unit of time) for a single system element is 10E-11.

If the architecture of the railway transport system is based only on one information processing channel, then its value would be equal to 1 based on the formula for *THR*. It means that the *THR* value would be equal to the average of resultant faults intensity in this system. Accordingly, the redundant systems are used in the railway traffic control systems. The correct *THR* value is there obtained by directly comparing information in parallel control channels [8, 10].

2.3. Different Methods to Increase the Safety Level of Railway Transport Systems

In addition to the hardware redundancy which is used to increase the safety level of computer-based railway traffic control systems, it is also applicable [6, 8, 11, 12]:

– various applications which control the system in both channels, written by independent teams of programmers;

– synchronization of both control channels operation, where the exchange of information between PLCs takes place as an appropriate serial interface;

– testing and analysing the correct operation of subassemblies which are part of the railway traffic control systems on a regular basis, i.e. control applications also include procedures for testing the correctness of component elements operation and even procedures and mechanisms of control systems self-testing;

– testing the control software on a regular basis by means of appropriate procedures checking the correctness of each program cycle and system parameters values, etc.

The software creation of the railway traffic control system made in computer technology should base on the system life cycle model which recommends [10]:

– methods of software control in every phase of its design considering the substitute programming;
– modular program structure assuming the possibility of software designing from tested modules;
– transparent documentation as a subject for verification;
– testing methods which are basis for approval.

The identification of software errors should be ensured by the programming language selection. The adopted translator (compiler) should have an appropriate certificate.

3. Technological Development of Railway Transport Devices

A good example of showing the fast technological development of railway transport devices are the ones included in the railway traffic control system. These devices, along with the development of the railway transport, improved their technical solutions as the needs, requirements and expectations increased. Over the years, the railway traffic control systems had a gradual evolution, starting from mechanical devices, through electromechanical, relaying to hybrid (relay-computer) and computer [3, 5].

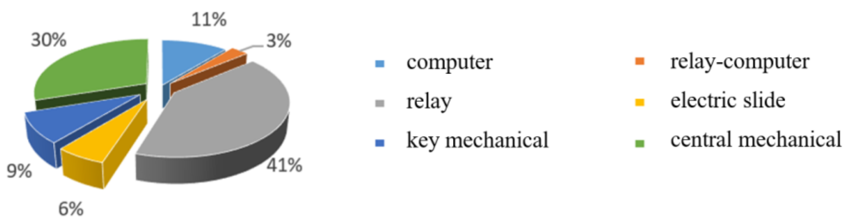


Fig. 3 Classification of railway traffic control devices produced in various technologies in 2016 year in Poland [7]

Modern railway traffic control devices are computer solutions that ensure a very high level of traffic safety. According to PKP Polish Railway Lines, 11% of used nowadays railway steering are computer-controlled devices and 3% are hybrid relay-computer devices. Most of the railway traffic control devices are made in electrical relay technology (41%), electric sliding (6%) and mechanical (39%), including centralized mechanical devices 30%, and key mechanical 9% - Fig. 3 [7].

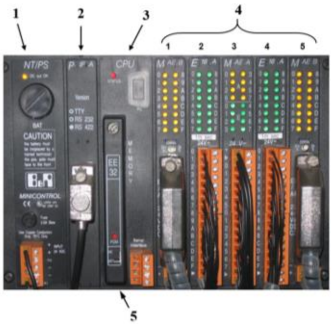
Railway traffic control devices of the new generation have developed diagnostic and autodiagnostics functions with the ability to remotely control the selected devices work. The implementation of modern computer railway traffic control systems, regardless of its purpose, reduces labor costs and stimulates the increase of employee productivity [2].

4. Examples of the Modern Secure Informatics Solutions in Polish Railway Transport Systems

4.1. Purpose of PLC Controllers Used in Railway Transport

PLC programmable controllers are modern universal devices - industrial computers (Fig. 4). They receive

information from analog and digital sensors, input circuits, communication modules, etc. and based on the operation algorithm stored in their ROM program they operate under the control of the real-time operating system and generate output signals to control work of the railway system [5, 7, 14].



Designations:
1 – power supply module;
2 – interface card;
3 – central processor card (microprocessor of the 6303 family);
4 – Input / Output cards;
5 – ROM program memory sub-module

Fig. 4 View of the MINICONTROL PLC controllers used in the automatic crossing signaling SPA-4 type manufactured by Bombardier Transportation S.A. [own study]

4.2. Computer Line System Block SHL-12 Type

The computer line block system SHL-12 type is designed for automatic regulation of train consequences with ensuring traffic safety and optimal route capacity of the railway line. The SHL-12 system is a set of modern IT devices forming a distributed structure, which consists of linear and station control points located along the railroad line, connected with each other by transmission links. Fig. 5 shows the general structure of the computer line block system SHL-12 type for the single-track railroad line [5].

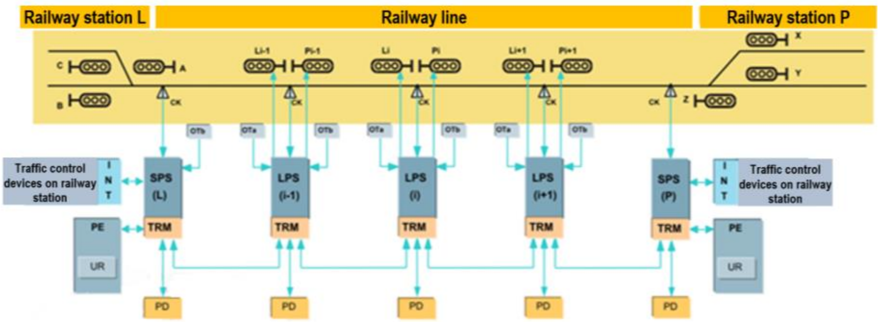
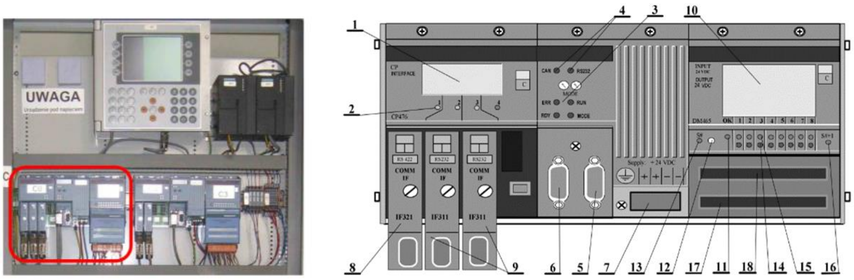


Fig. 5 Hardware structure of the SHL-12 system [5], here: A, B, C - signalling lights of railway traffic control devices on L station; X, Y, Z - signalling lights of railway traffic control devices on P station; Li - signalling spacing of automatic line block system for the direction P → L; Pi - signalling spacing of automatic line block system for the direction L → P; OTa,b - relay contacts of the railway tracks occupancy control device; INT - interface for railway traffic control devices on station

4.2.1. An Example of Using Programmable Logic Controllers MINICONTROL in Linear Control Point of Line Block System SHL-12 Type

The elements of the control point are formed by two channels: A – microprocessor controller EDH 2005 and M – EDH-2006, which communicate with each other by a transmission channel (Fig. 6).



a b

Fig. 6 The linear control point of line block system SHL-12 type [6]: a - Part of a container cabinet with two control channels A (EDH-2005) and M (EDH-2006); b - Architecture of the microprocessor controller EDH-2005 type (for channel A)

The EDH-2005 controller includes, among others (Fig. 6, b):
- processor module 7CP476.60 type (marked in the figure by number 1);
- RS422/485 transmission module 7IF321.7 type (8);
- two RS232 transmission modules 7IF311.7 type (9);
- digital input / output module 7DM465.7 type (10);
- LED signaling diodes for determining the operating status of the EDH-2005 controller components.

Each of the control points reads cyclically information about the technical condition of the external devices and the neighboring control points and processes it parallel in both channels. The processing result from channel A is sent to channel M which allows taken decisions to be implemented only if there is compatibility between the channels. The lack of correspondence between the state read out of the external devices control point or elaborated decisions between the channels causes initialising of the emergency response and bringing the line block system to the safe state. This is a condition for meeting the requirements of the SIL-4 safety level. Software of PLC programmable controllers is written on the assembler level of the used microprocessor and on the level of ladder diagrams [6].

The arrangement of the processor modules and inputs / outputs of the EDH-2006 controller in the M channel is analogous to that of the EDH-2005 controller (channel A), however, it is limited to two instead of three transmission modules.

4.3. PLC Controllers Used in Automatic Crossing Signaling SPA-5 Type

The automatic crossing signaling system SPA-5 type is designed to ensure safety at the intersection of a railroad line with a road in one level (Fig. 7).

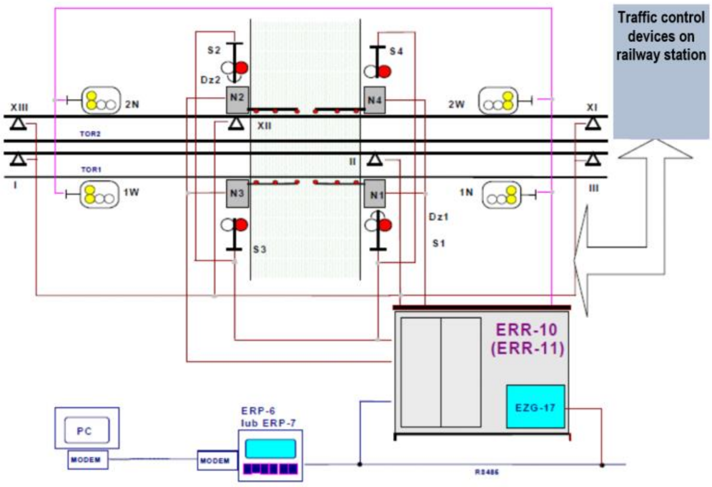


Fig. 7 Configuration of devices in the automatic crossing signaling system SPA-5 type [6]. Where: I, II, III, XI, XII, XIII – railway sensors, S1, S2, S3, S4 – roads signalling lights, N1, N2, N3, N4 – railway turnpikes, 1W, 2W, 1N, 2N – warning targets on level crossing, Dz1, Dz2 – sound signaling, ERR-10 (ERR-11) – container cabinet with devices for controlling the level crossing, EZG-17 – diagnostic device, ERP-6 (ERP-7) – remote control device, PC – Computer Control Center

The basic control devices in SPA-5 signalling are programmable logic controllers from Bernecker & Rainer the MINICONTROL type. The task of the both channels PLC is to enable, disable and permanently monitor the efficiency of external devices that secure the level crossing area. PLC controllers communicate with external devices through digital inputs and outputs modules and data transmission ports. Types, number and arrangement of digital inputs / outputs modules connected to the central processing unit CPU of PLC controllers are selected individually depending on the number and configuration of external devices occurring on the level crossing [10, 14].

5. Conclusions

Railway transport devices designed to control train traffic make a complex and interconnected system. The failure of even the smallest element of this system leads to the inability to conduct traffic on secured railroad lines in an organized manner. Modern informatics technologies introduced in Polish railways provide significant support for railway transport employees.

The basic methods of increasing the railway system safety integrity level is the redundancy of components and the usage of advanced diagnostics, both the control unit, the sensors and the executive elements. In practical solutions of modern railway traffic control systems, the increase of safety is most often achieved by redundancy. In the simplest way, it is implemented by two-channel constructed systems consisted of two parallel functional channels and the comparison of their work, and two independent programs written by different teams of programmers. Very

important are also PLC controllers.

The Intelligent Transportation Systems ITS are important in the safety development and implementation of the modern information solutions. They form a very effective tool used to improve traffic on main routes (including railway), eliminate delays generating huge costs, protect environmental, etc. Intelligent Transportation Systems implement in their architecture many modern technologies and subassemblies in the field of microelectronic, IT, telecommunication and vehicle technology. Most often, solutions of these systems are used in road traffic, but are also increasingly implemented in railway transport. Nowadays in addition to the old, technically simple train control systems, there are in use fully automated systems and ones which use high binary bit rate transmission and have low probability of wrong decisions. At present, there is also the possibility of access to precise train location systems in railway transport by receiving and processing signals sent by satellite systems [4, 7].

