TRANSPORT MEANS 2018

PROCEEDINGS OF THE 22nd INTERNATIONAL SCIENTIFIC CONFERENCE

PART III

October 03 – 05, 2018
Trakai, Lithuania

KAUNAS • 2018
CONFERENCE IS ORGANIZED BY
Kaunas University of Technology,
In cooperation with
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 wide 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 and 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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Prof. V. Ostaševičius
Steering Model of Exploitation Process of N1 Category Vehicles in Transport Companies

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Abstract

The rational usage of vehicles in transportation companies is the basis for minimizing costs and effective execution of transportation tasks. Steering the process of usage these vehicles is therefore a basic element of the entire vehicle exploitation system. The aim of the steering is to organize such an interaction so that, with given interference and limitations, it can extract from the process of usage the maximum energy, efficiency and effectiveness. The main purpose of the article is to present a model of steering process for the usage of N1 category vehicles in transportation companies. On the basis of the analysis of the functional properties of the exploited vehicles, the intensity of their use was assessed and a linear model of the loss of exploitation potential was presented. The presented analysis gave the basis for the construction of a model that provides optimal conditions of usage N1 category vehicles.

KEY WORDS: vehicle exploitation, usage intensity, N1 category vehicles, efficiency

1. Introduction

The subject of the presented research are N1 category vehicles, which according to Annex 2 to Dz. U. of 8 June 2017 Polish Law are defined as vehicles designed and constructed for the carriage of goods and having a maximum total weight not exceeding 3.5 tones (DMC up to 3.5 t) [1]. In practice, this type of vehicles is referred to delivery vehicles, that is why this term will be used in the further part of the study. Effective exploitation of delivery vehicles requires simultaneous measurement and analysis of many different parameters describing the operation of the vehicle. The need of assessment the parameters of: exploitation, maintenance, control, technical condition, environmental conditions and simultaneous analysis of the economic efficiency of transportation tasks allows to stand out from the competitors on transportation market.

2. Analysis of the Steering of the Vehicles Usage Process in Exploitation System

According to the definition of a technical and scientific lexicon [2] steering is an influence on a specific system aimed at ensuring its behavior in a desired manner. A distinction is made between the steering in the open system, where it is not possible to eliminate the influence of factors disturbing the course of a given process, and steering in a closed system (called regulation), where manual and automatic steering is distinguished depending on human participation.

The steering of usage according [3, 4] aims at the activation and operation on the object, which in certain interfering influences will lead to the realization of the task in accordance with the intended program of exploitation. If the exploited object is determined by the characteristic \( y(t) \), and the usage program determined for it in the period \( T \) is \( y_0(t) \), then the usage steering is a process according to the relation:

\[
\left| y_0(t) - y(t) \right| = \min .
\]  

Exploitation subsystem in steering aspect can be depicted as [4]:

\[
P_U = \{P_{UR}, P_{UZ}, R_{UP}\};
\]  

\[
U_R = \{C, A, D, R_{CD}\};
\]  

\[
P_{UZ} = \{P_{UR}, P_{UZ}, R_{UP}\};
\]

where \( P_U \) - exploitation subsystem; \( P_{UR} \) - working exploitation subsystem; \( P_{UZ} \) - subsystem exploitation’s management; \( P_{UR} \) - subsystem of exploitation’s steering; \( P_{UZ} \) - economic and financial subsystem of exploitation; \( P_{UP} \) - exploitation’s information system; \( C, A, D \) - exploitation’s objects; \( R_{UP}, R_{CD}, R_{PF} \) - relations.
Steering the operation process is the ability of the system to change the dynamic state of the vehicle from point 1 to point 2 (diagram 1). This change distinguishes the actions [3, 5]:

1. The first action is to maintain the value of the characteristic of the object or its corresponding change, in terms of operating time $t_1 \leq t \leq t_2$.

2. The second action, which is a component of the steering process, involves moving the dynamic state of the object to point 2.

3. The third action is to approximate the 1-2′ curve to the assumed 1-2 characteristic. The discrepancy between assumed $y_{0}(t)$, and the real $y(t)$ of the external characteristic curve is $\Delta y(t)$.

![Fig. 1 Discrepancies between the real and assumed characteristics of the object being exploited [3]](image)

The idea of steering of the usage process of vehicles in the exploitation system is to minimize the discrepancy between the real course of external and assumed characteristics. Many transportation companies do not comply with the principles of rational vehicles exploitation, that is why these discrepancies are significant. Often the reason for this behavior is the idea to increase the current incomes. Steering of the usage process is a very important element of the entire system, because it aims at effective and efficient management of vehicles, which in turn leads to minimization of operation costs and maximization of profits of transportation companies.

3. Assessment of the Intensity of Exploitation of Delivery Vehicles in Transportation Companies

The result of the maximum economic benefits of the enterprise is affected by the correct functioning of the entire vehicle operation system. Therefore, the steering process is extremely important to the system since it affect the final result of each activity. It includes planning, organizing and managing the exploitation process. Decision-making problems based on economic efficiency rely on determining [5-7]:

- the most favorable conditions for achieving the goal $y_{n}^{'(1)}(\phi_{n0}^{'}, \psi_{n0}^{'}, s_{n0}^{'})$;
- the most suitable mechanical devices $\phi_{n0}^{'(1)}(\psi_{n0}^{'}, s_{n0}^{'})$;
- the most favorable methods of exploitation $\psi_{n0}^{'(1)}(\phi_{n0}^{'}, s_{n0}^{'})$;
- the optimal commitment of funds $s_{n0}^{'(1)}(\phi_{n0}^{'}, \psi_{n0}^{'}, s_{n0}^{'})$.

at a minimum cost $k$, which can be presented in the form:

$$
\begin{align*}
\gamma_{a0}^{'(1)}(\phi_{a0}^{'}, \psi_{a0}^{'}, s_{a0}^{'}) & \in \Gamma_a  \\
\phi_{a0}^{'(1)}(\gamma_{a0}^{'}, \psi_{a0}^{'}, s_{a0}^{'}) & \in \Phi_a  \\
\psi_{a0}^{'(1)}(\phi_{a0}^{'}, \gamma_{a0}^{'}, s_{a0}^{'}) & \in \Psi_a  \\
s_{a0}^{'(1)}(\phi_{a0}^{'}, \psi_{a0}^{'}, s_{a0}^{'}) & < S \\
k(\phi_{a0}^{'}, \psi_{a0}^{'}, s_{a0}^{'}) & = \min .
\end{align*}
$$

The choice made on the basis of the above assumption determines the optimal and the most advantageous method of vehicles’ usage within exploitation system.

The real system of the transportation company strives to achieve a balance [6]:

$$P_{pp} = P_{pd},$$

where $P_{pp}$ - transportation work, expected by the demand side of the transportation market, which is most often described by two characteristics: $L_Q$ - transport distance of the reported load shipment and $Q$ - weight of each reported cargo shipment:

$$P_{pp} = \sum_{i=1}^{n} L_{Q_i} \cdot Q_i,$$

$P_{pd}$ - transportation work, possible for producing by a transport company using the full resources of the system.
The assessment of the intensity of usage of two delivery vehicles was made on the basis of the analysis of technical parameters (Table 1) and their exploitation properties.

### Table 1

<table>
<thead>
<tr>
<th></th>
<th>Renault Mascott</th>
<th>Renault Master</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year of production</td>
<td>2008</td>
<td>2010</td>
</tr>
<tr>
<td>Mileage</td>
<td>90 000 km</td>
<td>140 000 km</td>
</tr>
<tr>
<td>Engine capacity</td>
<td>3000 mm³</td>
<td>2300 mm³</td>
</tr>
<tr>
<td>Horse power of engine</td>
<td>140</td>
<td>150</td>
</tr>
<tr>
<td>Weight</td>
<td>2550 kg</td>
<td>2550 kg</td>
</tr>
<tr>
<td>Maximum load capacity</td>
<td>950 kg</td>
<td>950 kg</td>
</tr>
</tbody>
</table>

The exploitation's properties of the tested vehicles refer to:
- daily mileage - km;
- daily driving time - h;
- weight of the transported load - kg;
- average fuel consumption - 1/100km;
- average exploitation cost - PLN, (repairs, service, fuel cost, driver's employment cost, insurance, reviews, annual loss of value),
- average unit price for services - PLN / km.

Based on the analysis of the usage of delivery vehicles, it appears that in 2017 the average monthly mileage of the Renault Mascott vehicle was 11 113 km, and the average weight of the transported cargo was 1110.83 kg (Fig. 2). For the Renault Master vehicle, the average monthly mileage of the vehicle is 11 896 km, and the average weight of the transported load is 1198 kg (Fig. 3).

The basic conclusion from the above analysis is the fact of overloading both vehicles. The properties of the vehicles indicate that the transported load should be max 950 kg. The result of the load capacity analysis indicates that in 2017, Renault Mascott transported loads that exceeded by an average of 17% the allowed load of the transported cargo.
Overloading of the Renault Master in the same year was an average of 26% (Table 2).

Table 2: Analysis regarding the weight of the transported cargo of delivery vehicles in 2017

<table>
<thead>
<tr>
<th></th>
<th>Allowed weight of the load - kg</th>
<th>Average weight of the load - kg</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renault Mascott</td>
<td>950</td>
<td>1110.83</td>
<td>117%</td>
</tr>
<tr>
<td>Renault Master</td>
<td>950</td>
<td>1198</td>
<td>126%</td>
</tr>
</tbody>
</table>

On the basis of accepted transport orders, the average rate per kilometer in 2017 was specified, which for the Renault Mascott vehicle amounted to - 1.56 PLN / tkm, while for the Renault Master was - 1.59 PLN / tkm.

Exploitation costs, which include all costs of usage, including fuel, costs of changing tires, inspections, depreciation costs, drivers' salaries, maintenance services and repairs, were compared with the income earned each month for a specific vehicle (Figs. 4 and 5).

In the case of Renault Mascott in June and October, exploitation costs exceeded revenues. The reason for the surplus of costs over revenues in June was the break of the frame. The vehicle was dispatched to the service, what caused its seven-day downtime, loss of potential transportation orders and costs related to repair and replacement. For both vehicles, the average cost of exploitation exceeded revenues also in October, it was caused by the provision of seasonal service, tire replacement and performance of the review.

The transportation potential of a given transportation company depends to a large extend on the intensity of usage of delivery vehicles, which can be determined for both vehicles on the basis of the indicators (Table 3).

The appropriate level of the time efficiency indicator of the vehicles usage and transportation efficiency may contribute to making decisions about, for example reducing the number of vehicles in the company, increasing the efficiency of other vehicles and thus costs reduction. On the basis of the presented indicators, it turns out that the real conditions of usage exceed the assumed norms for both vehicles. The intensity of usage of vehicles that are overloaded affects their exploitation potential, which they lose much faster, and their threshold value of the labor resource is fully used while achieving, for example, 80% of the assumed service life, as illustrated in Fig. 6.
### Table 3

#### Analysis of intensity of usage of delivery vehicles

<table>
<thead>
<tr>
<th>Renault Mascott</th>
<th>Renault Master</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time efficiency indicator of vehicles usage</strong></td>
<td></td>
</tr>
</tbody>
</table>
| $F = \frac{T_d}{T_{d-1}}$ & $T_{d-1}$ – average, daily driving time with a load  
$T_d$ – daily working time |
| $F = \frac{6h}{10h} = 60\%$ | $F = \frac{4.5h}{10h} = 45\%$ |

#### Carriage efficiency indicator of vehicles usage

| $B = \frac{K_1}{K}$ &  |
| $K_1$ – average, monthly number of kilometers traveled with the load  
$K$ – overall monthly mileage |
| $B = \frac{7209 \text{ km}}{10959 \text{ km}} = 65.8\%$ | $B = \frac{5948 \text{ km}}{11896 \text{ km}} = 50\%$ |

#### Static loading indicator

| $C = \frac{Q}{q}$ &  |
| $Q$ – average, monthly, real weight of the load  
$q$ – loading capacity of vehicle |
| $C = \frac{1111 \text{ kg}}{950 \text{ kg}} = 117\%$ | $C = \frac{1197 \text{ kg}}{950 \text{ kg}} = 126\%$ |

#### Technical readiness indicator

| $G_t = \frac{T_e}{T_s}$ &  |
| $T_s$ – average time technical rediness of vehicle  
$T_e$ – average time operation of vehicle |
| $G_t = \frac{2286 \text{ h}}{2340 \text{ h}} = 98\%$ | $G_t = \frac{2340 \text{ h}}{2340 \text{ h}} = 100\%$ |

![Threshold value of the work resource](image)

**Fig. 6** Linear model of loss of exploitation potential [8]

In the event that the real conditions of usage coincide with the assumed, the vehicle reaches the threshold value of the labor resource at reaching the 100% target (point 1 in diagram 6). In a situation where the real exploitation conditions affect the object to a lesser degree than assumed, its durability may exceed the expected target standard (point 2 in diagram 6). If the vehicles are overloaded much faster they reach the threshold value of their labor resource and lose their exploitation potential faster (point 3 in diagram 6).