Acknowledgment

This material is based upon work supported by Polish National Center for Research and Development under Grant No. PBS3/A6/29/2015.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Production of Transport Infrastructure Elements Using Vibro-Pressed Fiber Concrete Technology

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Abstract

In this article, the authors present production of transport infrastructure elements using technology of manufacturing prefabricated components from fiber-enhanced vibropressed concrete in order to obtain new features of the products. The innovation is about using fiber-enhanced concrete composites in manufacturing prefabricated vibropressed concrete components. As a result of this implementation, innovative products will be introduced that have new features relative to the solutions now available on the market internationally. The newly-introduced product could find applications in transportation infrastructure, since prefabricated elements manufactured from fiber-enhanced vibropressed concrete will become especially relevant over the years to come, given the increasingly strict criteria of assessment for building components with regard to the impact on the environment over the entire life-cycle (cradle to grave approach).
KEY WORDS: *transport infrastructure*

1. Introduction

Concrete is the most ancient artificial material still used today for technological purposes. Five thousand articles about concrete are published every year [6,4,10-15]. Even if concrete is not considered the most important building material, it is undoubtedly the most widely used one, claiming for 20 billion tones of aggregate and 800 million cubic meters of water (used irrevocably, accounting for 5% of total water consumption) used every year, along with 500 billon MJ of energy. Future developments in an industry using that much energy and resources must not be a matter of indifference for the society. At the same time, concrete is a means of addressing basic social needs [9] Thus, development of the concrete industry in Europe will be based on sustainability and standards of usability – at least as far as Europe is concerned – will be rising. [2, 5, 7, 8].

Nowadays, there is an abundance of publications on the subject of concrete enhancement with different admixtures and additives. Over the last few years we have witnessed the development of fiber enhancement technology. Depending on the type of fibers added to the cement matrix, many different final properties of the concrete may be modified [2, 3]. While adding fibers to standard concrete is widely-known and practiced, the addition of fibers to semi-dry and vibropressed concrete is a brand new approach [1].

Knowing the mechanisms involved in the process of curing vibropressed concrete, as well as how microfibers influence concrete properties, it has been demonstrated that combining the two would result in improvements of many of these properties.

2. Research Purpose and Scope

The purpose of the research was to obtain detailed information regarding the extent to which the addition of microfibers influences the properties of vibropressed concrete used for manufacturing components of tansportation infrastructure. A detailed analysis of the occurring processes was conducted, along with a wide range of experimental testing – including both standard tests for assessment of vibropressed concrete and testes necessary to assess the effects of the structural modification.

3. Materials Used in the Tests

For preparing two-layer components, paving slabs used in transport infrastructure, two distinct concrete mixes are needed. Construction concrete K, with an addition of synthetic microfibers and wearing course concrete V – the conventional mix. Ingredients used for preparing the mixes of fiber-enhanced vibropressed concrete listed in Table 1.

Table 1

Ingredients of concrete V and concrete K

Concrete V	Concrete K
Cement I 42,5 R	Cement I 42,5 R
Sand 0-2 mm	Fly ash
Sand 1-3 mm	Aggregate 2-8 mm
Plasticiser Perpacolor 2025	Soft sand 0-2 mm
Plasticiser alphalith Duraphobe E	Polypropylene microfibers
Water	Plasticiser alphalith Plastifizierer S2

The test samples were as similar with regards to parameters as possible, differing only by the additive of polypropylene microfibers or lack thereof. The chief purpose of implementing the fibers is minimizing the risk of crevices and shrinkage cracks, which in later stages of curing and exploitation translates into improvement of many properties of the concrete and prefabticated components moulded from it. Fibers protect the concrete against internal stresses, increasing its initial strength, especially in the first 24 hours after hardening when it is most susceptible to cracking. Polypropylene fibers act as a micro-reinforcement, their size, shape and elasticity allow for uniform distribution within the concrete by mixing (Table 2).

Table 2

Microfiber properties

Ingredient	Polypropylene
Description	Single fibers/microfibers
Available lengths	6/12/18 mm
Colour	White
Specific weight	0,91 g/dm^3
Stress tolerance	400 – 500 MPa
Modulus of elasticity	7-9 GPa
Water absorbability	None
Chemical resistance	Full
Melting point	>160°C
Dosage	0,8 do 3 kg/m^3

The micro-reinforcement is not considered a substitute for traditional reinforcement, it functions independently and constitutes an ideal additive to vibropressed concrete, wherein the use of traditional reinforcement is overly problematic.

4. Preparation of Test Samples

Four kinds of samples were used in the testing, the choice depending on what a particular test was supposed to model. Each kind of sample involved preparing four distinct concrete mixes: one without any fiber addmixes and three with different fiber doses (Table 3).

Table 3

Kinds of concrete samples subjected to testing

Sample	Concrete K	Concrete V
P_0	No fiber addmixes	No fiber addmixes
M_1	0,8 kg/m^3 of synthetic microfibers	No fiber addmixes
M_2	1,5 kg/m^3 of synthetic microfibers	No fiber addmixes
M_3	3,0 kg/m^3 of synthetic microfibers	No fiber addmixes

Expansion test of the concrete samples while crushing was carried out on BEHATON type concrete slabs 80 mm thick. The process of forming the samples involved preparing concrete mixes of 0,9 m^3 volume each. Hardened samples underwent a 24 hour period of curing in a pre-curing chamber, after which they were stacked, packaged and

loaded onto handling pallets for further curing. The test would be performed on days 7, 14 and 28, so as to compare the speed of strength growth over time.

Bending strength test was carried out on concrete slabs sized 400 × 400 × 40 mm. Concrete mixes of 0,5 m^3 volume and same production parameters were prepared and, as in the case of the previous test, underwent a 24 hour period of curnig, followed by being packed and put aside for 28 days, after which period the first measurements would be made.

5. Testing Schedule

Table 4

Types of concrete samples subjected to testing

Tolerance to expansion while crushing BEHATON H 80 mm concrete slab		
Sample type: 7 days	**Sample type: 14 days**	**Sample type: 28 days**
P_0 6 pcs.	P_0 6 pcs.	P_0 8 pcs.
M_1 6 pcs.	M_1 6 pcs.	M_1 8 pcs.
M_2 6 pcs.	M_2 6 pcs.	M_2 8 pcs.
M_3 6 pcs.	M_3 6 pcs.	M_3 8 pcs.
Absorbability test BEHATON H 80 mm concrete block	**Bending strength test** 400x400x40 mm	**Fracture toughness test** beams with dimensions 80x150x700 mm
Sample type: 28 days	**Sample type: 28 days**	**Sample type: 28 days**
P_0 3 pcs.	P_0 3 pcs.	P_0 8 pcs.
M_1 3 pcs.	M_1 3 pcs.	M_1 8 pcs.
M_2 3 pcs.	M_2 3 pcs.	M_2 8 pcs.
M_3 3 pcs.	M_3 3 pcs.	M_3 8 pcs.

6. Methodology of Testing the Fiber-Reinforced Vibropressed Concretes

6.1. Ulitimate Tensile Strength Test

Ultimate tensile strength testing was carried out in three different stages of curing after 7, 14 and 28 days. As part of the testing, a visual assessment of the concrete microstructure was also performed. While performing the test one could observe that as fiber admix was increased, the sample was harder to break, even though it was already fractured. This occurred due to fibers, the additional constituent of the cement matrix, which altered its properties by increasing its fracture toughness. When focusing on the tensile strength alone, the following results were obtained for each series of samples.

After 7 days of curing, ultimate tensile strength results all are similar for all sample series, which indicates that the concrete has good density (Fig. 1).

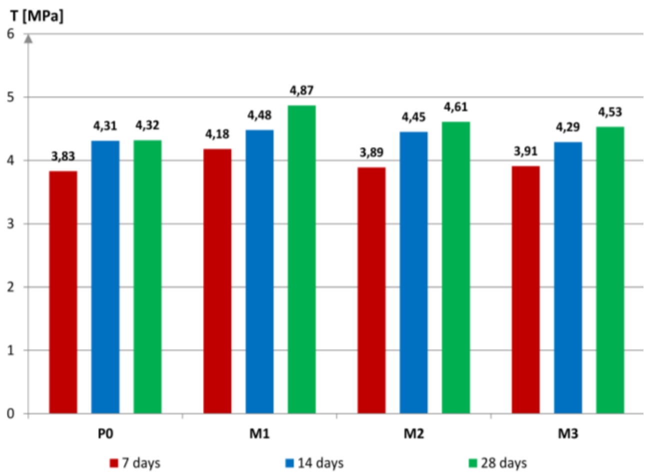

Fig. 1 Summary of ultimate tensile strength for samples P_0, M_1, M_2, M_3 after 7, 14 and 28 days of curing

The increase in initial strength of the samples reinforced with synthetic microfibers may be observed, relative to

the P_0 samples with no addition of fibers. Increase of initial strength is related to the inhibition of the formation of shrinkage cracks, due to addition of fibers in the initial stage of curing. The largest (10%) increase in strength occured in sample $M_{1.}$

In other cases, the increase in strength was also observed, although to a much smaller extent, most likely due to excessive dosage of the fibers, which as a result form clusters within the concrete. Excessive number of fibers still prevents shrinkage cracks, but air voids forming around the unmixed fiber clusters may decrease the strength.

All samples except the M_1 are characterized by a dynamic increase in strength of 10-14%. For sample M_1, the increase is 4%, which reflects high effectiveness of the fibers. A well balanced quantity of fibers in the concrete is intended to retain part of the mixing water, which is required the at the later stage of curing in order for all the cement to react. Hence, the strength growth rate may be slower relative to other cases.

After day 28 of curing, almost no strength increase occurred in concrete without the addition of fibers, relative to the samples at the age of 14 days. This is due to the fact that the sample P_0 reached "full" maturity earlier.

Vibropressed concrete samples reach their final strength earlier than in the case of ordinary concrete, as a result of processes occurring during compaction of concrete and special conditions of curing and care. An increase in strength occurred in all the fiber-reinforced samples, as a result of water retained by the fibers reacting, and continued hydration of the cement. The highest strength was reached by M_1 concrete sample, with fiber content of 0.8 kg/m^3. This is the lowest dosage recommended for ordinary concrete by the manufacturer of the fibers. In the case of semi-dry concrete mixes, formed by vibropressing, higher dosage becomes less effective due to formation of non-mixed fibers and mixing time would have to be longer in order to break them, rendering the process less efficient and more energy-consuming.

6.2. Absorbability Test Results

Absorbability test was carried out after 28 days of curing, so as to have the best idea of the extent of conversion of concrete constituents. Water absorbability rate below 4% was achieved by the sample M_1 (Fig. 2). The admix of synthetic microfibers, which retains mixing water in the early stages of curing, allowed to increase the degree of hydration of cement, while also slowing down the process of curing and rendering it more efficient. Reducing absorbability results in an increased tightness of the concrete, which improves its resistance to weather conditions. The high rate of concrete conversion reduces the risk of undesirable pores occurring in the microstructure, which also results in low absorbability. Such concrete is highly resistant to cyclic temperature changes. For samples M_2 and M_3 high absorbability compared to other samples was caused by air voids forming in the microstructure, located in clusters of unmixed fibers.

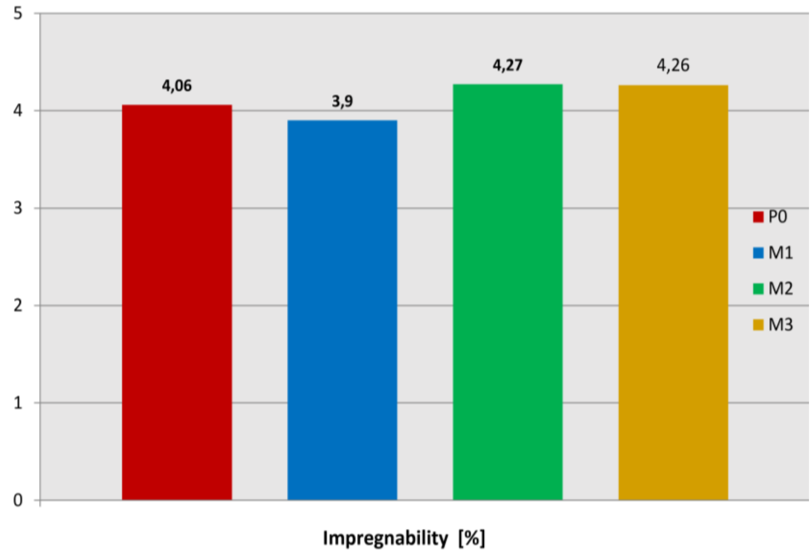

Fig. 2 Absorbability test results after 28 days of curing for samples P_0, M_1, M_2, M_3

6.3. Bending Strength Test

As far as bending strength is concerned, concrete reinforced with synthetic microfibers performs far better then concrete without the fibers. Bending strength increased by as much as 35% at fiber dosage of 1,5 kg/m^3, however due to remaining clusters of unmixed fibers and lesser homogeneity of the cement matrix the dispersion of measurements was significant, ranging from 4,6 up to 7 MPa. Such high bending strength results in all the samples enhanced with fibers M_1, M_2 i M_3 prove that the properties of the cement matrix had been altered as a result of the enhancement. The matrix, which is the most brittle constituent of a concrete compound, becomes a quasi-plastic material by acquiring certain qualities of the fibers. It is not susceptible to cold cracking and functions well under strain, even after its critical strength has been reached. Even a minimal fiber addition of 0,8 kg/m^3 resulted in a significant increase of bending

strength at 26,7% relative to non-enhanced concrete. A small fiber admix may alter the quality of a cement matrix, which in turn alters the properties of an entire concrete compound Average values of destruction force and bending strength are presented in Figs. 3 and 4.

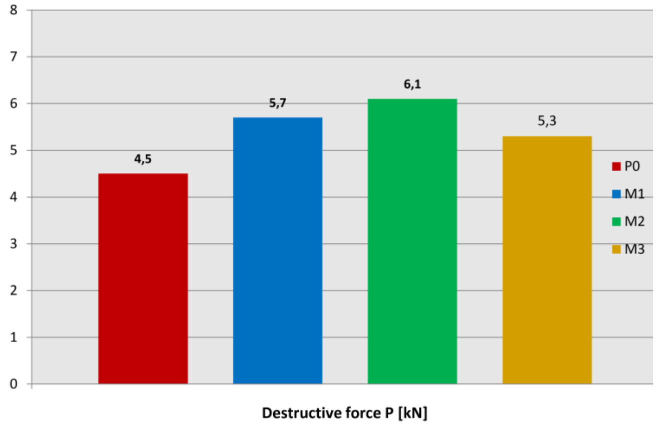

Fig. 3 Average destruction force values for samples P_0, M_1, M_2, M_3

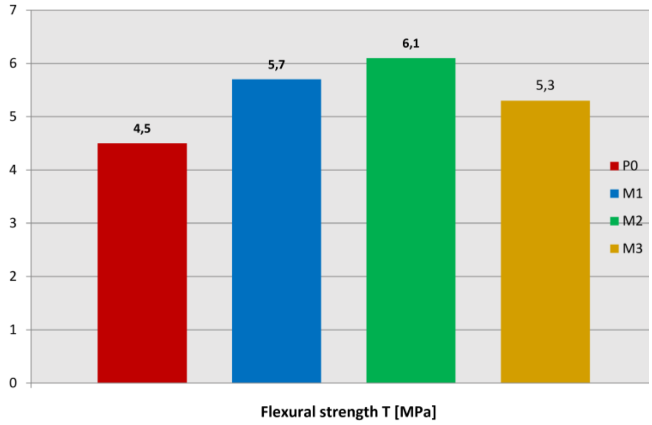

Fig. 4 Average bending strength values for samples P_0, M_1, M_2, M_3

7. Applications of Fiber-Reinforced Prefabricated Concrete Components in Transport Infrastructure

The term infrastructure is understood as basic machines, public buildings and service institutions, of which existance is indispensable for proper function of the economy and the society [16, 17]. Three basic areas of infrastructure can be distinguished: social, technological, and that of transportation [18].

Transport infrastructure encompassess constructions related to public and individual transportation (such as parking lots, shunting yards, driveways), along with engineering and service facilities (e.g. logistics centers, warehouses).

Prefabricated items may be classified into many categories, depending on intended application, shape, degree of finishing, employed structural and material solutions (Table 5, Fig. 5). One of the most important classification criteria is item size and weight. According to this criterion we distinguish pre-cast items that are small-sized, middle-sized and large-sized.

Table 5

Types of prefabricated items in transportation infrastructure

Infrastructure	**Intended function**	**Types of prefabricated elements**	
		Large-size	Small-sized, middle-sized
Transport infrastructure	Road surface	Surface coverings	paving
	Pedestrian pavement surfaces and bicycle lane surfaces	Surface coverings	paving
	Parking lots, shunting yards, driveways	Surface coverings	pawing
	Riverbank protection	Surface coverings	paving

Fig. 5 Transportation infrastructure

8. Conclusions

Production of transport infrastructure elements using technology of manufacturing prefabricated components from fiber-reinforced vibropressed concrete has numerous technical and technological aspects that justify labelling it as innovative.

The assumed effects of implementing this technology with the purpose of obtaining new product qualities is a process and product innovation on an unprecedented scale and it may be employed in transportation infrastructure.

Employing products manufactured from components made of fiber enhanced concrete will become especially important over the years to come, as criteria of product assessment regarding environmental impact over the entire life cycle (cradle to grave approach) gradually become stricter.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Methods of Vibrational Comfort Evaluation in Means of Transport

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Abstract

The issue of vibrational comfort experienced by the passenger is becoming increasingly important in recent years, due to growing expectations of passengers regarding their chosen means of transport. This article reviews selected methods for evaluation of ride comfort related to the influence of vibrations on the human body. The described methods are based on determining effective (rms) vibration accelerations in various frequency bands and comparing them with comfort-related limits or, alternatively, weighting these accelerations in the frequency domain to obtain synthetic indices of comfort which subsequently are used to evaluate the level of ride comfort in a descriptive scale. As an intermediate solution, a spectral (frequency-dependent) comfort index recently proposed by the author is also presented.
KEY WORDS: *vibrational comfort, means of transport, passenger*

1. Introduction

The ride comfort is one of the fundamental issues in transportation. It is a complex notion, which contains a series of components specifying, among others: thermal comfort, acoustic comfort, air quality, and vibrational comfort. The sensations related to ride comfort depend on various factors characterizing the surroundings which the passenger traveling in a vehicle is in, such as vibrations, temperature, humidity, noise, the passenger's position, lighting, and the length of time during which the passenger is influenced by the aforementioned factors [2, 6, 7]. Even visual effects and the psychophysical state of the passenger are taken into account. Although the level of ride comfort is related to the aforementioned factors, it is difficult to unambiguously evaluate it in a quantitative manner due to the subjective nature of the level of perception of various external stimuli received by the passenger. The influence of various factors related to comfort is studied using approximate models describing the effects of these factors on a human body. Comfort level indices, dependent on one or a few physical parameters characterizing the environment within which the passenger is located, are used for the synthetic evaluation of ride comfort [6, 7].

Although all the aforementioned factors describing the surroundings which the passenger is in substantially impact ride comfort, one of the most important among them are the vibrations experienced by the passenger during travel. The main parameters determining the comfort related to vibrations are the accelerations experienced by a person within the chosen means of transport.

In 1941, an early study was published [8], in which comfort limits related to the influence of vibrations on a human body were given for the frequency range between 1 and 12 Hz. The method of vibrational comfort evaluation was developed further by Sperling [17], who proposed W_Z as an index of comfort (Wertungsziffer in German). This index was used widely by European railways for a long time. The first official international regulation regarding the evaluation of comfort related to vibrations was the standard ISO 2631 published in Geneva in 1974 entitled: "Guide to the evaluation of human exposure to whole-body mechanical vibration and shock" [9]. This standard was established to replace the previously used W_Z comfort index. The ISO 2631 standard was substantially modified in 1997 [10], when an average comfort evaluation related to vibrations was added based on the total effective (rms, i.e. root-mean-square) acceleration weighted in the frequency domain by using correctional filters (weighting functions).

Because of differing opinions on the standard ISO 2631, in particular regarding the correctional filters used, new requirements were proposed for the evaluation of comfort in 1999, which were contained in the ENV 12299:1999 prestandard [3] developed by the European Committee for Standardization (CEN). This project, after consultations with institutions dealing with standardization and normalization in 28 European countries, has become the current EN 12299:2009 [16] European standard pertaining to the evaluation of the ride comfort for passengers in railway vehicles.

In the Sperling method, the weighted effective acceleration is determined by applying weighting functions for frequencies from 0.5 to 30 Hz, whereas in the later standards the upper limit of the frequency range was increased: to 80 Hz in the standard ISO 2631 [10] and the UIC 513R card [18], and finally to 100 Hz in the standard EN 12299 [16]. The use of weighting functions in the methods of vibrational comfort evaluation and the range of frequencies are related to the different sensitivity of the human body to vibrations of different frequencies. This has a close relationship to resonance frequencies of various parts of the body. In particular, the internal organs are most strongly influenced by vibrations of 3–18 Hz; the resonance frequencies of the head are 4–5 and 17–25 Hz, whereas those of the eyes are of 60–90 Hz. The influence of vibrations on the human body also depends on their direction as well as the body's pose (standing, sitting, lying down). A detailed overview of the issue of the influence of vibrations on the human body can be found in Griffin's monograph [6] and in Förstberg's comprehensive PhD thesis [4]. One should note that mechanical vibrations are a potentially harmful physical factor, so that its studies must not be limited to the issue of passenger

comfort, but should also look into the detrimental effect of vibrations with various frequencies on the human body. The period of time during which the passenger is exposed to vibrations is also very important, and it should be as limited as possible for that reason. The comfort boundaries described by the standards correspond to an 8 hour exposure to vibrations, and are lowered appropriately if the duration of the exposure is shorter. With regards to this, it must be noted that the aforementioned methods are applied in the evaluation of the mean ride comfort which is determined on the basis of the acceleration occurring within sufficiently long period of time. The standard EN 12299 [16] also contains indices used in the evaluation of comfort on discrete events related to changes in acceleration occurring in short periods of time.

2. Spectral Method of Ride Comfort Evaluation

The spectral method of ride comfort evaluation consists of determining the values of effective (rms) accelerations in 1/3-octave bands (for the horizontal and vertical directions), and comparing them for each band with the limit values which define the reduced comfort boundary and the fatigue-decreased proficiency boundary described in standard ISO 2631-1:1985 [10]. The standard defines these limit values for effective accelerations with different directions $\eta = x, y, z$ and 1/3-octave bands $(f_i - \Delta f_i / 2, f_i + \Delta f_i / 2)$ with the centre frequencies f_i from the 0.8-80 Hz range and the widths of $\Delta f_i = 0.213 f_i$. Fig. 1 represents these limits for the frequency interval of $0.8\text{ Hz} \le f_i \le 20\text{ Hz}$.

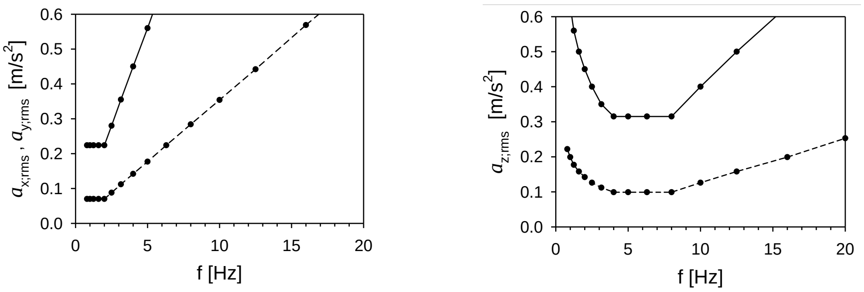

Fig. 1 The reduced comfort boundary (dotted line) and the fatigue-decreased proficiency boundary (solid line) for the horizontal and vertical effective accelerations in 1/3-octave bands, $a_{\eta;rms}(f)$ $(\eta = x, y)$ and $a_{z;rms}(f)$, respectively, for an 8 hour exposure to whole-body vibrations, in accordance with the standard ISO 2631-1:1985 [10]

2.1. Effective Accelerations in Frequency Bands

The effective (rms) accelerations are calculated for 1/3-octave bands separately for each direction based on measured or simulated accelerations $a_x(t), a_y(t)$ and $a_z(t)$. These rms values can be found by integrating the one-sided power spectral density $S_{a\eta}(f)$ of acceleration $a_\eta(t)$ over each 1/3-octave band using the following expression:

$$a_{\eta;rms}(f_i) = \left[\int_{f_i - \Delta f_i/2}^{f_i + \Delta f_i/2} S_{a\eta}(f)\, df \right]^{1/2} \quad (\eta = x, y, z). \tag{1}$$

The power spectral density can be determined using Welch's modified periodogram method [18]. Such a method of determining power spectral density and the spectral method of ride comfort evaluation for railway vehicles was applied in the author's papers [11, 12], among others.