The effect of the exploitation of each vehicle should be as higher as possible technical readiness with the maximum intense and economically profitable usage. Steering the process of usage therefore plays a key role in maintaining vehicles in a technical readiness and ensuring the reliability of the entire transportation system, and possible the most intense, planned, full and cost-effective usage of vehicles in order to achieve adequate efficiency and business results.

### 4. Conclusion

When assessing the usage process in terms of usage potential of the examined delivery vehicles, the most important fact is that the permissible load capacity of vehicles is deliberately exceeded each month which is proved by
value of static load indicator. This can contribute to breakdowns, damage, unplanned downtime and even the complete elimination of the vehicle from use for some time, as happened with the Renault Master in June and contribute to technical readiness at the level 98%. In order to exploit delivery vehicles rationally, their usage should be properly controlled, routes planned to optimize the time, tasks assigned accordingly and, above all, intensity of their usage ought be verified respectively. Based on the conducted research, it appears that we should focus on steering of the usage process, i.e. optimize routes and minimize the empty runs, what is confirmed by the low value of the time and transport efficiency indicator for both vehicles. The steering should also eliminate the overloading of vehicles, which in effect leads to the faster reaching of the threshold value of their work and the unplanned stoppages, which generate costs and affect the revenues of the transportation companies.

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Economic Evaluation of LNG Use in Road Freight Transport

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Abstract

The substitution of fossil fuels in road transport is one of the dominant themes at this time. For a long time, compressed natural gas has been used mainly in bus transport. The test process is primarily focused on electromobility or hydrogen drive. Another option is the use of liquefied natural gas (LNG). Advantage of LNG is (compared to CNG) longer driving distance. Therefore, the article focuses on the possibilities of using LNG in freight road transport, the technological issues of propulsion and, especially, the economic cost model compared to conventional fuels.

KEY WORDS: transportation, alternative fuels, costs calculation, LNG

1. Introduction

LNG is liquefied natural gas with a temperature of approximately -162°C at atmospheric pressure (101 325 Pa). It is a bluish, non-toxic, non-corrosive, transparent liquid with a minimum viscosity. The fact that the volume of LNG is 600 times smaller than natural gas and can be more efficiently stored and transported is its key advantage. LNG is from 90 to 100% composed of methane and depending on the mining site it further comprises residues of ethane, propane, higher hydrocarbons, nitrogen and other gases. The energy value of LNG is around 55 MJ/kg, which is approximately 22 MJ/l. Its ignition temperature is 540°C. LNG can be either liquefied at set places or transported from storage facilities where it is stored as a liquid until use. LNG is one of alternative fuels that will reduce emissions primarily from road transport, or else water transport (In this respect air transport moves in another direction).

Nowadays, as we talk about the need in transportation to change over to alternative energy sources, the example of switching to LNG is the demonstration of how costly such a transition can be. Investment costs for two liquefaction facilities will exceed EUR 100 million. Other investments (storage facilities, construction parts, conversion of vehicles, etc.) may amount to about EUR 350 million. If we ask ourselves whether it is possible to use LNG in Europe, or even in the Czech Republic, we must be concerned with the investment costs in the first place. Of course, at the same time we can find out for what kinds or types of transport LNG would have been useful in the future.

Potential user must consider all the advantages and disadvantages of liquefied natural gas. The biggest drawback for LNG today is the insufficient infrastructure of filling stations. Directive2014/94/EU of the European Parliament on introduction of alternative fuel infrastructure remembers this, as it sets the necessary average distance between filling stations to be approximately 400 km, compared to CNG with the distance of 150 km. Unlike the other countries the Czech Republic has no LNG filling stations yet. There are about 75 LNG stations in the EU, mainly in the United Kingdom, Scandinavia, Benelux, or in Spain. Therefore, in terms of international transportation it is necessary to evaluate LNG utilization until the infrastructure is adequately developed. [1]

As for the local carriers, the situation might be different, especially for those, whose services are carried out "radially", i.e. every day cars operate certain territories and return to the same place in the end of the day, as is the case for public bus transportation. [2] These transport companies can use mobile filling stations, whose price is about CZK 6 million. This brings us to the undeniable advantage of the LNG propulsion system and thus the fuel costs which are lower than for conventional diesel propulsion. Operating range of the bus reaches 600 km, which is sufficient for daily running. Furthermore, the regular operation of LNG eliminates one disadvantage, namely, the liquefied gas evaporating gradually. It is therefore not suited for such vehicles which are put out of operation for longer periods of time.

Problems connected to tank range in freight transport are even more significant. The LNG-fueled vehicles offer about 800 km range. In Europe, the vehicles are primarily produced by Ivec and Scania manufacturers (EURO 6 models); LNG-fueled trucks by Volvo and MAN are currently being developed. Their utilization lies in regular routes of short or medium distances; longer routes are complicated due to underdeveloped infrastructure of LNG filling stations in Central Europe.

Another question to be addressed is related to transportability – how to move LNG to the Czech Republic? The first option which offers to liquefy the gas right in the Czech Republic is unrealistic in economic terms. It can be considered only in the case of daily LNG consumption of 160t, which implies approximately 1600 LNG-fueled vehicles in use. That is, of course, the far future vision for the time being. Therefore, the option to import LNG to the Czech
Republic is considered to be more suitable. Special tanker trucks or ISO containers are used for LNG transport. There are two applicable options, either LNG terminal in Rotterdam, the Netherlands, or Swinoujscie terminal in Poland.

LNG can be used directly to drive vehicles or for storage. It can then be used for both types of gas-fueled vehicles, both liquefied and compressed (Fig. 1).

![LNG and LCNG filling stations chart](image)

**Fig. 1 LNG and LCNG filling stations chart [3]**

### 2. Comparison of LNG and Diesel Consumption

For the calculation of economic efficiency, it is necessary to calculate the equivalent oil (diesel) consumption for LNG. We assume net calorific values and conversion designated as:

\[
S_{\text{LNG}} = S_D \cdot \frac{E_D}{E_{\text{LNG}}},
\]

where \(S_{\text{LNG}}\) - LNG consumption (kg/100 km); \(S_D\) - diesel consumption (kg/100 km); \(E_D\) - diesel calorific value/energy = 41.8 MJ/kg; \(E_{\text{LNG}}\) - LNG calorific value/energy = 49.9 MJ/kg.

When considered densities of these fuels (diesel 0.84 kg / l; LNG 0.411 kg / l) and the estimated truck fuel consumption of 30 l / 100 km, LNG consumption is equivalent to road haulage of 51.36 l / 100 km [4]. That corresponds to a ratio of one liter of diesel for 1.71 liters of LNG.

### 3. Comparison of Economic use of Diesel and LNG

In this part, we draw a comparison between diesel and LNG economic efficiency as we calculate the costs related to the equivalent diesel consumption for LNG. We consider it appropriate to present individual items of the used calculation formula for comparing LNG and diesel as fuels determined for freight transport. Our calculations are based on the long-term tracking of freight costs for different routes across Europe [5, 6]. For these purposes, we sort the costs into the following categories:

- Consumption of fuel and lubricants;
- Rubber tires;
- Wages, social and health insurance;
- Depreciation of the vehicles;
- Repairs and maintenance;
- Per diem;
- Road toll costs;
- Overheads (other direct costs);
- Operating and administrative costs.

Subsequently, the total unit cost in monetary units per kilometer is equal to the sum of following items:
\[ c_s = c_F + c_T + c_W + c_D + c_M + c_{RT} + c_H + c_D, \]  

(2)

where \( c_s \) - total costs (CZK/km); \( c_F \) - fuel costs (CZK/km); \( c_T \) - tire costs (CZK/km); \( c_W \) - wage costs (CZK/km); \( c_D \) - depreciation costs (CZK/km); \( c_M \) - maintenance costs (CZK/km); \( c_{RT} \) - road toll costs (CZK/km); \( c_H \) - overheads (CZK/km); \( c_O \) - other costs (CZK/km).

The economic comparison is based on the assumption that only some cost items are different: tire costs, wage costs, overheads and other costs are independent of the drive method. Therefore, our interest lies in combinations of fuel prices (diesel and LNG) where the total unit costs stay the same. Let us substitute fuel costs with the product of fuel consumption and fuel price and mark the costs of the fuel system used as \( c_V \), then we have:

\[ c_F = s_{fuel} \cdot p_{fuel}, \]  

(3)

where \( s_{fuel} \) - fuel consumption (l/km); \( p_{fuel} \) - fuel price (CZK/l).

\[ c_V = c_D + c_M + c_{RT}. \]  

(4)

We assume that maintenance costs as well as road toll costs will tend to fall slightly as the LNG complies with the EURO VI emission standard, i.e. if compared with EURO V diesel vehicles. Then it may come to cost savings in some countries. On the contrary, the cost of purchasing the LNG-powered vehicle will be higher. Once fitted, the following will apply to the equality of total unit costs when using different types of fuels (in our case LNG and diesel):

\[ s_D \cdot p_D + c_{V,D} = s_{LNG} \cdot p_{LNG} + c_{V,LNG}, \]  

(5)

where \( s_{LNG} \) - LNG consumption (l/km); \( p_{LNG} \) - LNG price (CZK/l); \( s_D \) - diesel consumption (l/km); \( p_D \) - diesel price (CZK/l); \( c_{V,LNG} \) - costs dependent on LNG fuel system; \( c_{V,D} \) - costs dependent on diesel fuel.

The following expression then indicates the calculation of such an LNG price for given diesel price, in which the total unit costs for the two types of fuel are the same:

\[ p_{LNG} = \frac{s_{col} \cdot p_{col} + c_{V, col} - c_{V,LNG}}{s_{LNG}}. \]  

(6)

Various combinations of LNG and diesel prices for which the expression \( c_{S,LNG} = c_{S,D} \) (ie the total cost of using LNG is equal to the total cost of using diesel), applies are plotted through line \( p \); see Figure 2. If the actual combination of diesel and LNG prices is below line \( p \), i.e. in the blue field, then LNG will be more expensive to use. Conversely, if the real combination of prices lies above the line \( p \), i.e. in the red field, diesel will be more advantageous to use from the costs perspective.