2.2. Proposal of Spectral Comfort Index

The rms accelerations $a_{\eta;\,rms}(f_i)$ corresponding to vibrations in the direction η can exceed the reduced comfort boundary $a_{\eta;\,lim}(f_i)$ in some frequency bands while staying below this limit in other bands. To quantify this effect the author proposes [12] to introduce a new frequency-dependent index C_η of the vibrational comfort defined as the ratio:

$$C_\eta(f_i) = \frac{a_{\eta;\,rms}(f_i)}{a_{\eta;\,lim}(f_i)} \quad (\eta = x, y, z). \tag{2}$$

According to this definition, the reduced comfort boundary corresponds to the limit value of the spectral comfort index $C_\eta = 1$ which is the same for all frequencies (i.e., for all 1/3-octave bands) and all considered directions. The

variation of the comfort level with the change of different parameters (like the ride velocity or the passenger's position in the vehicle) can be analyzed separately for each of vibration components of various frequencies f_i. In addition, the values of the spectral comfort index $C_\eta(f_i)$ obtained for different frequencies can be directly compared with each other since the limit of comfort ($C_\eta = 1$) is the same for all frequencies. In this way, the vibrational comfort related to specific eigenfrequencies of various human organs can be conveniently investigated.

3. Weighted Methods – Synthetic Comfort Indices

Evaluation of comfort related to influence of vibrations on passengers can also be done with synthetic comfort indices. They are determined by weighted effective accelerations [10] calculated with the use of weighting functions related to the effect of vibrations of various frequencies on the human body. Among others, the W_Z index, proposed by Sperling [17] belongs to the synthetic indices of this type, used separately for each direction of acceleration (x, y, z), as well as the mean comfort index, N_{MV} [16, 18], based on weighted accelerations of vibrations along all three directions. A graded scale is usually related to such indices, which descriptively determines the vibrational comfort level. The comparison of comfort evaluation results using different methods is presented in [12].

3.1. Sperling Method

The W_z comfort index introduced by Sperling [17] is calculated according the following formula:

$$W_z = W_{z\eta} = 4.42\left(a^w_{\eta;rms}\right)^{0.3} \quad \left(\eta = x, y, z\right), \tag{3}$$

where $a^w_{\eta;rms}$ is the effective (*rms*) value of the $a^w_\eta(t)$ acceleration expressed in $\mathrm{m/s^2}$ and weighted in consecutive t moments in time with the help of the appropriate correctional filter in the domain of the f frequency. This index is determined separately for each component of the a_η acceleration, whereas the weighting function $B(f) = B_\eta(f)$ also depends on the direction η of acceleration. For vertical acceleration $(\eta = z)$ this function is expressed as follows:

$$B_z(f) = 0.588\left[\frac{1.911\, f^2 + \left(0.25\, f^2\right)^2}{\left(1 - 0.2777\, f^2\right)^2 + \left(1.563\, f - 0.0368\, f^3\right)^2}\right]^{1/2} \tag{4}$$

and $B_x(f) = B_y(f) = 1.25\, B_z(f)$ for longitudinal and lateral directions $(\eta = x, y)$. The Sperling method takes into account the range of frequencies from 0.5 Hz to 30 Hz.

The correctional filter $B_\eta(f)$ can be directly applied to the Fourier transform of the measured acceleration a_η – such an approach is used in measuring systems. The weighted acceleration $a^w_\eta(t)$ obtained in this way allows for determining its rms value:

$$\left(a^w_{\eta;rms}\right)^2 = \tfrac{1}{T}\int_0^T \left[a^w_\eta(t)\right]^2 dt \tag{5}$$

in a time interval T. Then the index $W_z = W_{z\eta}$ is calculated in accordance with the formula (3).

The effective value $a^w_{\eta;rms}$ of the weighted acceleration a^w_η can also be calculated as the frequency integral using the power spectral density [15]:

$$\left(a^w_{\eta;rms}\right)^2 = \int_{0.5}^{30} S_{a\eta}(f)\, B^2_\eta(f)\, df \quad \left(\eta = x, y, z\right) \tag{6}$$

and is subsequently used in (3). This way of calculating $W_z = W_{z\eta}$ is convenient for the acceleration obtained in simulations of railway vehicles motion.

The obtained values of the index $W_z = W_{z\eta}$ are used to determine comfort levels according to the scale represented in Table 1. It should be noted that this scale is identical for all directions, since the dependence on direction is incorporated in the weighting function $B_\eta(f)$.

Table 1

Sperling comfort index W_z – scale of comfort evaluation [17]

W_z	Level of comfort (sensitivity to vibrations)
1	just noticeable
2	clearly noticeable
2.5	more pronounced but not unpleasant
3	strong, irregular, but still tolerable
3.25	very irregular
3.5	extremely irregular, unpleasant, annoying, prolonged exposure intolerable
4	extremely unpleasant; prolonged exposure harmful

3.2. ISO Weighted Method

In the original ISO 2631 standard [9] of 1974 and its later form [10] of 1985, the basic method of vibrational comfort evaluation is the spectral analysis of specific acceleration components and the comparison of its effective values in 1/3-octave bands with comfort limits dependent on the frequency. This standard also permits the determination of weighted effective values of the acceleration components and their comparison to the comfort limits as a simplified method of comfort evaluation in the case of an inability to conduct a full spectra analysis. However, as Griffin notes [5], the two mentioned methods of comfort evaluation used in this standard are not completely compatible with each other, since exceeding the reduced comfort boundary in some of the 1/3-octave bands does not imply exceeding the comfort boundary by the weighted rms acceleration a_{rms-w}. The weighting functions used in standard ISO 2631-1:1985 [10] are represented in Fig. 2 and are defined using the inverse values of the rms accelerations in 1/3-octave bands.

The later ISO 2631-1:1997 standard [10] only applies a modified weighted method to evaluate level of comfort related to vibrations. The method consists of calculating a_{rms-w} as a synthetic ride comfort index. It is defined with effective accelerations $a_{\eta;rms}\left(f_i\right)$ in 1/3-octave bands and the weighting functions $w_\eta\left(f\right)$ depending on the frequency and the vibration direction *η*. The weighted averaging is done over all *n* considered 1/3-octave bands:

$$a_{\eta,rms-w} = \sqrt{\sum_{i=1}^{n}\left[w_\eta\left(f_i\right)a_{\eta,rms}\left(f_i\right)\right]^2} \qquad \left(\eta = x, y, z\right), \tag{7}$$

where $w_\eta\left(f\right)=W_d\left(f\right)$ is identical for the x, y directions and $w_\eta\left(f\right)=W_k\left(f\right)$ for *z* direction. The standard ISO 2631:1997 recommends the inclusion of 1/3-octave bands with f_i centre frequencies within the range of 1 to 80 Hz.

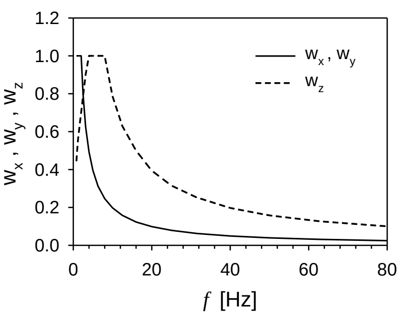

Fig. 2 Weighting functions $w_\eta\left(f\right)\left(\eta = x, y, z\right)$ applied in standard ISO 2631-1:1985 [10]

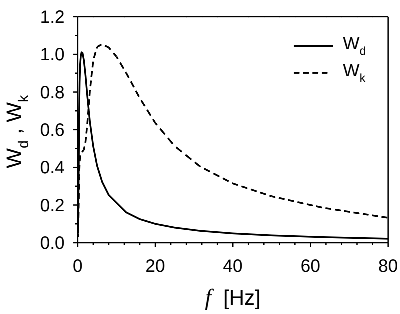

Fig. 3 Weighting functions $W_d\left(f\right)$, $W_k\left(f\right)$ applied in standard ISO 2631-1:1997 [10]

The weighting functions used in standard ISO 2631:1997 are shown in Fig. 3. The weighting function $W_d\left(f\right)$, applied to the longitudinal ($\eta = x$) and lateral ($\eta = y$) components of the acceleration, is the same as in standard BS 6841 [1], whereas the weighting function $W_k\left(f\right)$ for the vertical acceleration component is similar to the function $W_b\left(f\right)$ used in the British standard, as emphasized in paper [5]. The standard ISO 2631:1997 even recommends using weighting function $W_b\left(f\right)$ (instead of $W_k\left(f\right)$) for ride comfort evaluation in the case of railway vehicles.

The total weighted acceleration is finally determined as:

$$a_{rms-w} = \sqrt{a^2_{x,rms-w} + a^2_{y,rms-w} + a^2_{z,rms-w}}. \tag{8}$$

Depending on the value of the a_{rms-w} acceleration, the standard ISO 2631-1:1997 [10] specifies the level of comfort in a 6-tier scale presented in Table 2. The same scale is used in the British standard BS 6841 [1].

Table 2

Comfort levels according to standard ISO 2631-1:1997 [10]

a_{rms-w} [m/s^2]	Perception
less than 0.315 m/s^2	not uncomfortable
from 0.315 m/s^2 to 0.63 m/s^2	a little uncomfortable
from 0.5 m/s^2 to 1 m/s^2	fairly uncomfortable
from 0.8 m/s^2 to 1.6 m/s^2	uncomfortable
from 1.25 m/s^2 to 2.5 m/s^2	very uncomfortable
greater than 2 m/s^2	extremely uncomfortable

3.3. Evaluation of Ride Comfort According to European Standard

The European standard EN 12299 [16], published in 2009, defines methods of ride comfort evaluation in railway vehicles using effective values of the weighted acceleration. A discussion on various aspects of this standard are presented by its authors in work [13]. According to the standard, acceleration is measured in the longitudinal, lateral, and vertical directions, denoted as X,Y,Z, respectively, and determined relative to the planes of symmetry of the human body [6]. The measurement of acceleration is done in specific points of the vehicle: P – on the floor (in the X,Y,Z directions), A – on a passenger seat (in the Y,Z directions), and D – on the backrest of a seat (in the X direction). In the full method of ride comfort evaluation, the following index is used:

$$N_{VA} = 4 a_{ZP95}^{W_d} + 2\sqrt{\left(a_{YA95}^{W_d}\right)^2 + \left(a_{ZA95}^{W_b}\right)^2} + 4\left(a_{XD95}^{W_c}\right)^2 \tag{9}$$

for the seated passenger, and

$$N_{VD} = 3\sqrt{16\left(a_{XP50}^{W_d}\right)^2 + \left(a_{YP50}^{W_d}\right)^2 + \left(a_{ZP50}^{W_b}\right)^2} + 5\left(a_{YP95}^{W_d}\right)^2 \tag{10}$$

for the standing passenger. In the simplified method, comfort evaluation is done by using a single index:

$$N_{MV} = 6\sqrt{\left(a_{XP95}^{W_d}\right)^2 + \left(a_{YP95}^{W_d}\right)^2 + \left(a_{ZP95}^{W_b}\right)^2}\ . \tag{11}$$

The calculation of the weighted components $a_{\eta M}^{W}$ of the acceleration ($\eta = X,Y,Z$, $M = P,A,D$) is done using a weighting function $W(f)$ depending on the acceleration direction: $W_b(f)$ for the Z direction, $W_b(f)$ for directions X,Y, and $W_c(f)$ for accelerations in the X direction measured at the seat backrest. The weighted $a_{\eta M}^{W}$ accelerations are determined in 60 consecutive time intervals of the 5-second length for four blocks that are 5 minutes long each. By conducting a statistical analysis of the 240 $a_{\eta M}^{W}$ values obtained in the aforementioned way, their 50th percentile (median), $a_{\eta M 50}^{W}$, and their 95th percentile, $a_{\eta M 95}^{W}$, are found, which are subsequently used in formulas (9), (10) and (11) for the evaluation of the N_{MV}, N_{VA} and N_{VD} comfort indices. The value of the N_{MV} index corresponds to one of the five comfort levels shown in Table 3. The same descriptive comfort scale applies to indices N_{VA} and N_{VD}.