Fig. 2 The cost comparison model for diesel and LNG

4. Case Study – Route Brno – Milano

The economic advantage of LNG can be verified using real data tracking of truck costs, e.g. for Brno - Milano route. Route parameters:

- Distance: 984,25 km;
- Transport time: 1 day;
- Route through: Czech Republic, Austria, Italy;
- Road toll costs are calculated for EURO V emission standard – CZK 249, 53/route; for EURO VI – CZK 219,
For cost calculation, we use the following input data for EURO V and VI diesel fueled engine and LNG-powered propulsion (corresponding to EURO VI emission standard) (Table 1):

<table>
<thead>
<tr>
<th>Input data for economic comparison of diesel and LNG [6]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit</strong></td>
</tr>
<tr>
<td>Consumption ( s )</td>
</tr>
<tr>
<td>Maintenance costs ( c_M )</td>
</tr>
<tr>
<td>Truck price ( p_{truck} )</td>
</tr>
<tr>
<td>Road toll costs per route ( c_{RT,route} )</td>
</tr>
<tr>
<td>Vehicle running ( L_Y )</td>
</tr>
<tr>
<td>Lifetime ( T_L )</td>
</tr>
<tr>
<td>Length of the route ( L_R )</td>
</tr>
<tr>
<td>Exchange rate ( e )</td>
</tr>
<tr>
<td>Calorific value</td>
</tr>
<tr>
<td>Density</td>
</tr>
<tr>
<td>Road toll costs ( c_{RT} )</td>
</tr>
<tr>
<td>Depreciation costs ( c_D )</td>
</tr>
<tr>
<td>Dependent costs ( c_v )</td>
</tr>
</tbody>
</table>

Unit cost in CZK / Km is calculated as follows:

Depreciation costs \( c_D \):

\[
c_D = \frac{p_{truck} \cdot e}{T_L \cdot L_Y}. \tag{7}
\]

Road toll costs \( c_{RT} \):

\[
c_{RT} = \frac{c_{RT,route} \cdot e}{L_R}. \tag{8}
\]

The following graph shows the combination of LNG and diesel prices, at which total unit cost is the same for both fuel types (Fig. 3). With the current oil price, the maximum price limit for LNG fuel to be still favourable is around 13 - 14 CZK/l.

![Fig. 3 Cost comparison of diesel and LNG based on real data](image-url)
5. Conclusions

The method presented in this article is based on the assumption that the key factor which determines the use of alternative fuels is the price of oil or, more precisely, the price of classic fuels, i.e. petrol and diesel oil. Under the current circumstances, LNG is an economically more efficient type of fuel, but we must not forget that unlike diesel or petrol, LNG is not yet burdened with excise duty. The current price of LNG in Europe is around 8 CZK / l, the threshold price for LNG to be still worth it is at 13 to 14 CZK / l. At the same time, LNG has some technological deficiencies. The most notable is the reduction in payload. This is due to the fact that a LNG cryogenic unit of about 250 kg must be built on the vehicle. Another weak point is the still inefficient infrastructure of filling stations, so drivers need to be careful and fill the vehicle sufficiently and in time. Yet another disadvantage is the necessary replacement of the fleet - from the operational point of view, when changing the fleet, at least 30 vehicles have to be replaced in order to ensure sufficient fuel consumption so the LNG vapor loss would be minimized. Despite above mentioned disadvantages, LNG is clearly the most significant substitute for classical diesel fuel in road freight transport.

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Social Vulnerability and Resilience to Risks Associated with Road Transport of Dangerous Substances

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Abstract

The issue of the safe transport of dangerous substances is currently very topical, as the emergency events associated with the escape of dangerous substances have undesirable consequences not only for human lives and property, but also for the environment. Identification and assessment of societal vulnerability is important part of emergency events preparedness and adaptation strategies. The number of dangerous goods transportation is still increasing leading to increased risk of emergency event occurrence. The paper is dealing with theoretical aspects of vulnerability, social risk and resilience. It describes our approach to determination of social risk caused by leakage of a dangerous substance which represents the social dimension of societal vulnerability.

KEY WORDS: social risk, road transport of dangerous substances, vulnerability, leakage of a dangerous substance

1. Introduction

Carrying goods by road transport involves the risk of traffic accidents. Especially in the case of dangerous substances, there is an increased risk of fire, explosion, chemical burns, poisoning, death or environmental damage. The carrier is primarily responsible for the safe transport through the trained driver of the vehicle. The carrier who arranges the shipment must meet the essential requirements of the ordering party to maintain the quality, quantities and delivery dates. Besides the transport operator itself, the parties involved in the elimination of the consequences, either by the carriers or by the state administration authorities, play an important role [1]. It is also necessary to take into account other road users, e.g., drivers, pedestrians, children playing near roads. An important factor is the fact that this kind of transport cannot be excluded from the life of society; it is in close proximity to a large number of people who are not involved at all in the transport of dangerous goods.

2. Vulnerability, Social Risk and Resilience

The concept of vulnerability has been emerged, discussed and continuously developed over the almost past five decades especially in the fields of geographic development and poverty research, and hazard and disaster risk research. In the 1970s, research focused on disasters and crises associated with droughts in Africa, significantly contributed to the development of social vulnerability concept in geographic development and poverty research. Hazard and disaster risk research associated with disaster risk reduction started in the 1980s. In the last two decades vulnerability has become also a key topic in the climate change science [2].

At present the term “vulnerability” is used very loosely and there is no consensus about the precise meaning of it. According to Birkmann (2013), the current literature encompasses more than 30 different definitions, concepts and methods to systematize vulnerability. It is viewed as multidimensional, differential and dynamic phenomena and it can be misleading to establish a universal definition of vulnerability [3].

Based on the study of scientific literature, vulnerability can be defined as a function of three elements [3-5]:

- exposure to emergency event;
- susceptibility to change;
- capacity to adapt to that change.

But except for the three above mentioned key factors, it is necessary to deal also with vulnerability dimensions encompassing e.g. social, environmental and economic aspect. The social aspect can be included e.g. in the form of calculation of social risk which is presented in paragraph 2.1. The economic aspect deals with damages and economic loss and environmental aspect deals with the fragility of ecological and biophysical systems.

Measuring vulnerability need to be based on a systematic procedure dealing with specific indicators and criteria. Defining the relevant indicators is challenging process since they should be able to indicate the required characteristic of a system. By the determination of individual indicators, it is crucial to consider the specifications of given affected region or country according to the socio-economic development context as well as the cultural and institutional aspects of daily life and also, to consider respective statistical data available [2].

Concerning the societal vulnerability caused by leakage of dangerous substance indicators should include such aspects as:

- total traffic intensity;
the range and number of transports of dangerous goods;
the characteristics of transported dangerous goods;
parameters and technical condition of the roads;
the technical level and capacity of the means of transport;
the quality of the crew of the means of transport;
population density;
weather and climate conditions;
the availability of assistance from the Integrated Rescue Systems units, and others.

Development of indicators for measuring societal vulnerability and the way of calculating the vulnerability index is more detailed described in paper Luskova et al. [6]. The mentioned paper was dealing with societal vulnerability related to impacts of extreme weather events on land transport infrastructure. Concerning the measuring societal vulnerability caused by leakage of a dangerous substance the same approach can be applied but the new and relevant indicators have to be defined.

2.1. Social Risk

Risk in a complex concept is understood as a relationship between the expected loss (damage to health, loss of life, loss of property, etc.) and uncertainty considered losses (usually expressed probability or frequency) occurrence of an unexpected event). Frequencies of occurrence of unexpected events or probability occurrence events are very small numbers and are usually in the form of $10^{-x}$. This form also indicates the measure or the acceptability / risk acceptability criterion.

Assessed social risk represents the possibility of fatal injury population at an emergency event. It is very difficult to set criteria acceptability for social risk. Conventions are usually accepted in Europe drawn up in the Netherlands. The criterions, used to accept social risk, are illustrated in the image (see Fig. 1). For acceptability social risks are, besides the frequency, the potential loss to human lives.

The social risk for 1 fatal case is considered acceptable at the time frequency $10^{-5}$, with an increasing number of fatal cases acceptable frequency decreases. Unacceptable social risk is characterized by a frequency of $10^{-3}$ at 1 fatal case, with an increasing number of fatal cases an unacceptable frequency again decreases. The band between the acceptability limit and the unacceptable risk is indicated as a band in which risk is required to reduce to an acceptable limit.

2.2. Resilience

Resilience describes the capacities of societies, communities and individuals or a social-ecological system to deal with adverse consequences and the impacts of hazard events [3].

Like vulnerability, multiple definitions of resilience exist within the literature, with no broadly accepted single definition. In the research domain of the global environmental change community, resilience in socio-ecological systems is defined as a system's capacity to absorb disturbance and re-organize into a fully functioning system. It includes not only a system's capacity to return to the state that existed before the disturbance, but also to advance the
state through learning and adaptation [8].

Despite a wide range of discussions concerning the relationship between vulnerability, adaptive capacity and resilience in recent literatures, a clear understanding is still rare. In our approach for measuring societal vulnerability we understand resilience as integral part of adaptive capacity.

3. Emergency Events for Transport of Dangerous Goods in Road Transport

Long-term statistics from different countries agree that the most common cause of traffic accidents is man in approximately 85% of cases, traffic is the primary cause in 10% of cases, and the means of transport is the source of accidents for about 5% of cases. There are many factors involved in the occurrence of accidents at the same time [9]. Despite the fact that safety issues and compliance with the standards, rules and regulations for the transport of dangerous substances in road transport are handled by the authorities, carriers and drivers, we are occasionally informed of accidents involving the escape of dangerous substances. Luckily, none of these accidents have passed into a disaster of catastrophic proportions, which would endanger the lives and health of the population, infect large areas of land, water with toxic substances that act on the environment for a long period of time.

An example may be a recent tragic accident on the D1 motorway in the Slovak Republic, where a 33-year-old driver died (Fig. 2). The driver, for not identified reasons, went out of the way to the field, where he overturned the fully loaded tanker (30 000 liters of fuels). Transport on the D1 motorway at the place where a tragic accident occurred was diverted for safety reasons because there was a risk of explosion.

After almost four hours the tractor with an empty tank arrived. However, firefighters failed to pump gasoline from the crash tank by a traditional method, so inter-state assistance was requested from Czech firefighters who, using the special Coldcut Cobra technique, tried to cut off the holes in the tank and dispose of gasoline.

![Fig. 2 Tank accident on D1 [10]](image)

3.1. Determination of Social Risk

Transport routes are mostly run by industrial agglomerations, and storage and spending facilities are located in areas densely populated by the population and therefore there is a risk of threatening the population with dangerous substances at the onset of an emergency event. The largest percentages of dangerous substances transported by road are flammable liquid substances – fuels [11]. Our aim is to determine the number of people at risk in the event that such an above mentioned accident occurs in a densely populated area or in a city.

In the order to assessing the social vulnerability it was necessary to carry out a determination of social risk in dangerous substances transport. The social risk determination was carried out according to the recommended risk assessment of transport activities described in the second part of the publication "Purple Book"[12].

For the calculation of social risk is important to assess the presence of the population. The presence of population changes over 24 hours is different in day and night time [13]. In the case study is considered daytime. In the calculation social risk is assumed that part of the population is indoors. For that reason methodology Purple book provides share of the population residing inside $f_{pop,\text{in}}$ and around buildings $f_{pop,\text{out}}$. The basic values of these parameters are given in Table 1. Values are valid for residential and industrial areas, unless other information is available.
Table 1

<table>
<thead>
<tr>
<th>Time</th>
<th>( f_{\text{pop, in}} )</th>
<th>( f_{\text{pop, out}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day time</td>
<td>0.93</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Modelling releases and consequences of accident scenario showed that in the case of atmosphere stability class F fatal impact on the population in case of fire around 66 m from the site of spill, which represents a 1.4 ha area [14]. In the estimated population density of 160 people / ha (according to the Decree n. 489/2002 as amended) the number of persons affected area of approximately (1.4 ha x 160 people / ha) 224 people. In case of fire, it is assumed that people inside the building are protected from heat radiation. Mortal threat of people is expected around 66 meters from the site of the fire, which represents the number of people outside the building, see Table 2. Number mortally injured during the day by gasoline fire was set for 16 people.

Table 2

<table>
<thead>
<tr>
<th>Accident scenario</th>
<th>The number of people inside buildings</th>
<th>The number of people outside buildings</th>
<th>In total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire (day time)</td>
<td>208.32</td>
<td>15.68</td>
<td>224</td>
</tr>
</tbody>
</table>

Social risk for selected accident scenario has been determined from the matrix probability and impact (Fig. 1). For assessing activity were determined a pair of numbers - the total frequency of accident scenario and the number of fatalities. The overall frequency of the modelled accident scenario (leakage of fuel and its subsequent fire) was calculated
\[ Fo = 3.24 \times 10^8 \text{ vehicles} \] Social risk for the population was estimated by combining the two values. From the matrix acceptability of risks is clear that the risk to the population in the event of an accident, which resulted in leakage and subsequent fire spilled fuel, was evaluated in an acceptable risk.

4. Conclusions

The transport of dangerous goods on the roads has become an integral part of everyday life, it is therefore necessary to pay increased attention to the issue of its safety. Based on the results of determination social risk analysis we can state that, in case of leakage and subsequent explosion and fire of transported dangerous substances (in our case fuel) there is a possibility of threatening the nearest population that is located in residential buildings around the road.

In assessing the interrelationship between the state of road traffic that need to be transported, the technical condition of the means of transport, climatic conditions and the assessment of the reliability of the human factor and other factors it can be stated that not all conditions for achieving safe transport of fuels are further improved. By complying with technical standards and applying new research results, the technical condition and equipment of the means of transport improves, which corresponds to the readiness of their crews, especially in international transport.

Acknowledgements

This work has been supported by VEGA grant No. 1/0240/15 named „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”.

References


Crisis Management in the Railway Transport and their Additions

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Abstract

Directive 2004/49/EC of the European Parliament and of the Council about on safety on the Community's railways so-called Railway safety directive on the basement of the directive and national Czech laws in is used in the Czech Republic the System for security (SESY). Every train operating company (TOC) must create the plan for the crisis situation in accordance with the SESY. Every plan creates by the TOC’s must be regularly checked and updated by the possible threat. The SESY brings indicators, methods, goals and the ability to proactive approach to the risks elimination and protection. From the crisis management point of view the SESY brush with intervention plans, warning branch and information plans for the event of an emergency. Theses plans are agreed between authority and TOC. The regular plan check is necessary for the crisis situations and for the searching of weak points of planning. The plan check is realized like training with other subjects, too. For the plan sustain plans actual is necessary the proactive indicators and checking mechanism in the railway transport system.

In the railway transport system is necessary to use the reactive and proactive approach in the SESY. The using of proactive methods, guides and monitoring systems, control and communication mechanisms can be improved thank to the crisis management additions.

KEY WORDS: Crisis management, proactive approach, business continuity management system

1. Introduction

Crisis management in the railway transport was characteristic with a reactive approach. A reactive approach means, that if the crisis situation occurred, the SESY guidelines was very effective for impact reduction. The specific of reactive approach is solves problems when they happen and the main attention in regard to the removal of impacts. On the other hand, currently the crisis management in the railway transport take into account the prevention of crisis and it is the proactive approach. The proactive approach in the long-time horizon offers a wide flow of specialized expertise that respects broad contexts and views. Thanks to the focusing on risks and vulnerability, and through the multi-risk scenarios in a dynamic design, crisis management can be more effective. By the [1] proactive approach in the crisis management is based on the prevention and on the early detection of the initial signs of the problem. This approach in the crisis management is based on the prevention and early detection of the initial signs of the problem. Last but not least the problem solution during the crisis is an initial part, too. The proactive approach generally reduces the time to identify the problem and significantly increases the practical effectiveness of crisis management.

In the current crisis management are various tools (additions) for better opportunities for improvement SESY. Very useful addition for railway undertakings is the business continuity management system (BCMS). BCMS is a mean for applying the proactive approach, too. BCMS increases the company resilience against disruption, interruption, or loss of ability to meet its strategic goals. In the proactive approach is applicable predictive diagnostic. The predictive diagnostic is another addition to the process of crisis management in the railway transport. If BCMS and predictive diagnostic merge, new tool for the diagnostic of railway transport resilience will be created [1-3].

2. Crisis Management in the Railway Transport

Rail transport is a coherent system of activities. The principal role of the performer in rail transport activities is represented by infrastructure managers; TOC’s and rail administrative authorities (RAA). In the paper, these subject will be called like railway entities. Individual activities in the railway transport seem to be outlying. However, the opposite is true. The activities fulfilled by railway entities are linked, moreover, the activities are blend together. This is also related to the co-operation of the individual railway entities in the activities. Infrastructure manager tries to improve railway infrastructure. Usually (in the Czech Republic and in another European Countries) the infrastructure manager create the timetables and control the railway traffic. TOC provides services related to train running (provide transport services to passengers and freight transport customers). RAA is national supervision in the field of railways and building regulations. RAA also assess the extraordinary events and investigate the extraordinary events. Last but not least RAA approve the type of technical device and approve the personal competence.
Function of important processes in the railway transport system is necessary. These processes are linked and blend together. Every change in the system is transferred further.

Due to interdependence was creating the Commission Implementing Regulation (EU) no. 402/2013 on the common safety method for risk evaluation and assessment. The regulation no. 402/2013 solved procedures for the occurrence of incidents on the railways and the assessment of changes in the railway system in terms of safety risks.

For solving the different types of crisis situations and extraordinary events, the TOC’s in the Czech Republic are created and permanently updated the crisis plans. These crisis plans are created for readiness on the crisis situation, too. Current crisis management in the railway transport branch is part of management and it is responsible for the tasks:

- In the normal situations (normal train operations and standard traffic situation) ensures through the Security Council actions in for prevention of crisis situations;
- During the crisis situation monitored the situation through the security council and assesses the situation in its field of competence, cooperates with crisis management units of local authorities in the implementation of emergency measures, manage the elimination of the consequences of the crisis situation and restore traffic and the operability of the railway infrastructure;
- After crisis situation ensures inspections of objects and equipment that manages and evaluates damage on their property.

3. BCMS Like an Addition in the Crisis Management

The integral part of proactive crisis management must be continuity management process. The continuity management process represents readiness for the unexpected events with the negative impact on the railway transport branch. BCMS systematic approach is a way to start the continuity management process. In this case, BCMS is a set of organizational, personal, material, technical, financial and other measures to provide the necessary resources for the implementation and strengthening processes during extraordinary and crisis situations.

For ensuring the continuity is necessary various resources (technical equipment, humans, etc.) and measures (systematic planning documents, procedure plans, etc.). The BCMS elements are a set of measures, steps, procedures or resources which secure resources and faces to the higher resilience of activities.

BCMS solve the human activity, as well. The BCMS is a soft system (human activities) with elements related to hard systems.

Soft systems are more compatible with fuzzy structure systems and with systems of uncertainty and risk. The important aspect is system development over time (dynamic system). Dynamic system can be very difficult defined. In the BCMS for railway system are the coexistence of values inaccuracy, the uncertainty of attributes ability and the unpredictability of processes.

The problematic situation in the railway transport system can be shown on the Rich Picture. The rich picture is a complex situation capture with main tasks and problematic situation. The rich picture is figured on the Fig. 1 BCMS Rich Picture.

The problem in the continuity of activities ensuring on the railways is the interruption of the train operation. The interruption of train operation can be caused by several caused. The reason may be to stop the activity which is directly before the investigated activity or resources do not provide what is required for the activity. Fig. Fig. 1 illustrates the problem of interruption of activity. Some sources of activity are in the object, some of them are in the neighbor of the object. Fig. Fig. 1 also shows links. Links to sources from the neighbor are one-way because the system is not set to transform resources which are out of the system.

1.1.14

Fig. 1 BCMS Rich Picture
Links in the system are two-way due to mutually interaction. Main sources for continuity of activities are “means” (hardware, buildings, workplaces, energy, etc.). On the figuration, these means are marked with a light and dark green color. Humans out of the systems are marked with blue color and processes are marked with yellow and brown. The figure shows the senior manager and person who proceed documents because it is a system with desirable behavior. The system is controlled by a senior manager [4].

For creating BCMS are important 4 basic processes. The results from these processes are transformed outputs meeting the BCMS requirements and expectations from the surrounding area. It is PDCA (plan do check act). In the first step is determined politics, goals, tasks, measures, process and procedures of continuity. In the next step, every point which arises in the first step is implemented by the strategic business goals. The system is monitored and tested in the third step. In the third step are provided outputs. The last step, based on the results of the third process, can accept any change, update, or confirm the processes in the first document process as a correct. The system structure is on the Fig. 2 [5-6].

![Fig. 2 Continuity of activity system - structure](image)

In the process of the BCMS goal must be constantly monitored. Continuity of object is characterized by the transition from one state to another when there is no significant conflict in the change. That continuity of object is a BCMS goal. The BCMS must help ensure the level of criticality in the operations at an acceptable level. This level of criticality should not be exceeded in the normal situation and in the crisis situations, too [1, 6-8].

4. Prediction Diagnostic

Prediction diagnostic is a tool, which finds its application especially in reliability and the life cycle of complex systems. Thanks to the prediction diagnostic are possible to estimate crisis or extraordinary situation and do timely warning.

Despite the fast, that prediction diagnostic is a very efficient tool, it has a disadvantage, too. In many real systems, it is not possible to determine the exact values for all incoming parameters and their uncertainty must be taken into account. In the railway transport cannot be possible to determine the all incoming values parameters exactly. If the imputing values have an indefinite character, it is handle to use the theory of fuzzy sets to solve multi-criteria evaluation of such tasks.


Logic works only with two options: Yes or No. In the real world is another option. Tool for closer capturing of reality which makes the solution more precious for the evaluation can be found in fuzzy logic.

In comparison with usual procedures, the fuzzy logic is their sets are variable. The fuzzy logic is able to work with variable intermediate values. The specific of fuzzy logic is a variable set of values.

Although the concepts of Fuzzy logic and Fuzzy set first appeared in 1965, its use in crisis management is not a common issue. The fuzzy means also matte, hazy, vague or undefined. It also corresponds with a problem which is solved in fuzzy theory. It is trying to cover the reality of its inaccuracy and uncertainty [7-8].

The fuzzy set is a set that, in addition to yes or no, allows partial option. It means that the element belongs to a set with a certain degree of belonging (level of affiliation). Its mean, that element belongs to the set with defined level of affiliation. The strict description leads to the reality description only by means of a two-element set \( \{0, 1\} \). If the problem is not possible to define by this two-element set, it splits into smaller sub solutions. Thanks to the dividing problem to the subsolution there is a deviation from reality, which can be called a mistake. With frequent dividing, deviations increase. The phrase above is a principle of incompatibility.
Creating a fuzzy logic system involves three basic steps. The first is a fuzzification. In the fuzzification are real variables converted to a fuzzy value. The second step (fuzzy interference) defines the behavior of the system on the linguistic level. The resolution in the fuzzy interference is a linguistic variable. Defuzzification is the third step. Defuzzification changes the fuzzy interference to the real value [8, 10-11].

4.2. Choice of Criteria

The criteria choices are the most important step for prediction diagnostic. The criteria evaluation could have a different nature. In the crisis management is necessary, distinguish between criteria, whether the parameters exist independently of the evaluator's will. Parameters exist independently on the evaluators will are characteristics, the properties that are created are attributes. The specified set of evaluation criteria should meet certain requirements. Assessment of the set of criteria should allow regard all important (long-term and short-term, positive and negative) impacts. Each criterion must be clearly defined and the way it is measured must be defined, too. Each aspect should enter into the evaluation once, the criteria should not overlap each other.

For evaluation is most important choose the right number of characteristics. Too high number can complicate finding the solution. If there is too little number of characteristic, there is a risk that some important feature will be neglected. It is proper to find a sufficient number of characteristics with sufficient information. The rationality of creating evaluation criteria depends on the knowledge of the assessment object and on the knowledge of their structure and functions. Expert evaluation calculates with a low number of criteria. The low number of criteria is desirable, otherwise, the outcome of the variants is complicated. However, some of the above requirements are contradictory and cannot be met at the same time. Sometimes a compromise is needed [12].