Table 3

Scale of vibrational comfort based on the indices N_{MV}, N_{VA} and N_{VD} according to EN 12299 [16]

N (N_{MV}, N_{VA}, N_{VD})	level of comfort
$N < 1\,\mathrm{m/s^2}$	very comfortable
$1\,\mathrm{m/s^2} \le N < 2\,\mathrm{m/s^2}$	comfortable
$2\,\mathrm{m/s^2} \le N < 4\,\mathrm{m/s^2}$	medium
$4\,\mathrm{m/s^2} \le N < 5\,\mathrm{m/s^2}$	uncomfortable
$N \ge 5\,\mathrm{m/s^2}$	very uncomfortable

4. Summary

The ride comfort, aside from the cost and travel time, is a key factor, that determines the competitiveness of available transport means. One of the main components of ride comfort that strongly affects passengers' preferences is the vibrational comfort which is therefore essential in evaluation of the ride comfort.

Selected methods of comfort evaluation related to the influence of vibrations on a passenger in means of transport are discussed in this paper and it is shown that such an evaluation is dependent on different factors. The sensation of vibrations depends not only on their amplitude, but also on their frequency and direction, as well as the position of the passenger. The effect of vibrations with various frequencies on different parts of the human body is best accounted for in the spectral method where rms accelerations are determined in the relevant 1/3-octave bands and compared with limits related to ride comfort. The advantage of weighted methods of comfort evaluation, which average the effect of the whole-body vibrations over a frequency range, is that they determine synthetic indices that subsequently allow for expressing vibrational comfort in a multilevel descriptive scale.

As an intermediate approach proposed by the author [12], a new index of vibrational comfort is defined separately for each frequency band as the ratio of the rms acceleration and the reduced comfort boundary. The proposed spectral index is dimensionless and its limit value is frequency-independent which makes it particularly suitable for a direct comparison of the level of ride comfort in different frequency bands and its changes with the ride velocity or other relevant parameters.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Degradation of Oil in Turbine Engines, Aviation Equipment Type L 410th

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Abstract

This article is concerned with the degradation of turbine engine oils used in turboprop engines of aircrafts of type L410th (Figs. 1 and 2). These oils are used in gas turbines of jets or turboprop aircrafts and helicopter engines in all types of industrial and military applications. It is also recommended that these oils are used in gas turbines for aircrafts used for various industrial and marine purposes. The samples were taken from turboprop engines of the specific aircrafts. The size of degradation of the specific samples of oils used was compared with the reference samples of new unused oils. At the end of the measurement the usability of oil in next aircraft operations was defined.

KEY WORDS: *aviation turbine oil, density at 15°C, viscosity index, kinematic viscosity, flash point, flow point, total acid number (TAN), oil foaming, flight hour (FH)*

1. Introduction

Turbine oils used in turboprop rotary engines are very complicated and include a lot of specific parameters. Despite the fact that these oils, which are currently being sold, reached a high level of technological performance they may degrade prematurely [1].

Conditions and operation of aviation equipment is characterized by features that increase the risk of premature oil degradation, e.g.: cold starts, frequent and short engine restarts, long-term operation of engines at extremely low temperatures. In order to maintain the maximum capacity and reliability of aviation equipment, we have to take a closer focus on examination and evaluation of engine oil degradation.

The importance of early engine oil diagnostics is based on the determination of the size of engine oil degradation because excessive deterioration of oil usually leads to increased wear on contact surfaces or to accumulation of defects resulting from excessive wear. Additionally, the diagnostics is also important for drawing conclusions regarding the future operation of aircrafts. The benefits associated with proactive inspections of engine oils are significant. In the past, there were lot of misconceptions regarding the impact of oil deterioration on engine life. Based on the diagnostic studies of aviation equipment it can be concluded that contamination of lubricating oils is the main cause of engine wear which causes the subsequent chain reaction of other failures, defects and accidents.

Fig. 1 Aircraft L 410th FG (front of the aircraft)

Fig. 2 Aircraft L 410th FG (right side of the aircraft)

2. Technical Description of the Measured Oils

Requirements for the quality of turbine oils (O-156/O-160/according to the NATO nomenclature) for the aviation equipment of type L 410th are as follows [2]:

MSU-26.2/L (military specification of the Armed Forces of the Slovak Republic); MIL-PRF-23699F; DEF STAN 91-101, DEF STAN 91-100 (international standards).

Reference turbine oils measured and used: (Figs. 3-5).

Mobil Jet Oil II and Exxon Mobil Aviation oils were used in the measured aviation equipment.

Mobil Jet Oil II, which is a high performance turbine oil, is made from a combination of a highly stable synthetic base fluid and a package of chemical additives. This combination provides excellent thermal and oxidation stability to resist deterioration and formation of deposits in the liquid and vapour phase, and the excellent resistance to foaming. The effective operating range of Mobil Jet Oil II is between -40°C and 204°C. It is designed for engines of aircraft gas turbines used in commercial and military service and require the performance at the level MIL-PRF-23699-STD.

Specification - MIL-PRF-23699-Approved; PRI-QPL-AS5780/SPC. ´Use-by-date´ of the measured turbine oil is: 25.04.2022 (E12C539).

Fig. 3 Reference oil type

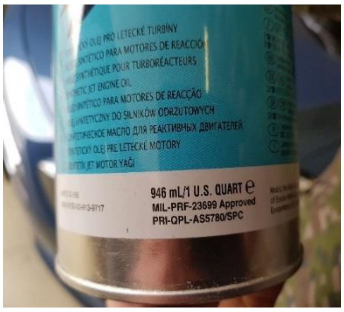

Fig. 4 Reference oil parameters

Fig. 5 Reference oil type and use- by-dates of reference oil

3. Methods and Procedures Applied [3]

1. ASTM E 1252: Standard practice for general techniques for obtaining infrared spectra for qualitative analysis
2. Own methods: The visually established relation
3. STN EN ISO 12 185: Crude petroleum and petroleum products. Determination of density. Oscillation U-tube method.
4. STN EN ISO 3104 + AC: Petroleum products. Transparent and opaque liquids. Determination of kinematic viscosity and calculation of dynamic viscosity.
5. STN 65 6218: Petroleum products. Methods of calculation of viscosity index.
6. ASTM D 97: Standard test methods for determination of pour point
7. STN EN ISO 2592: Determination of flash and fire points. Cleveland open cup method.
8. ASTM D 2896: Oils and additives. Standard test method for base number of petroleum products by potentiometric perchloric acid titration (TBN).
9. STN 65 6070: Petroleum products: Determination of acidity and acid number.
10. STN EN ISO 2160: Petroleum products. Corrosiveness to copper. Copper strip test.
11. STN EN ISO 10370: Petroleum products. Determination of carbon residue. Micro method.
12. ASTM D 892: Petroleum products. Standard Test Method for Foaming Characteristics, metal diffuser.
13. Own methods: The determination of characteristics by IR oil analyser.

4. Measured Turbine Oil in the Aviation Equipment L 410th

Images (Figs. 6-9) shows the turboprop engines on which the oil fill measurements have been made. The most important task was to assess the condition of engine oils for aircrafts, the oil brand is Mobil Jet Oil II for aircrafts of the type L 410. The samples from the types of the equipment stated in the Table 1 were taken for testing.

Fig. 6 Turbine engine of the aircraft L 410th FG (right engine)

Fig. 7 Turbine engine of the aircraft L 410th FG(left engine)

Fig. 8 Turbine engine of the aircraft L 410th FG (engine detail of right side of the aircraft)

Fig. 9 Turbine engine of the aircraft L 410th FG (front of the engine)

The samples of oils from the engines Walter M601E were taken by a commission that consisted from members of the project VV-5 „Exploitation of simulation methods for diagnostic and modernization of the military equipment used in the Armed Forces in the Slovak Republic”. The samples were taken into sampling bottles and the qualitative as well as quantitative assessment of the samples was performed by laboratory analysis at the certified workplace in CMaS Žilina. After the assessment of the measurement a professional recommendation was made for each type and further procedure was stated for unsatisfactory (non-compliant) samples of oils.

5. Comparison of Parameters of Turbine Oils - Mobil Jet Oil II; (O-156/O-160) in Turbine Engines of the Aviation Equipment L 410th

The results of the engine oils measurements for aircrafts show that the most serious problem of oils is foaming. Due to this fact, it is necessary to pay a particular attention to the foaming of oil I., II. III. as it is one of the fundamental characteristics of oil which is assessed. The most contributing factors that cause foaming include: the presence of air in the lubrication system and its current rate of degradation; i.e. decomposition of anti-foaming additives. Lubrication oils always comprise some dissolved air. In view of tribology air is considered as being an impurity which influences the oxidation of lubrication oil and which can have fatal consequences.

Table 1

Measured values of selected turbine oils parameters (*accredited by SNAS)

No.	Characteristic	Unit	**Measured values**							Uncertainty ($2u_c$) for (k=2)
			190/17 Reference **TL/TO E12C539**	**187/17** L410 FG/No.1521 TL/TO E12C539 Left engine No.912002D		**188/17** L410 E20/No.2818 TL/TO E12C539 Left engine No.M601E894048		**189/17** L410 E20/No.2818 TL/TO E12C539 Right engine No.123002E		
x1.	Number of FH from the manufacture	FH	unused	New TL (TO)		338		545		-
x2.	Number of FH from changes	FH		0		TL (TO) change 19.12.2016		TL (TO) oil change 12.09.2016		-
x3.	Lifetime standard	FH		-		-		-		-
1.	*IR spectrum (4000-400) cm^{-1}	cm^{-1}	record	**record**	-	record	-	record	-	1
2.	Appearance	visually	complies	dark	-	dark	-	dark	-	-
3.	*Density at 15°C	$kg.m^{-3}$	1.000.3	**1.000.3**	0	**999.7**	-0.6	**1.000.2**	-0.1	0.2
4.	*Kinematic viscosity 40°C.	$mm^2.s^{-1}$	25.18	**25.15**	-0.12% -0.03	**25.19**	+0.03% +0.01	**25.19**	+0.03% +0.01	0.42
	*Kinematic viscosity 100°C.	$mm^2.s^{-1}$	4.968	**4.941**	-0.15% -0.027	**4.964**	-0.09% -0.004	**4.971**	+0.06% +0.003	0.60
5.	*Viscosity index	-	125	**123**	-2	**124**	-1	**125**	0	1.5
6.	*Pour point (PP)	°C	-66	**-63**	|2|	**-66**	|0|	**-66**	|0|	3
7.	*Flash point in OC according to Cleveland	°C	276	**260**	-16	**266**	-10	**266**	-10	4
8.	*Total acid number (TAN)	mg KOH/g	0.02	**0.02**	0	**0.03**	+0.01	**0.04**	+0.02	0.01
9.	*Corrosiveness to Cu, 3h/100°C	degree	1a	**1a**	0	**1a**	0	**1b**	+1	-
10.	*Carbon residue (CCT)	% w/w	-	-	-	-	-	-	-	0.07
11.	Foaming I., II., III.	ml	15/0/10	**25/0/10**	+10/0/0	**550/70/550**	+535/+65/ +540	**550/70/550**	+535/+65/ +540	80/10/80

Flight hour - FH; Turbine liquid - TL/Turbine oil – TO

6. Conclusion

The SAMPLES No.188/17 and 189/17 ARE NOT SUITABLE for further use - No.11.FOAMING. According to the laboratory tests of turbine oils in the aviation equipment L410 E20/No.2818 (sample 188/17 and 189/17) it is necessary to stop the operation immediately and change oil in both turbine engines. The parameters I., II. and III. of turbine oils are exceeded in terms of foaming. Before changing the oil it is recommended that the engines are flushed.

According to the laboratory tests of turbine oils in the aviation equipment L410 FG/No.1521 (sample 187/17) the oils are suitable for further operation. There was a new tank in the second turbine which corresponds to the ± reference sample. Based on the findings it is recommended that the equipment for foaming tests is added in airport laboratories according to the "ASTM D 892: Petroleum products. Standard test method for foaming characteristics, metal diffuser“.

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Vehicles Assembling Technological Systems Creation Experience with the Use of Hand Pulse Tools

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Abstract

The article provides the analysis of the hand pulse tools application scope within the vehicles production and repair processes for implementation of riveting, burnishing, piercing, fastening elements removal, etc.; describes the existing charts and structures, advantages of the hand pulse devices engineered in National Aerospace University "KhAI"; presents the functional-element chart of the hand air-pulse tools; formulates the concept of vehicles assembling technological systems creation with the use of hand pulse tools.
KEY WORDS: *hand air-pulse tool, impulse riveting, burnishing, direct impact device, synchronous riveting, functional-element chart*

1. Introduction

One of the key requirements for the newest aircrafts is the increase of the efficiency and service life. Thus, for passenger and transport aircrafts the value of design service life for the last decade increased from 15-20 thousands of flight hours (An-22, Tu-134, IL-86, IL-96) to 50-70 thousands of flight hours (SSJ-100, AN-140, AN-148, etc.). In general case the usage efficiency of aircraft determines its multipurpose nature. The growth of performance in decisive extent provided by increase of airframe durability, which in turn determines mainly the endurance of bolted and riveted joints. The amount of such joints in airframes increases sharply with increasing of its dimensions.

Thus, for example, if in the airframe of Tu-204 more than 49960 bolts are installed (wing – 38550 pcs., fuselage – 7590 pcs., engines pylons – 820 pcs.), then on passenger aircraft IL-86 the total number of bolts reaches 152800 pcs. The use of impulse setting methods of fasteners (rivets, lockbolts, bolts), as well as surface plastic deformation is an effective way to increase the lifetime of aircraft structures. However, impulse technologies are not used in production in full due to the high cost, low productivity and limited technological capabilities of both the process and device for its implementation.

Research and development of schemes and designs of hand-held impulse devices to perform the operations of assembly and installation works are conducting in the National Aerospace University named after N.E. Zhukovsky "Kharkiv Aviation Institute" at the Aircraft Manufacturing Processes Department since the 60-ies years of the last century. Power sources for these devices are powder gases, high-pressure hydraulic fluid, and compressed air. During these years the staff of the Department: S.G. Kushnarenko, V.S. Lepetyukha, V.S. Krivtsov, V.G. Chistyak, I.A. Vorobiov, V.V. Voronko and others, designed and manufactured dozens of different schemes and designs of impulse devices for riveting, lockbolts setting, piercing, punching and holes mandrelling.

The main advantages of impulse technologies of fasteners setting, holes punching and holes mandrelling include high stability and quality of the output parameters that do not depend on the executor skills, simple design, low cost, low weight and dimensions of hand-held impulse devices (HID) [1-4 et al].

Unfortunately, due to the collapse of the Soviet Union, these technologies have not been fully implemented in serial aircraft production. However, in recent years due to the great interest of such companies as Boeing, Airbus, Volkswagen and others, these works have been renewed in KhAI.

In addition, the enterprises of automobile sector have begun to show interest to these technologies due to the complication of vehicles structures, implementation of new materials (e.g. carbon fiber reinforced plastics, fiberglass, and other PCM), an increase of requirements for static strength, stiffness and lifetime of joints and whole construction.

2. Problem Statement

The objects of the study are the classifier of impulse technologies during the assembly of aircraft structures using HID (riveting hammer, devices for synchronous riveting, as well as holes burnishing and lockbolts installation); the generalized scheme of numerical simulation process of technological system for the implementation of assembly impulse technological process; the approach to the creation of HID for aircraft jig assembly.

3. Technological Processes of Assembly and Installation of Aircraft Using Hand-Held Impulse Devices

Technological processes' classification used for assembly and installation of aircraft with help HID is shown in Fig. 1.

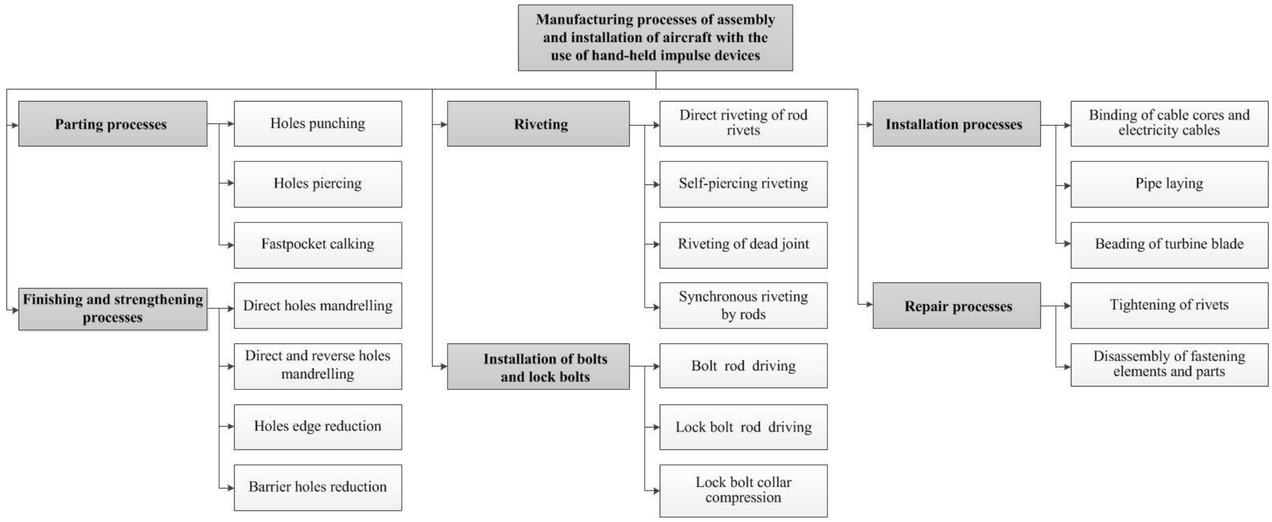


Fig. 1 Manufacturing processes of assembly and installation of aircraft with the use of HID

The choice of technological processes depends on the following factors: the required resource of the product, the quality of the connection (including aerodynamic), economy, assembly conditions (approaches to connection), productivity, improvement of working conditions and etc. As a result of the analysis of the assembly's technological processes and installation of aircraft created generalized scheme pulse technologies (Fig. 2), which consists of the following elements:

1) working part of the instrument:
  - crimping (riveting the stud rivets, bolt drive);
  - support (synchronous riveting by rods);
  - mandrel (ring compression);
  - mandrel (direct and reverse mandrelling);
2) reinforcing element:
  - support (riveting the stud rivets, bolt drive, ring compression);
  - crimp-support (synchronous riveting);
  - reinforcement element of the structure (direct mandrelling);
  - thrust bushing of the device (reverse mandrelling);
3) resistant bushing of the device:
  - elastic clamping (riveting the stud rivets, synchronous riveting, bolt drive);
  - the stop washer of the device (ring compression, direct mandrelling);
  - thrust bushing-support (reverse mandrelling);
4) fastening element:
  - rivet (riveting the stud rivets);
  - rod (synchronous riveting);
  - bolt (bolt drive);
  - ring (ring compression);
5) package of connected parts.

The generalized scheme makes it possible to develop a unified approach to the numerical modeling of impulse processes, geometrics' calculation and energy parameters of HID.

4. Numerical Modeling Of Technological Operations Of Aircraft's Assembly Using Hand-Held Impulse Devices

Experimental methods of choosing rational technological parameters of impulse processes for assembling aviation structures require considerable material and time costs. The current level of software and computer technology development makes it possible to numerically model these processes by the finite element method (FEM) in software packages Ls-Dyna, Abaqus, etc.

At numerical modeling of technological operations of the assembly of aircraft with the use of HID the following works were performed:

1) geometric modeling of the system elements: package, fastening element, tool working part (crimping,

mandrel), reinforcement element and thrust bushing (see Fig. 2);

2) modeling of physical properties of the materials of the tool working part, support, a package of joined parts, a reinforcing element and a thrust bushing;

3) setting the contact conditions for the interaction of the system’s elements;

4) setting the initial conditions for the state of the system’s elements.

The following assumptions were made:

1) the materials of system’s elements are specified by standard modules;

2) the problems are solved in an axisymmetric setting;

3) friction on the contact surface is described by the Amont-Coulomb law;

4) the thermal effects caused by plastic deformation are not taken into account.

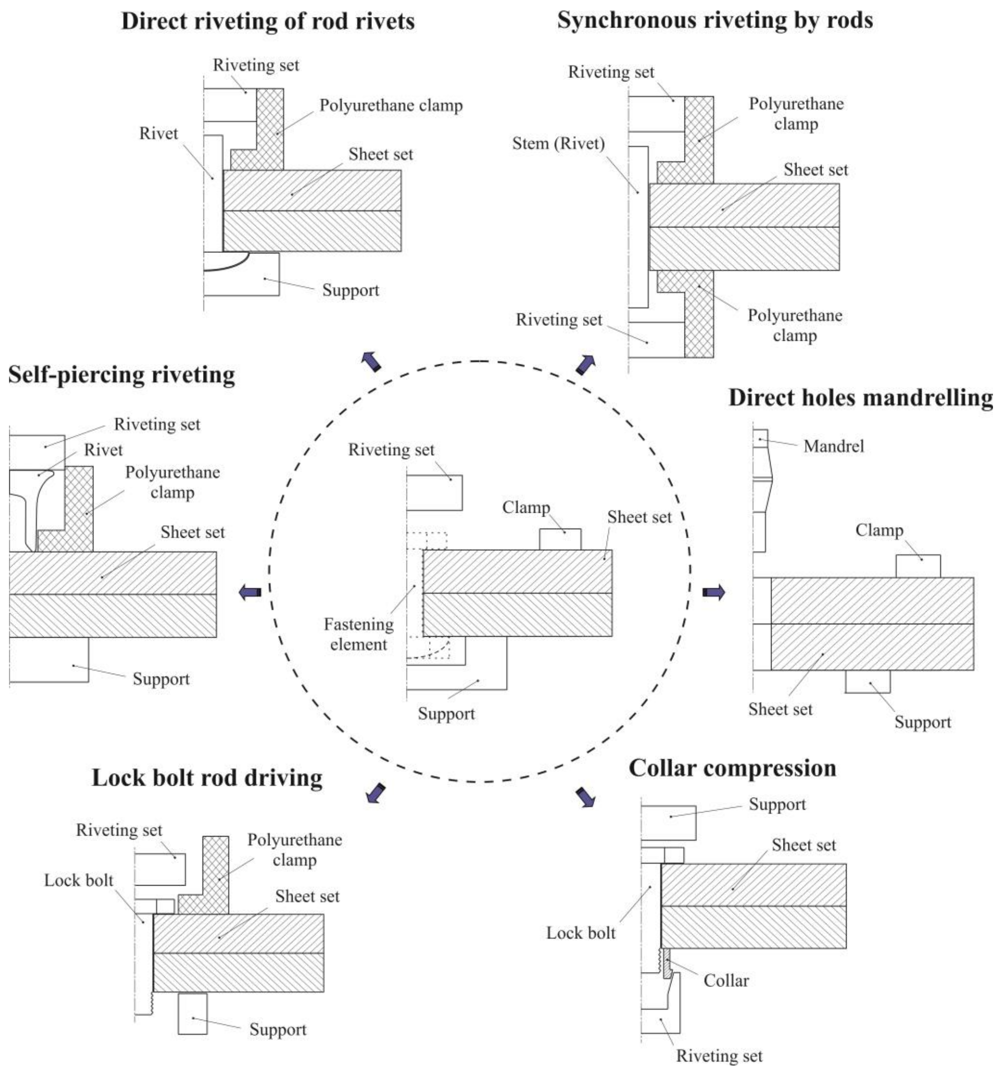


Fig. 2 Generalized schemes of technological processes of the assembly of aircraft using HID

The most optimal standard modules for describing the properties of the materials of system’s elements are given in [4, 5] and include:

– package of parts to be connected: "MAT_POWER_LAW_PLASTICI-TY" (E, μ, B, m – coefficients of the power law $\sigma = B\varepsilon^m$);

– deformable fastening element: "MAT_POWER_LAW_PLASTICITY" (μ, B, m – coefficients of the power law $\sigma = B\varepsilon^m$);

– tool working part (crimp, mandrel) and reinforcement element (support): "MAT_RIGID" (E, μ);

– the stop washer of the device (polyurethane clamp): "MAT_HYPERELASTIC_-RUBBER" (μ, material constants $C01\,(\mathrm{Pa})$ и $C10$ (Pa)).