5. BCMS and Prediction Diagnostic

Continuity of activities aims to minimize the reconstruction time in order to avoid the development of a crisis situation. The seriousness of the crisis situation usually exponentially increasing. The seriousness of the crisis situation depends on the interruption time. The continuity of activities can improve the resilience of the railway transport system and effectively overcome potential traffic disruption.

For the effective management of the continuity of processes on the railways, it is necessary to pay attention to the evaluation of the activities in terms of continuity and continuity monitoring. Combining these two additions, it is possible to estimate when and how the crisis situations can occur and to carry out the early warning and the necessary action. In the specific situations, the activity setting can be changed. Thanks to the changes, the problem will be completely or partially eliminated.

Therefore, the combination of predictive diagnostics with BCMS appears to be an extremely effective tool for dealing with crisis situations in the railway transport.

The evaluation of the continuity of activities is a typical task of multicriterial evaluation. The input system values of the continuity of activities are indefinite. For the following solution can be used the theory of fuzzy sets. The first, in evaluating, must be specifying the basic system problem. The basic problem of continuity is a specific event. It is such an extraordinary event with a limitation of resources or other activities. Such an episode can be called an event of discontinuity. In the continuity of activities in crisis situations is necessary to find a way of buffer of activities otherwise boost activities that will allow the continuation of transport and can solve the crisis situation. The core of the problem is finding the point for sustain the original activities in the railway transport on the necessary level.

The level of continuity of activity depends on:
- how much can be realized in extraordinary events or crisis situations;
- how long the desired activity mustn’t be realized without another impact;
- how many activities are linked with the activity;
- it is possible activity replaced by another worker or on another workplace.

The six basic criteria for assessing the continuity of activities corresponding to the previous questions. In the Table 1 are individual criteria for evaluation [12].

<table>
<thead>
<tr>
<th>Criterion name</th>
<th>label</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fulfillment of Activity</td>
<td>p</td>
</tr>
<tr>
<td>Continuity of Activity</td>
<td>k</td>
</tr>
<tr>
<td>Interconnectivity of Activity</td>
<td>v</td>
</tr>
<tr>
<td>Reachability of Activity</td>
<td>d</td>
</tr>
<tr>
<td>Difficulty of Activity</td>
<td>n</td>
</tr>
<tr>
<td>Vulnerability of Activity</td>
<td>z</td>
</tr>
</tbody>
</table>
5.1. Interpretation of Individual Parameters

Fulfillment of an activity $p$ is the parameter that evaluates the overall use of the activity in any situation, both in the normal state and in crisis situations. The value of the Fulfillment of an Activity $p$ can indicate that the activity is suitable only for a normal situation, a normal day-to-day regime without the possibility of its use in emergency situations or crisis situations. Under normal circumstances, all activities are valued equally because they meet the essential requirements for the outcome of the activity resulting from the expected benefit of performing the activity. In crisis situations, this standard expected performance requires more effort which is positively related to increasing intensity of the crisis. The value of this criterion of given activity is directly linked to individual crisis situations. For the actual evaluation of the value of the continuity of activities, a direct link to non-military crisis situations has been used.

The continuity of activity $k$ is the very essence of continuity of activity, the basic observed parameter. It is assessed by the time lag between the termination of the activity and the renewal of the performance without any subsequent problems.

The interconnectedness of the activity $v$ indicates a number of previous and subsequent activities in general. For this evaluation, only a two-member causal chain was used in the sense of the cause (the activity under consideration) and the consequence (the number of follow-up activities per activity evaluated). The resulting value $v$ can then be determined by the relationship:

\[ v = v_p + v_0 \]

In the formula, $v_p$ stands for Interconnectivity, which tells about intra-company synergies, and it is the number of links of individual activities to other activities in the department, in the unit or in the enterprise. The second part in the formula $v_0$ stands for External Link, which is the number the activity is connected to the surroundings outside of the enterprise.

The reachability of activity $d$ is understood here as the representation of a worker who normally carries out the work by a worker from another, from another department, section, enterprise or outside the enterprise. In other words, it is about the substitution or substitutability for the worker who performs the activity and which, in the event of an emergency, would not be able to perform the activity himself. The term “reachability” was chosen from the point of view of its letter $d$ because letters $z$ and $n$ are already used for following parameters. In the short term, the job performed by one worker can be divided among other workers who perform the same work in parallel workplaces. In the long-term absence, workers cannot be overloaded, as their fatigue would negatively influence their job performance. Therefore, it is also possible to consider the possibility of substitution of a worker who has been absent for a long time with a worker from a different workplace who would be able to perform the activity after a short period of training. In the partial evaluation of Reachability of Activity $d$, the required quality of representation can be expressed by the weight of the criterion, depending on whether a worker from the workplace is required (by increasing the weight of the criterion) or whether the worker can work from external sources (by reducing the weight of the criterion).

Criterion the Difficulty of activity $n$ is characterized for this purpose as the number of workers involved for achieving this activity. If the number of people performing the activity is dropped consequently the performance is reduced and the desired result is not achieved. The value of this parameter can be extended by the financial cost, possibly space requirements for its implementation.

Due to the difficulty in obtaining the financial cost data and the space requirement for its implementation, the third feature was used – the number of workers who carry out the activity.

The Vulnerability parameter is $z$ is reduced by rules, steps, or procedures. Measures to eliminate risks can only be partial or complex, depending on the degree of practice and their form.

5.2. Relation Between Criteria

The relationship between the criteria is also important for evaluation. It is also important to find the possible interdependencies or similarities between the various aspects of the assessment.

The basic concept for examining the relationship between two characters is their independence. The two criteria are independent if the assessment of the first one does not depend on the value achieved by the latter.

There is interconnection between the Activity $p$ and the Continuity of activities $k$. It has its justification both in its normal state in terms of meeting its expected benefit and speed and the need for its use. If the activity is fulfilled even in crisis situations when the time demands for the activity are usually increased, then the period of possible interruption of the given activity should be one day at the most, in order to avoid the risk of delay.

Therefore, if the p performance of the p activity is highly valued, there should not be too long interruptions, so the value of Continuity of activities $k$ should be also high. Otherwise, there is a logical disproportion.

Indirectly there is also relation between the parameters of the activity Interconnectivity $v$ the Fulfillment activity $p$. The low value of the activity $p$ leads to the assumption of the low connectivity to the surrounding activities, in other words, the greater the demand for performing the activity, the more other activities require such an activity and the more requirements for the results of given activity. It is not a direct link with any exceptions, however, the general trend the connection is significant. Therefore, it can be generally assumed that the higher the value of the Fulfillment activity...
p higher the Interconnectivity activity v.

The Reachability activity d has a direct link to the Fulfillment Activity p, therefore, the activity p can be maintained in the long-term even in crisis situations. There is also another parameter for the need for the performance of the activity. If the activity is not sustained and continuously claimed, the activity is less necessary and for this reason, it is not necessary to provide substitution.

There was no immediate link between the Fulfillment Activity p and the Difficulty Activity n. Both parameters are independent of each other. However, if the number of workers carrying out the activity in normal condition is reduced to a smaller number of workers in a crisis situation, the difficulty in performing the activity will consequently increase.

If the Vulnerability of the activity z is defined as the resulting effect of the threat elimination procedures, it is quite obvious that there is no bond or relationship to the p performance of the activity.

The continuity of activity k influences the relevance of activity v and vice versa. An activity that has several previous and sequential activities is clearly more required and has a higher requirement for continuity of activities k. The more people participate in the performance, the more difficult is to achieve the imperceptibility of such activity. Changes in the performance of the original activity can happen if the conditions change. The severity of activity n is therefore indirectly dependent on Continuity of activity k.

Indirect dependence is also between the Vulnerability of Activities z and the Continuity of Activities k, because the more the risk is eliminated, the less the activity is interrupted. It is an indirect dependence.

The vulnerability activity z does not have direct effect on the Difficulty activity n. In the case that the substitution is full within required scope, it will fulfill given activity and thus there is no direct link between the parameters of Reachability activity d and the Vulnerability activity z. Table 2 shows the relationships between the criteria.

<table>
<thead>
<tr>
<th></th>
<th>p</th>
<th>k</th>
<th>v</th>
<th>d</th>
<th>n</th>
<th>z</th>
</tr>
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<tbody>
<tr>
<td>p</td>
<td>-</td>
<td>Direct</td>
<td>Direct</td>
<td>Direct</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>k</td>
<td>Direct</td>
<td>-</td>
<td>Direct</td>
<td>Direct</td>
<td>Indirect</td>
<td>Indirect</td>
</tr>
<tr>
<td>v</td>
<td>Direct</td>
<td>Direct</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>d</td>
<td>Direct</td>
<td>Direct</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>n</td>
<td>-</td>
<td>Indirect</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>z</td>
<td>-</td>
<td>Indirect</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

The partial value of the continuity activity can be noted as h and its magnitude is determined by the dependency of the observed continuity criteria.

For expert evaluation of continuity of activity is proper to create own calculation tool. The calculation tool can be created in the Microsoft Excel [12].

6. Conclusion

In the continuity of activities is necessary to find way to boost activities which allow maintaining the train running, on the other hand, reduce activities that make the crisis situation more serious. The necessary is allowing the continuity of transport and solving the crisis situation. The core of the problem is finding the point for sustain the original activities in the railway transport on the necessary level. BCMS should be monitored regularly.

Finally, authors must note that important additions for better use of all possibilities of crisis management in the railway transport are blending of the traditional reactive and new proactive approach. Despite the fact, that unlike reactive approaches, the proactive can be applied even before an accident occurs. Experiences of reactive approaches are necessary to ensure the continuity of crisis management in the railway transport.

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The Model of Flying Objects in the Relative Navigation System

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Abstract

In the contribution, we present a model of motion of five flying objects that we will use when examining the accuracy of a relative navigation system in the air communications network. The design of the simulation model is based on a mathematical description of the motion of a flying object in a geocentric coordinate system (ECEF - Earth - Centered, Earth - Fixed). We have chosen the trajectory of flying objects, which consists of a straight section and two turns. We describe the process of transforming the coordinates of the local motion of the flying object into a geocentric coordinate system in the topocentric coordinate system. The computer simulation was performed in the Matlab programming environment.

KEY WORDS: modeling, simulation, a flying object, relative navigation

1. Introduction

The movement modelling of flying objects serves for gaining information about the geocentric position of users in space[1, 2, 6]. The results presented in this study have been obtained on the basis of mathematical modelling and computer simulation of the relative navigation system performed in the Matlab programming environment. The aim of the research was to evaluate the accuracy of flying objects (FO) positioned in the relative navigation system (RelNav) using the algorithms created. The first part of the research has been devoted to the general model of the flying object movement. We determined the initial coordinates of the FO from the real flight situation from flightradar24. We have created a general model of an aircraft movement trajectory which consists of direct flight and two turns. The advantage of this model is that it is flexible and can be modified. It can be used to model the movements of any FO located on the Earth, i.e., its initial coordinates are associated with the WGS-84 in the geodetic coordinate system [4, 5]. This model was subsequently used to create FO trajectories that work in the relative navigation system. Our goal is to model the motion of five FOs and then to visualize them in a three-dimensional visual display of the ECEF co-ordinate system.

2. Coordinate Systems Used in FO Motion Modelling

2.1. ECEF Geocentric Coordinate System

It is a three-dimensional coordinate system with a centre in the centre of the Earth. The X axis of the system passes through the intersection of the zero meridian and the equator, the Y axis is pointing from west to east, the Z axis is having the north-south direction. It is a rectangular coordinate system and is shown in Fig. 1

Fig. 1 ECEF Geocentric Coordinate System [8]
2.2. Geodetic Coordinate System

The local model of FO motion is necessary to transfer to the geodetic coordinate system. The Geodetic Coordinate System (LLH) is shown in Fig. 2 and used in aviation in the processing of data in the autonomous navigation, in radio air navigation devices and the like. The geodetic coordinate system determines the position of the point on the surface of the ellipsoid. The latitude \( \varphi \), the longitude \( \lambda \) and the ellipsoidal height \( h \) are coordinates. The difference between the ellipsoidal height \( h \) and the normal height \( H \) is the so-called height anomaly for which: \( \zeta = h - H \), where: \( H \) - altitude, \( \zeta \) - height of geoid, or Quasigeoid.