The use of the above-mentioned standard functions in the numerical modeling of the technological processes of the assembly of aircraft using HID yields no more than 15% of the error in comparison with the full-scale experiment [2, 5].

In solving problems of pulsed plastic deformation, an explicit method of integrating differential equations is used.

Based on the results of the numerical simulation (Fig. 3), rational technological parameters are determined, which are taken into account when designing the design of HID.

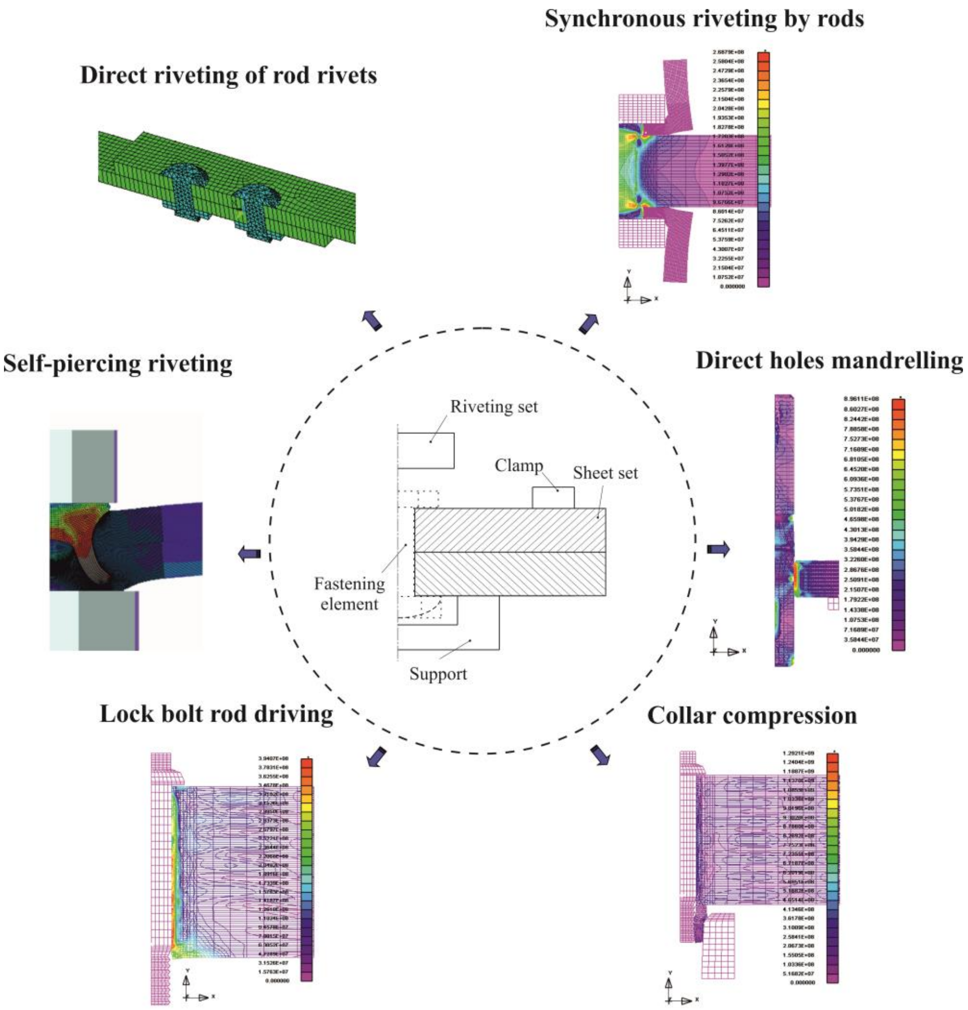


Fig. 3 The results of numerical modeling aircraft's assembly with the use of HID in the software packages Ls-Dyna and Abaqus

5. Scheme's Classification And Designs Of Hand-Held Impulse Devices

To perform technological assembly operations, an analysis was made of existing schemes and designs of HID, which allowed to classify devices according to the principle of action and design (Fig. 4 - Fig. 5).

In Fig. 6 shows the schemes of pneumatic impulse hand devices developed by the authors in recent years at the National Aerospace University "Kharkiv Aviation Institute": a) direct action devices used for riveting, bolting, compression of the washer, punching, direct mandrelling, smoothing, embossing; b) direct and reverse action devices used for direct and reverse mandrelling and smoothing; c) synchronous action devices used for synchronous riveting.

During the analysis of manual pneumatic impulse devices, their functional-element block diagram is developed, which allows taking into account all the factors that determine the technological operations of the aircraft assembly in the jig.

The block diagram (Fig. 6) shows the connection between the energy source 1 and the working element 2 through a system of functions: a control system 3, control differentiation system 4, drainage-damper chamber 5 that are connected by an energy box 6 consisting of:

- control mechanism of return to origin position 7;
- storage of potential energy (receiver) 8;
- chain of striker returning 9;
- chain of instantaneous discharge 10;
- chamber before striker 11;
- chamber after striker 12;
- striker 13.

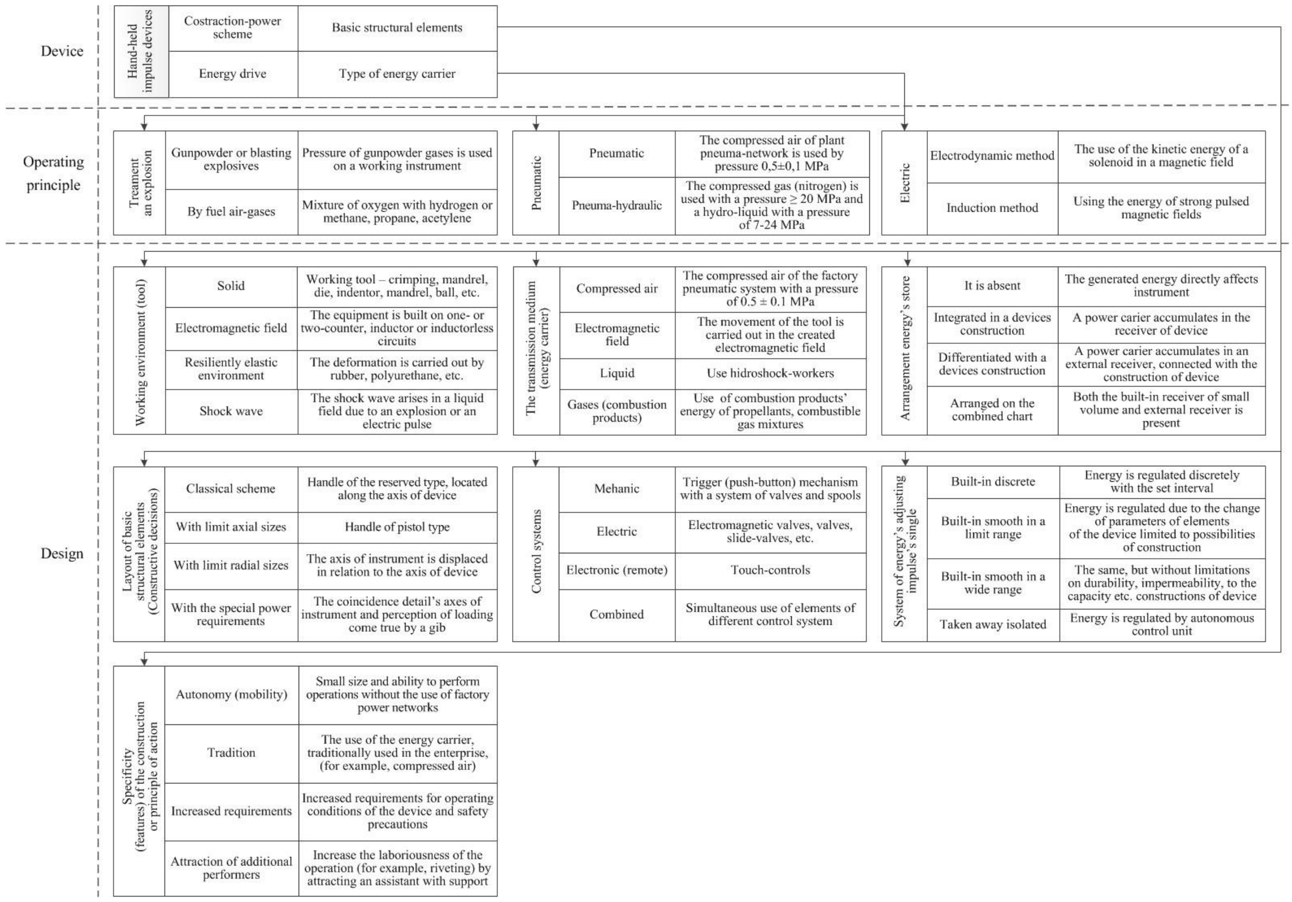
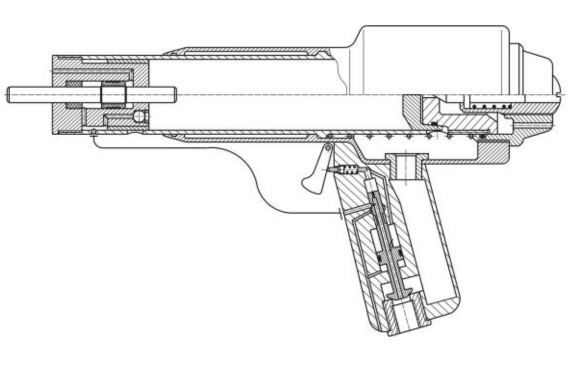
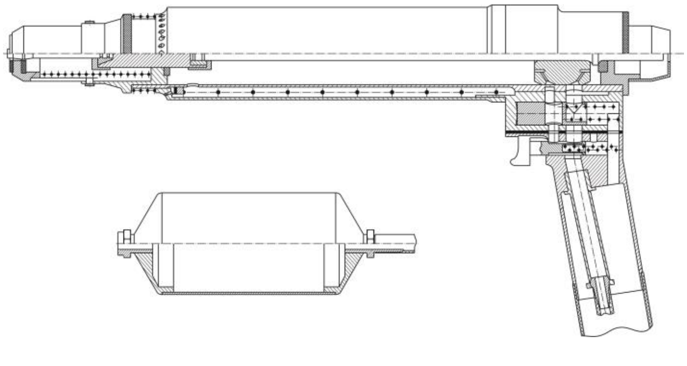


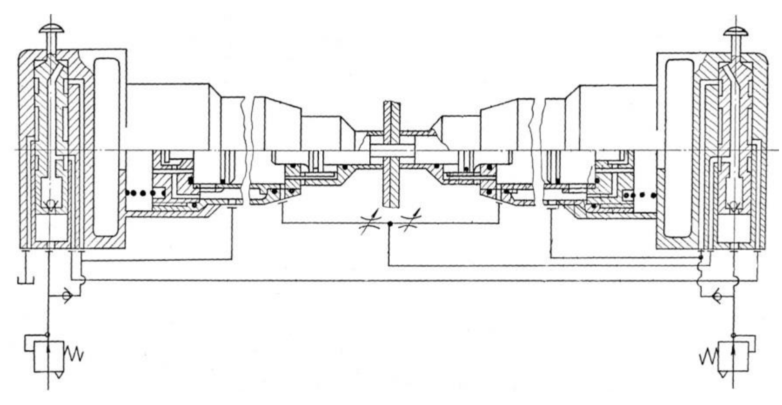
Fig. 4 Scheme's classification and designs of HID



a



b



c

Fig. 5 Pneumatic HID: a - direct action (rivet hammer mod. MPO-4); b - direct and reverse action device (mandrelling devise mod. PIUD-90); c - synchronous device (Inventors certificate of USSR №839138)

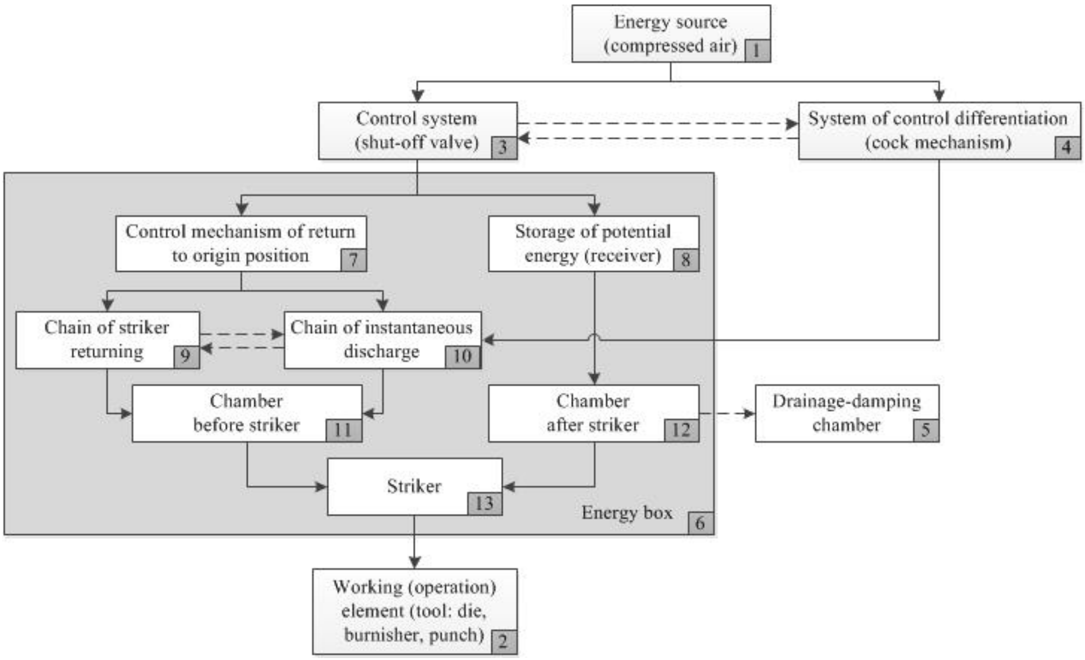


Fig. 6 Functional-element block schematic diagram of the pneumatic HID

5. Conclusions

A classifier of pulse technologies for the assembly of aviation structures using hand-held impulse devices (riveting hammer, device for synchronous riveting, device for holes mandrelling) is developed.