![Fig. 2 Geodetic coordinate system [3]](image)

2.3. Local Topocentric Coordinate System ENU

ENU is the local topocentric coordinate system with the origin of the coordinate system at the reference point. The U axis passes through the topocentre and the E and N axes are perpendicular to the U-axis, with the E-axis pointing east and the N-axis pointing northwards. Both coordinate systems are shown in Fig. 3. Input and output co-ordinates are reported in meters relative to the origin of the coordinate system.

![Fig. 3 Geodetic and local topocentric coordinate system [8]](image)

3. General Model of FO Motion

The model of FO motion is designed to verify the principle of a relative navigation system operating on the air communications network. The model of FO motion serves to gain information about their geocentric location in space. We have abstracted from the forces acting on FOs during the flight. For the purpose of simulating the relative navigation system, we may consider this fact irrelevant. To clarify the principle of the model of FO motion, we chose the real point according to flightradar24, in which we place the FO and simulate its further movement. As initial co-ordinates (starting point) LO, we have chosen real FO coordinates, i.e., FO No.1 with coordinates: latitude 0.84672193 rad, longitude 0.38293172 rad and altitude 10628 m. These coordinates are considered to be reference. In Table 1 shows the aforementioned coordinates of the reference point.
Table 1

<table>
<thead>
<tr>
<th>Identification</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Height above ellipsoid (m)</th>
<th>Altitude (m)</th>
<th>Geoid curl (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFL1846</td>
<td>48,538</td>
<td>21,9515</td>
<td>10668</td>
<td>10628</td>
<td>40</td>
</tr>
</tbody>
</table>

In modelling FO trajectories, each part of its trajectory is modelled in the local (Figure 3) of the ENU topocentric coordinate system. The FO trajectory is composed of a direct flight and two turns. Based on this, it will be possible to evaluate the accuracy of FO position determination in the relative navigation system not only in the level flight, but also in FO manoeuvres. Trajectory model input parameters that can be changed according to current requirements are:
- the initial position of the FO;
- the duration of the level flight or in turns;
- trajectory of motion;
- radius of curvature.

The first phase of the FO motion, straight and level flight, is 2600 s at an altitude of 9628 m. Altitude of flight does not change. We chose the initial coordinates for local movement as follows: $x = 570$ m, $y = 250$ m, $z = 9628$ m. For the first phase of FO flight (straight movement):

\[
t = 1:2300 \\
x(t) = 570 + t \\
y(t) = 250 + t \\
z(t) = 9628 \\
\text{end;}
\]

(1)

The second phase of FO flight - the turn to the left is 150 s at an altitude of 9628 m. For the second phase of FO flight:

\[
i = 1:150; \\
x(t+i) = x((t+i)-1)+1.9 \cdot \cos(ink(i)+beta); \\
y(t+i) = y((t+i)-1)+1.7 \cdot \sin(ink(i)+beta); \\
z(t+i) = 9628.
\]

(2) (3) (4)

The third phase of the FO flight – right turn is 150 s at an altitude of 9628 m. For the third phase of FO flight:

\[
k = 1:150; \\
x(k+t+i) = x((k+t+i)-1)-(2 \cdot r) \cdot \cos(ink(k)+beta); \\
y(k+t+i) = y((k+t+i)-1)-(2 \cdot r) \cdot \sin(ink(k)+beta); \\
z(k+t+i) = 9628;
\]

(5) (6) (7)

end,

where $x$, $y$, $z$ - coordinates for FO motion; $t$, $i$, $k$- counter of repetitions; $ink$ - step vector to generate movements of the same length; $beta$ - angular increment; $r$ – radius.

3.1. Transformations of Coordinates

In the transformation of coordinates, it is necessary to be aware of the kinds of heights we will be working with. Transformation coordinate functions work with ellipsoidal heights. In practice, however, the altitudes $H$ (Fig. 2) that apply to the geoid are used. Geoid is difficult to define mathematically, so the so-called ,Quasigeoid is used. It is a
mathematically definable area and refers to so-called normal height. Our task is to show the model of FO motion in the geocentric coordinate system. However, the start point coordinates are assigned according to the flightradar24 in the geographical coordinates and the model created represents the FO flight in the local coordinate system. Therefore, we must make the corresponding transformations of these coordinates. The process of transforming the co-ordinates of the resulting FO motion with the start in the given initial coordinates in the LLH system to the ECEF is divided into the following steps:

- Transformation of geodetic starting point coordinates into the ECEF system.
- Transformation of the coordinates of the local movement model into the ECEF system.
- Linking of the created FO local motion model to the starting point.
- Transformation of the resulting model of FO motion into geodetic coordinates.
- Transform the resulting model of FO motion back into the ECEF for the purposes of our task.

For each transformation of coordinates we have used the following Matlab functions:

- Function to transform initial co-ordinates from LLH to ECEF: `llh2xyz`

The function serves to convert the geographical coordinates (latitude, longitude and altitude in WGS-84) into the rectangular geocentric coordinates X, Y, Z in meters. The latitude and longitude are given in radians and the ellipsoidal height in meters is given.

- Function for transformation of local motion coordinates from ENU to ECEF: `enu2xyz`;
- The function for transforming the coordinates of the resulting model of FO motion from ECEF to LLH: `xyz2llh`.

Using this transformation, we can determine the FO position on the map, because the coordinates of the latitude, radius of the radii, and the ellipsoidal FO height in meters relative to the WGS-84 reference system are the outputs. The task solution is to determine and display the FO position in the ECEF rectangular coordinate system with the center at the Earth's ground. Therefore, it is necessary to transform the coordinates of the resulting model of FO motion into the Earth system again using the `llh2xyz` function \((lat, long, h)\). After performing individual transformations, we can visualize the model of FO motion in the ECEF system. The FO position will be determined in each second by the coordinates \(x, y, z\) in meters. In accordance with algorithms 1 through 9, we have simulated FO trajectory. Initial flight conditions are specified in table No. 1. The FO motion trajectory is shown in Fig. 4.

![Simulated trajectory of motion](image)

**Fig. 4 Trajectory of FO motion in three-dimensional space**

The relative navigation system is able to evaluate the position of the FO in the air communications network in case it receives data from at least four other users. To simulate the RelNav system, we therefore created five models of FO motion. We have chosen an airspace that is analogous to actual flightradar24 traffic. Flightradar24 is a flight tracking service that provides real-time information about thousands of aircraft worldwide [7]. Based on observations of the movement of aircraft over the territory of the Slovak Republic 15.03.2018 12:30 pm, we accidentally picked up 5 planes and found their coordinates at a given time. We will consider these data as the initial coordinates for FO flight simulation. Because the data come from GPS, they are determined by latitude and longitude according to WGS-84. Fig. 5 shows a random selection of five FOs with a known position. Table 2 shows the information about their starting position.
In accordance with algorithms 1 through 9, we have simulated the trajectory of five FOs. Initial flight conditions are specified in Table 2. Initial co-ordinates of the FO flight simulation model 1 to 5 in the ENU system are shown in Table 3. Trajectories of motion of five FOs are shown in Fig. 6.

**Table 2**

<table>
<thead>
<tr>
<th>S.n.</th>
<th>Identification</th>
<th>Latitude (°)</th>
<th>Latitude (rad)</th>
<th>Longitude (°)</th>
<th>Longtitude (rad)</th>
<th>Height above ellipsoid (m)</th>
</tr>
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<td>21,9515</td>
<td>0.38293172</td>
<td>10668</td>
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<tr>
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<tr>
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</tbody>
</table>

From the simulation results shown in Table 3, it is clear that the algorithms used for FO flight trajectory modelling are functional and allow modelling of not only straight flights but also the FO manoeuvres.
4. Conclusion

The results presented in the article were obtained by examining a relative navigation system that operates in the air communications network. To solve this problem, we modelled and simulated the operation of such a system under conditions that are close to real. Such a system includes individual users who are flying objects. That is why we have come up with the FO trajectory models that are part of the relative navigation system. Our goal was to create FO models that would respond to real conditions as much as possible. Based on this fact, we chose a flight trajectory for modelling, which consists of a straight flight and two turns. We also originated from the assumption that FO will work in a communications network when creating FO flight trajectory models. We have created this network from five FOs, one of which will determine its location based on its distance measurement to the other four FOs by assuming that the coordinates of the other four users are known. Therefore, it was necessary to create five FO models that are part of the relative navigation system. The result of modelling is a total of five models describing FO motion in a geocentric coordinate system.

The models of FO motion represent input data for computer simulation. For the simulation to be as accurate as possible, we have performed air traffic observation over the territory of the Slovak Republic via the Flightradar24 application. We randomly selected five FOs whose geographic coordinates and altitudes have been implemented in our model. For the purpose of solving the problem, it was necessary to transform their coordinates into a geocentric coordinate system. The results of modelling and simulation of five FO flights are shown in Fig. 6. The simulation results have confirmed that the models created sufficiently accurately describe FO flights in real-world conditions. Modelling trajectories consist of straight sections and two turns. The generated simulation models can be used for further research and development of communication, navigation, or anti-collision systems, based on the principle of data exchange among users working in the air communications network.

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Assessing Accuracy of Piloting as Pilot Performance Indicator in Training

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Abstract

Aviation safety is an important element of the entire transport system. Safety depends on many factors, but according to various international studies it is most affected by the human factor. There are various factors influencing the pilot during a flight that affect his performance. To ensure a sufficient level of safety in air transport, it is important that pilots are best prepared for the unexpected events they may encounter. This article deals with pilot performance during flight simulation training. In the article, the accuracy of piloting was selected as the performance indicator, which was evaluated on the basis of absolute deviations from the prescribed operations. Based on an assessment of the piloting accuracy of the beginner pilots, effective flight simulation training time was set.

KEY WORDS: pilot training, pilot accuracy, human performance, training efficiency

1. Introduction

Human performance is cited as one of the major factors in most air accidents [2]. In the case of a requirement to reduce aviation accidents, it is necessary to better understand the problem of the human factor and actively apply that knowledge [3, 5]. A proactive approach should be used to understand and evaluate a human factor, and therefore knowledge gained from this area should be used and integrated in the design of new certification systems as well as in the certification of operational staff. The objective of assessing the performance of the human factor is to ensure that systems and people in air transport become functional.

The main causes that lead to a disruption of aviation safety include, in particular, failure to master the piloting technique, the inconsistent performance of mandatory operations or the erroneous assessment of the meteorological situation [8]. Other factors that need to be mentioned include, for example, misallocation of the pilot's attention, which may result in collision with obstacle, such as a power lines [7].

Performance appraisal is based on performance criteria, which are a simple evaluation of the required result, capability and description of the criteria used to assess whether the required performance level has been achieved [6].

2. Pilot Performance in Flight Simulator Training

Pilot sensitivity decreases proportionally with time. The longer the flight is, the pilot at the end of the flight is more exhausted and unable to perceive as intensely as it was when leaving the primary airport (see Fig. 1).

Factors affecting performance in aviation:
- Physical condition and health;
- Time pressure;
Sleep and fatigue;
Work on shifts;
Alcohol and medicines;
Workload [4].

The load in individual occupations in aviation is not the same. Beno, Dzvonik (2009), in his book Human Factors in Aviation, lists nine methods or data that are used to measure the performance of aircraft crew in air transport [1]. We include the following flight data:
1. Altitude;
2. The angle of pitch of the aircraft;
3. The angle of yaw of the aircraft;
4. The angle of roll of the aircraft;
5. Vertical speed;
6. Indicated flight speed;
7. Magnetic course;
8. Deviation from the track;
9. Deviation from the angle of descent[1].

Based on these flight data, we were able to evaluate the performance of five flight parameters, including [1]:
• Standard deviation - the variability around the average value is measured. The smaller the deviation, the better performance.
• Median square error value - used to measure monitored performance. The smaller the number, the better the performance.
• Number of deviations outside the tolerance - describes the occurrence of the deviation of the aircraft from the specified tolerance. The smaller the deviations, the better the performance.
• Time out of tolerance - in this case, the cumulative time that aircraft are spent outside tolerance limits.
• Average tolerance overrun time - this time is calculated from the ratio of the changes between the success of the airplane position points and its position relative to the tolerance.

3. Methods

Based on an analysis of pilots' performance assessments and the impact of the human factor on aviation safety, the following objectives were set: assessment of changes in pilots' performance in training on a flight simulator and to determine the possibilities of using the flight simulator effectively in the training of pilot beginners.

Pilot-students’ performance was evaluated on the basis of pilot precision of pre-selected subjects. The training was conducted on a TDR 40 simulator.

3.1. Methodology of Data Collection and Evaluation

Measurement of performance consisted of a record of the characteristic flight tasks (maneuvers) that pilot-students had to perform. The data collection consisted of recording deviations from the prescribed flight parameters when performing:
• Horizontal Direct Flight (HPL);
• Horizontal turn of 360 degrees (H360) with pitch of 30 degrees;
• Climb and descend turn of 180 degrees (S/K180) with pitch of 15 degrees and vertical speed 500ft/min.

Fig. 2 shows the representation of the training program showing the measured flight hours.

Deviations were recorded by the instructor in the form of maximum deviations from the prescribed flight parameters. Such a concept of data collection was also used in a study [10], where a strong correlation between the error rate assessed by the instructor and the errors calculated from the simulated flight record.

Fig. 2 Representation of the training program showing the measured flight hours

The character of the instructor records can be understood as \( X_{UE} \), where \( X \) is the required value, \( UE \) is the maximum plus error from the required value, and \( LE \) is the maximum minus error from the required value. The total
error $E$ for a specific flight parameter then was $A = U_E - L_E$. Obviously, this is an absolute error.

The data, characterized by error $\Delta$, were separated to the datasets characterizing the accuracy in performing the prescribed flight parameters and the sub-data characterizing the measurements (T2M, T6M, T11M and T16M).

Because on the basis of Kolmogorov-Smirnov test not confirmed the normality of data for subsequent statistical evaluation of data was used nonparametric Wilcoxon test.

4. Evaluation of Piloting Accuracy

The results below are presented in the form of pairs of graphs and tables representing statistical evaluation and error distribution for the observed flight parameter (see Figs. 3-6). The P-values in the presented tables represent the Wilcoxon test results, where $p < 0.05$ shows a statistically significant difference between the two groups of measurements. The graphical representation represents the distribution of the calculated error rate for a given flight parameter in the form of a boxplot.

Fig. 3 Distribution of calculated error for the horizontal turn of 360 degrees – Pitch/Altitude

Fig. 4 Distribution of calculated error for the horizontal direct flight – Altitude/Magnetic Course
5. Conclusions

The development of air transport places emphasis on increasing air traffic safety. The introduction of new technologies also raises the demands on the theoretical and practical skills of aircraft operators, including pilots. Air accident studies are reported that the one of the main causes of the air accidents is human factor.

Nowadays, flight simulators have become an important element in pilot training, which, with the help of computers, creates a virtual illusion of flight. Incorporating flight simulators into pilot training has contributed to reducing risks and improving the quality of training, which further increases overall flight safety and reduces the cost of aircraft training and aircraft maintenance. Allowing flight simulation training can logically make a significant contribution to improving training.

Critical use of aviation simulators, however, represents their integration into the pilot training process, especially when considering the basic pilot license in the form of PPL or ultralight pilot license (ULL) [10]. This type of training
assesses experience, skills and habits of pilot-students [11]. Considering the above, the study dealt with the issue of monitoring flight performance changes in flight simulation training and evaluating the effectiveness of simulator use in training.

Based on the assessment of the accuracy of piloting of respondents in the prescribed actions, it was found that the performance of pilot-students significantly increased, but only to a certain threshold. In the case of this work, this threshold was set for 11 hours of flight simulation training where progress was monitored in keep prescribed flight parameters. Determining the optimal number of flight hours for pilots of small airplane allows for a more efficient use of the flight simulator to increase safety and reduce flight crew errors. The efficiency of simulator use in aviation is directly reflected in the cost of training, as well as in the time-consuming handling of the first part of practical pilot training.

References

Unmanned Aerial Platform Using for Monitoring of Oil Pollution of Sea Aquatorium

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Abstract

The objective is to carry analysis of oil spill monitoring using Unmanned Aerial Platform (UAP). Authors are using analysis of functional requirements for UAP. Recommendations for implementations of UAP with two types of aerial carriers with oil pollution measuring cell and sampling device are proposed in paper. The challenges of oil pollution detecting and monitoring were defined and possible solutions described. Sampling device with oil pollution measuring cell and sampling device were developed for minimizing time of monitoring programme and online transmitting to ground control centre with presentation on electronic chart had proposed.

KEY WORDS: Oil spill, oil spill monitoring, Unmanned Aerial Platform

1. Introduction

Oil pollution of sea aquatorium is very serious problem due to increasing of activities connected to oil production, transportation and increasing intensity of shipping. Only 26 percent’s of oil are directly discharged into the sea. The remaining oil, of the total pollution quantity is discharged from dry cargo vessels (bilge waters, residues of fuels and oils that are accidentally or intentionally discharges into the sea), from natural sources, but most of all oil production enterprises, in particular from companies located on the coast or on the rivers flowing into the sea. The oil pollution monitoring of large marine areas with objective to detect oil pollution of today being carried out using various technical equipment - satellites, seagoing ships and various aircraft. At present, the use of a remote piloted aircraft (RPA), which provide more detailed information for monitoring aquatorium tasks is intensively developed. GPS-guided remote piloted aircrafts (RPAs) have the capacity to obtain very high spatial resolution (<10 cm) imagery of specific landscape features with revisit times determined by the operator as opposed to fixed satellite revisit times [2]. For effective solution of this problem with many factors should be created automated unmanned aerial platform, which will provide online detecting, monitoring dynamic of oil slick and sampling.

2. Functional Requirements for Unmanned Aerial Platform.

The main objective is developing a highly effective system-complex platform for monitoring of oil pollution of sea aquatorium. This approach will provide protection against intentional or accidental oil pollution.

The basic criteria of the requirement to increase the possibility of identifying possible pollution of the water surface with oil pollution is the methodology with using aerial platform equipped with a complex device with several types of sensors and a special device for sampling from the surface of the water.

As a result of the analysis of the identified oil pollution data, the main Unmanned Aerial Platform (UAP) tasks are oil pollution detection, monitoring of dynamyc of oil spill, obtained data transmission and processing. The monitoring of oil pollution includes surveilance of the main parameters of the marine environment and the preparation reports about changes in time.

The UAP concept has to be developed for data collection about water quality, detecting of oil pollution control and liquidation of oil spills. For development of effective loew cost monitoring, it is necessary to establish a special system based on using UAP for monitoring, detecting of oil spills and estimation of sea aquatorium status taking into account ship traffic and technological process in terminals for transportation of oil in ports.

The UAP for oil pollution monitoring program should include the following tasks:
- the possibility of a 24-hour operation of sensors, moreover, the image characteristics must not depend on the time of day;
- possibility of detection regardless of weather conditions;
- performing a determination of the type of polluting product;
- ensuring the monitoring of the distribution dynamics of oil spill;
- sampling with the help with using a specially designed RPA;
- monitoring of large areas of the marine region where illegal pollution is present;
- quantitative estimation of oil pollution according to the parameters obtained with the help of RPA sensors;
- discovering and collecting evidence of oil pollution from ships;
- transmitting of operational information to the responsible services in the event of an oil pollution accident;
regular sampling of background pollution of oil products.

The large number of sources of pollution and refuse of the polluters to provide information creates certain difficulties, for determination volume of oil spills and taking operational measures to eliminate it. The distribution of pollution levels and nature of statistical data is also increasing due to uncertainties in the events of oil spills and illegal discharges.

Due to the UAP for surveillance mission of oil pollution of sea aquatorium must cover coastal areas and districts that are far from the coast, as well as inland waters and ports. Taking into account the monitoring of the marine waters using the platform, which includes RPA, specifics, needs for continuous information and dynamically changing movements of ships, the area of aquatorium should be divided into areas with short and long range Fig. 1. The radius of short range areas is 50-80 kilometres, the radius of the long range areas is 150-200 kilometres.

The dividing of the controlled area into monitoring zones should be done taking into account the RPAs types, which is parts of the UAP, and their technical characteristics.

The implementation of UAP for monitoring of pollution of sea aquatorium will increase reliability, safety and to eliminate the human error factor.

An unmanned aerial carrier with a multifunctional payload will solve the problems of water pollution with oil products and monitoring of contamination. The UAP with an algorithm that includes automatic take of, landing and the flight optimization algorithm for objects, which are divided into groups, depending on the type will allow the display of information on the state of water pollution and the real-time and sampling from the water surface [6]. The main criteria for reliable operation of UAP, taking into account the wide range of monitoring is flight speed and operational range of the RPAs.

For oil pollution monitoring performance, the RPA speed must be in the range from 0 km / h to 180 km / h. According to the analysis of HELCOM statistical data, the largest amount of accidents and unauthorized oil spill occur near the coast. The UAP should be developed on base of fixed wing RPAs and multirotor RPAs. For improvement of effectiveness of remote sensing should be used complex approach which individual RPA monitoring in defined areas and multi agent monitoring. The multi agent monitoring is perspective solution for large areas of sea aquatorium because provide communications between agents. This is very important because distances between RPAs and ground control centre are large. These agents often reside within an agent framework, where they may operate independently on open environments [7]. The implementation of fixed wing RPAs and multirotor RPAs provide opportunity maximally used of strong features of each type. RPAs as part of UAP can use for take off other mobile units such as ships. In addition, the use of opportunities for RPA to take off from ships increases their operational mobility [4]. The UAP should provide tracking of all flight parameters, automatic control system of alarms and transmission of messages for all changes in flight parameters (altitude, flight direction, speed). Careful design of the aircraft trajectory (waypoints, strips, speed, attitude, etc.) and a flexible real-time mission management capacity (sensor configuration, flying directions, etc.) are instrumental in achieving productive and safe acquisition missions [3].

3. Using of UAP for Oil Pollution and Spill Monitoring

Implementation of two types of aerial carriers with unique capabilities and characteristics to monitor water quality and oil pollution will allow simultaneous monitoring of areas with large areas and the taking of samples of water oil pollution in defined areas. For development UAP for marine monitoring missions must take into account, in particular, the following principles: reliability, compliance with maritime observation requirements, simplicity of management and, finally, price [1]. Small RPAs potentially offer a low-cost alternative to conventional remote sensing platforms, and research to date shows promise [5].

First type aerial carrier for monitoring: an airplane type RPA with a multifunctional payload system focused on the maximum range of observations, analysis and transmission of data in all circumstances and in all situations. A payload system that delivers maximum accurate information about water quality, allows you to simultaneously use a VNIR camera, a thermal camera, and a hyperspectral or multispectral camera [4]. The carrier is designed for long-term flying to provide extensive monitoring area coverage, the system provides for unique flight safety systems on the
4. Development of UAP and Devices for Monitoring

Eliminating of deficiencies and compliance with the contemporary requirements for oil pollution monitoring system is possible with development of UAP with devices for detecting, measuring and sampling from surface of water. This solution is complex and allows surveillance and detection of contamination with a view to confirming the results. The use of RPA with fixed wing during monitoring as unit of UAP allows for the visual identification of contaminated areas using payload sensors. For effective monitoring of large areas of sea aquatorium UAP should be equipped with device with oil content measuring sell. The implementation of measuring sell in special device will provide evidence of oil pollution and online transmitting information for multi agents of UAP. In this case second type of aerial carrier will be sent to position where detected oil contamination. This solution allow maximally efficiently using endurance of multi rotor RPA in hovering position regarding requirements of monitoring program. The obtained data, for example, the spots of pollution, must be compared with the parameters of the assessment of water pollution of sea aquatorium. This requires taking a sample from the surface of the water to check the accuracy of the visual observation and measuring cell signal results. Using UAP complexes that include RPA provide possibility practically constantly track the situation on the area.