A generalized scheme for numerical simulation of the technological system of pulsed technologies for the assembly of aviation structures in the software products Ls-Dyna and Abaqus is created. Numerical models are verified.

A generalized classification of schemes and designs of hand-held pulse devices is developed, which takes into account the operation principle of the device and the design features of the devices (working and transmitting field, energy storage, operation control and single-pulse energy control, device layout).

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Proceedings of 22nd International Scientific Conference. Transport Means 2018.

Using a Dynamic Simulation to Determine the Power Requirement for the Tracked Vehicle Movement

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Abstract

This article deals with the computational modeling of the tracked vehicle dynamics to determine a quantity of power required for moving the vehicle. More specifically, the article presents a description of the examined model of the vehicle – a forwarder with two frames and four tracked undercarriages. The focus is also devoted on a description of virtual terrains and dynamic simulations. Obtained results in the form of time-power characteristics roughly correspond with results obtained experimentally.
KEY WORDS: *dynamic simulation, tracked vehicle, forwarder, power*

1. Introduction

Generally, a determination of drive unit power requirements is important step during development of all types of vehicles and transport machines. In the past, the power requirements of drive units for transport machines were estimated heuristically and calculations were based on simplified ideas, how much energy the machine will need to overcome the terrain obstacles and to work properly. Nowadays, the possibilities of computational methods allow calculation of behaviors of complex systems with a lot of degrees of freedom. Commonly used computational methods include multi-body simulations (MBS). The possibilities to create a virtual prototype of transport machine, including main parts such as powertrain and its components, using a multi-body simulation have been reported in [1-4].

For the purpose of this paper, using MBS enables to calculate power requirements of transport machine's powertrain in different operational situations. The above-mentioned machine is forwarder, which is designed to transport tree trunks from a forest to a paved road, where these trunks are taken away by specialized trucks.

In the text below, the computational model (virtual prototype) of the forwarder and a movement of this model through the virtual terrain are presented within the basic description of this virtual terrain. Next, there are presented two time-power characteristics, which were obtained as results of two dynamic simulations. Each simulation took 320 seconds and forwarder moved through a plain terrain, which was composed of five main parts with different slopes, -10, -5, 0, 5 and 10 degrees. Further details are given below. The results of the movement of similar computational model of this forwarder through a simple plain terrain with no slope have been presented in [5].

2. The Prototype of Forwarder and its Computational Model

The virtual prototype (see Fig. 1) is designed as a two-frame articulated vehicle with four tracked undercarriages with rubber tracks with steel inserts. The computational model (see Fig. 2) and simulations were created and performed using Project Chrono - An Open Source Multi-Physics Simulation Engine [7]. Weights of main parts of the forwarder and its virtual counterpart are shown in Table 1. Weights are slightly different, because the computational model of forwarder was created before the prototype was built and only in accordance with CAD model and documentation.

Components of the computational model of the forwarder can be split into two groups. The front frame and the rear frame within the joint constitute the first group. On the front frame there are placed a cabin, engine, etc. On the rear frame there are placed the bunk and load representing tree trunks [5]. In the multi-body simulation there are 3 bodies connected by 2 revolute links [3, 5]. Four tracked undercarriages constitute the second group, see [5].

The drive sprocket (number *7* in the Fig. 2) is driven by computational model of a general motor, which approximates a real hydro-motor. In order to create a tension in the rubber track, the constant force acts on the tensioning mechanism (number *10* in the Fig. 2). This is approximation of a hydraulic piston which drives the tensioning mechanism.

The track (number *3* in the Fig. 2) is created from 74 bodies (shoes) connected to each other by revolute links. Next, there are a torsion spring and a damper for the accumulation and dissipation of the energy [5].

One virtual terrain was created. This terrain consists of five main parts with different gradients, -10, -5, 0, 5 and 10 degrees. The longest part is plain straight road with no slope (0 degrees) and length of 160 meters and it is situated in the middle of the virtual terrain. Other parts are shorter with same length of 40 meters. The second half of the virtual terrain is shown in Fig. 3. Possibilities of making virtual terrains for the needs of multi-body simulations are described in [6].

Fig. 1 Forwarder without the load [8]

Table 1

Weights of main parts of the forwarder and its computational model, [kg]

Part of vehicle	**computational model**	**prototype**
Front frame	3070	9670
Rear frame (inc. joint, crane etc.)	2594	
Tracked undercarriage (without rubber track)	811	
Rubber track	148	
Load (tree trunks)	3600	3650
Sum of all parts	**13100**	**13320**

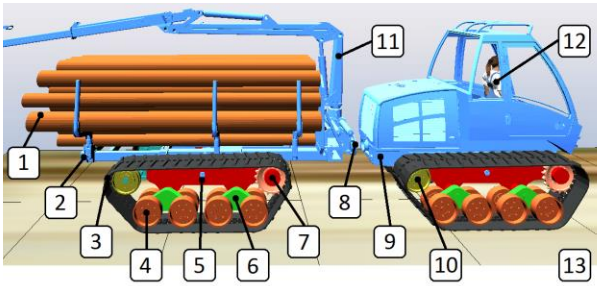

Fig. 2 Computational model of the forwarder: *1* – weight; *2* – rear frame; *3* – track; *4* – roller; *5* – undercarriage frame; *6* – arm; *7* – drive sprocket; *8* – joint; *9* – front frame; *10* – idler; *11* – crane; *12* – driver; *13* – virtual terrain [5]

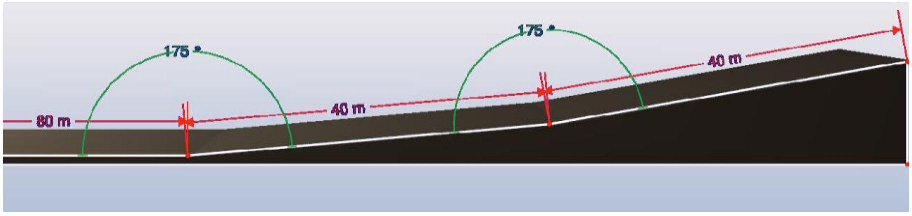

Fig. 3 The second half of the virtual terrain – peaved road with three different slopes of 0, 5 and 10 degrees

3. Dynamic Simulation

Two dynamic simulations were performed with using libraries of the Project Chrono [7]. During these simulations the computational model of the forwarder with or without the weight moves in a downhill and uphill direction. According to Kašpárek et al. [3], the forwarder's driving mode was chosen, because it achieves higher energy demands in contrast to the forwarder's operation mode.

According to Jonák et al. [5], SOR was used as a formulation for the solver and a time step value was set on 0.00025 seconds. In order to move the virtual prototype a torque was acting on the drive sprocket. To accelerate the forwarder from 0 to 1 meter per second and then to brake again, when the end of the terrain was achieved, the PID controller was used to control instant value of acting torque. The power was obtained from the angular speed and the torque of individual sprockets. Fig. 4 shows time-power characteristics of the power required for the driving mode of the machine. Average values are shown in the Table 2.

Time-power characteristics shown in Fig. 4 consist of a several parts. Individual parts correspond with parts of the virtual terrain when the slope is changing according to Fig. 3, where a half of the virtual terrain with positive slopes is shown. Shorter left part in range from 0 to 5 seconds corresponds with acceleration and the last part at time of 306 seconds corresponds with deceleration of the virtual prototype. It is also apparent a steeped increase in required power when the slope of the virtual terrain was changing. Finally, it should be noted that the oscillation of the time-power characteristic is due to the way the PID controller was used.

After the manufacturing of the virtual prototype the experimental tests were performed. All test results are available in [8] and roughly correspond with multi-body simulations.

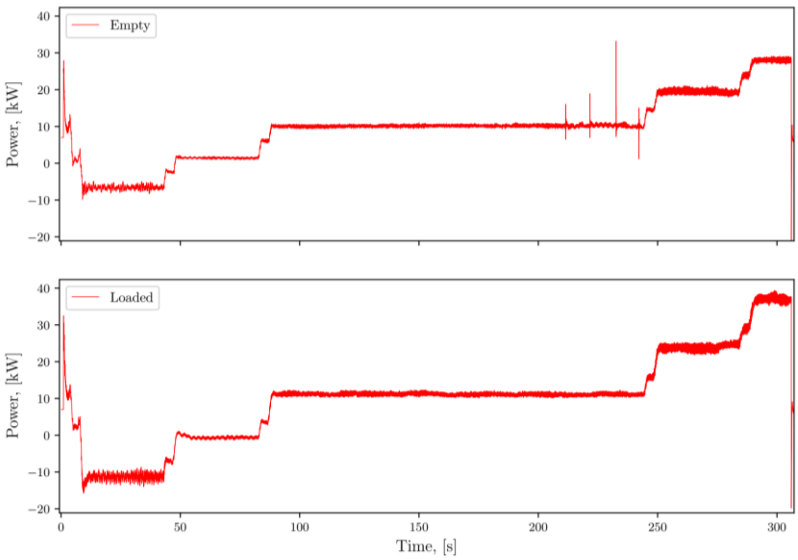

Fig. 4 Calculated time-power characteristics in range from 0 to 306 seconds.

Table 2

Average values of calculated power requirements, [kW]

Load / direction	downhill		driving along the plane	uphill	
	-10 deg	-5 deg	0 deg	5 deg	10 deg
Empty	-6.6	1.6	10.1	19.7	28.1
Loaded	-11.2	-0.7	11.4	23.8	37.3

4. Conclusion

The virtual prototype of forwarder with four tracked undercarriages created in an open source multi-physics simulation engine Project Chrono was presented. From the point of view of dynamic simulation and its confidentiality, the most problematic part of whole computational model was the rubber track, because material properties of such tracks are generally unknown and complete identification of these material properties couldn't be performed.

However, if all uncertainties and approximations of the computational model are taken into the account, all time-power characteristics which were obtained computationally roughly correspond with characteristics obtained experimentally.

The future work will be focused on identification of parameters of material models, which are used for description of the rubber track behavior. Furthermore, qualitatively new virtual terrains must be created in order to solve tasks in the field of terramechanics. These terrains will be probably based on DEM and FEM approaches.

Acknowledgement

The research leading to these results has received support from the specific university research program of Brno University of Technology, project No. FSI-S-17-4104.

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Proceedings of 22nd International Scientific Conference Transport Means
ISSN 1822-296 X (print)
ISSN 2351- 7034 (online)

Design by Rasa Džiaugienė, Rolandas Makaras, Robertas Keršys, Saulė Kvietkaitė

Cover Design by Publishing House „Technologija“

Printer‘s sheets Order No. Price on request.
Publishing House „Technologija“ , Studentų st. 54, 51424, Kaunas