In order to implement the operational monitoring and prevention program of the existing problems, a method and device for controlling oil pollution of marine waters and internal waters was developed in the research process. The method and the device include the taking samples of water from the surface of the water, preparation for transportation, possible determination of oil pollution by the measuring device, data transmission over the data transmission channel, display of the contaminated area on the electronic map, and delivery of the sample to the specified location using a fixed wing RPA.

![Fig. 2 RPA equipped with a special sampling device with measuring sell](image)

The total payload of a RPA depends on the power it can provide. Consequently, the possibilities for taking oil pollution are limited. Taking into account the requirements for the flight radius, the RPA with fixed wings solves the problem of remote sensing for areas with long distance from coast.

The device schematically displayed on Fig. 2 contains a fixed wing RPA equipped with a special sampling device that is to be executed in the form of a metal holder. A sampling device installed in the RPA hull and a sampler 1 mounted on the holder.
Innovative solutions were used in the development of the sampling device. In order to ensure precision and possible immediate detection of oil pollution, a device with a sensor for detecting pollution in its body was developed. In order to provide high-quality information on the state of water, it is envisaged to take samples on a variety of levels. The construction of the sampling device includes a cylindrical sampler with solenoid valve with spring 2 connected to the rod 3 with sleeve with pistons 5 of sampler’s chamber. In the cylindrical body of sampler, holes were made for receiving water during taking sample. Inside the upper section in the sampler’s in the upper piston photoelectric cell 4 was mounted and in the lower piston lighting led 6. This solution provides for the possibility after sampling make water control over the presence of petroleum products and contamination. A photoelectric cell consisting of a photocell and a diode in case of presence of petroleum products (optical changes are recorded) sends signals to the RPA Electronic Control Module (ECM) and further through using communication system to control centre. The method is implemented as follows. RPA is sent to a oil spill area with known GPS coordinates. After the RPA arriving to the assigned area, the ECM gives the command to open the shutters of compartment of sampling device.

After opening of shutters ECM gives command to rotate the sampler holder in an upright position. RPA is lowering at a height where the probe device touches the surface of the water. When the probe device touches the surface of the water, the ECM gives the solenoid valve a command to open the distributor of the sampling device. The water inlets in the housing of the sampling device. The ECM gives to the solenoid valve a command to close the sampling device. The distributor pistons will make after sampling sealing of sample in sampler. ECM allows the mechanism to rotate the probe holder horizontally. After turning the probe holder back, ECM gives a command to close the shutters of the sampling device compartment. Collection of samples and transportation process is done in automatic mode. The photoelectric cell consisting of a photocell and a diode in the presence of oil products (optical changes are recorded) sends a signal to the RPA ECM and then transmitted through communication system to control centre; simultaneously, the coordinates of the verification point are also transmitted. The information on pollution received is displayed in the electronic cartographic system. In the process of research, a fixed-wing RPA has been developed for the purpose of taking of sample, oil pollution detection, online transmission of information and transport of specimens. Unlike other devices, RPA is equipped with a sampling device that is installed in the RPA hull section with the help of a holder is raised to the working position. In order to ensure the legal requirements for the sampling procedure, a container with a cylindrical sampling device, consisting of 2 sections with openings and a distributor with a plunger inside, a solenoid valve, which opens the distributor of the sampling device and, after the assembling of the container, is carried out the container sealing. Measuring cell in a container in case of oil pollution detection, sends a signal to the ECM and transmits information about pollution with a presentation on the electronic cartographic system. This technical device ensures long-distance oil pollution monitoring.

5. Conclusions

This paper is aimed to analyse possibilities of implementation of UAP for solving existing problem of detecting and monitoring of oil spills. Functional requirements for UAP using for oil pollution monitoring program were overviewed. Recommendations for implementations of UAP with two types of aerial carriers with oil pollution measuring cell and sampling device were offered. Using UAP based on two types of aerial carriers fixed wing and multirotor improve efficiency of performing of designed tasks. Using UAP with aerial carriers equipped with oil pollution measuring cell and sampling device provides on line transmitting of result to ground control station with presentation of results on electronic chart. The automated control system will provide on base of online information effective use of each type of aerial carrier and eliminate deficiencies of existing remote sensing methods.

References

Virtual Reality in Aviation Training

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1. Introduction

The purpose of this article is to present the meaning of virtual reality in civil aviation, in particular its beneficial impact on the environment and the ever-increasing influence on training strategies. VR is an interactive virtual reality environment created to train professionals in a safe and engaging virtual space. 3D solutions for virtual reality training are specially designed to meet the needs of training in various cases, specific to professional training. The system provides basic information helpful in making decisions in the aviation industry and the academic environment. The article uses empirical methods to demonstrate the effectiveness of training using VR tools in comparison with traditional training methods.

Modern virtual reality duplicates the handling of aircraft with a high level of fidelity and offers a way to speed up the operator's experience, which can be more effective than regular training. For example, the instructor can choose harsh weather conditions, the exercises can be repeated, and the registration can be saved in a later analysis of the results. Aircraft crews may also experience system failures and operational conditions that would be too dangerous to perform aircraft exercises.

The aviation authorities have established international rules to ensure that virtual flight crew training conducted by different organizations meet an approved safety standard. These standards are designed to ensure not only a consistent regulation of virtual simulators and training standards around the world, but also enable manufacturers to create VR that is compatible with different systems, encouraging competition and ensuring quality.

Virtual Reality is constantly rising an imagination and the human potential. For engineers it is only a tool for creating a new reality. For consumers it is a new world, alternative place where they could lead a different life. VR is different from reality however it creates opportunity to perceive situations possible to happen [3]. Depending on how deep user is able to be transferred in to a virtual world there are types of virtuality.

VR - virtual reality, it is a computer programme stimulating basic human senses. VR looks like a reality, You can feel it like a reality with Your senses but still it is not a real environment. The biggest advantage of VR is a similarity to the real conditions. This advantage is the main cause that a VR is used in real tasks simulators.

Virtual Reality enables an interaction between user and VR environment, however it is possible only by using a dedicated tools.

KEY WORDS: aviation training, airline, virtual reality, innovation, safety, pilots, cabin crew.

2. How it’s Working

Communication in VR system is based on computer graphics systems and sound systems, where in the simulated environment it is possible to control and move simulated objects. Helmets placed on the head, equipped with two liquid crystal displays located at eye level or so-called "helmets" are an exemplary tool used for communication. Set involves projection screens arranged in such a way as to surround the user. Helmets are used to report the position of the head or the direction of the sight of the users eyes. Sensors with gloves or a full-body coverall are used for control. Sound systems are used for spatial acoustics, speech synthesis and its recognition. Devices with those functions enable the computer to be commanded by the user[2].

VR is received through the prism of games, what contributes negative perception of new VR technology in some environments. There are fears, that virtual technology poses a threat to human health or life. However, this article confirms possibility of using another way, constructive application, the virtual environment. Currently, the widespread use of virtual reality includes:

- operating in dangerous or hard-to-reach conditions;
- visualization of the results of science experiments;
- architectural and architectural visualization;
- training simulations, e.g. flight simulators;
- medicine;
- televisions.

VR, AR, MR often appear in the media. All of them define virtual reality but with some differences. The basic differences between the types of virtual reality are focused on involvement of the human senses. There are categories of virtual reality:
VR (ang. Virtual Reality) - this type literally makes it possible to experience anything, anywhere, anytime. It is the most immersive type of reality technology, it can convince the users' brain that it is somewhere it is really not. Head mounted displays are used together with headphones, controllers and provide a fully immersive experience. The future of VR is already set to be a pillar of our everyday lives. The example of VR is Oculus Rift made by Facebook. The device consists of a virtual reality helmet that displays to the user two different images on two lenses at the same time. This allows the reception of artificial surroundings in a manner very similar to the behavior of human eyes. Oculus is used for entertainment, it allows, among other things, to visit beautiful places in various corners of the world, while the user sits at home on the couch. VR projects are eg: Virtual Forbidden City or Google Earth VR.

AR (ang. Augmented Reality) is not as exciting as a rollercoaster ride, however the technology is proving itself as a useful and great tool in our everyday reality. AR can mix elements of the virtual world with our real world. Augmented reality stand out of other reality technologies because is placed in the middle between the real world and the virtual world. Example of AR is Aero Glass technology, currently is testing. Using a lightweight AR head-mounted display the pilots can use data without taking their eyes off the cockpit glass, and without wasting time on physical controls or a touch interface (Fig. 1).

MR (ang. Mixed Reality), is is used as an independent concept, mixed reality combines the both virtual reality and augmented reality in one idea. Mixed Reality technology combine the best aspects of both VR and AR. In mixed reality environments, users navigate through both the real and virtual environments at the same time. Virtual objects are placed into a user’s real world, making virtual interactions appear to be “real.” An example of the project is Microsoft's Microsoft MR HoloLens. It is a helmet of mixed reality that imposes holograms on the real image. The device scans the surroundings in which the user is located and adapts the application to it. The main function of the HoloLens user is to place holograms in selected locations. Some of them are stable, the other model is an example presented on Fig. 2.

Presented Technologies, of virtual reality, are widely used in the industry and also in aviation. They can be used by engineers to create models of cars and aircrafts and aircraft parts such as propellers or engines. The basic concepts that are important in distinguishing virtual technology are immersiveness and interactivity. Immersiveness is the level of user’s involvement. This concept determines how deep technology affects our senses. Using this nomenclature, VR is the most immersive environment, MR average and AR the least [3].

![Fig. 1 Cockpit with AR system](image1)

![Fig. 2 MR technology example](image2)
3. Virtual Reality in Trainings Implementation

Aviation in the world is commonplace, however it is still very dangerous. People fly because it is easier and faster then travel by car, but we should not forget that flying means being ten kilometers up in the sky. For some people using an aircraft is very stressful. For the mental peace of people is good to known that the crew of a commercial airliner is responsible for passengers and the success of each flight, depends on perfection in every step in passanger’s handling. The crash or a small incident could be a disaster for the crew and ground services. The nature of aviation is connected with technological progress and virtual reality owes a great opportunity to try in training.

In November 2014, International Air Transport Association (IATA) invited Brightwave’s Learning Technologies VR lab partner to speak to their symposium about virtual simulation and the opportunities of using virtual reality as a training platform. VR is one of those rare mediums that enables to try the realism, the feeling of presence in virtual environment. Modern simulators mimics every aspect of flight, controls to the vistas, rumble of the engine and turbulence. IATA organization is employing VR to assist in training for pilots and flight attendants and ground services. VR development is presented by demonstration of performing pre flight check. Using an Oculus Rift head-mounted display, participants could go through the entire pre-flight process including walking around a plane, checking it for malfunctions or problems. The most challenging exercise was to locate safety equipment inside the aircraft. After enter the craft, system allows to see several key areas are highlighted to show where the fire extinguisher located is. Moreover in the middle of the cabin user can interact with a fire extinguisher and find out more information about that device. Gaze is a great way of allowing people to interact with objects until a standardized VR system is solved presented on Fig. 4.

From the airlines point of view using modern solutions is time and money saving. This is important part of VR training, ability to be carried out on the ground. Thanks to VR solutions cabin crew can be traineed without involving real aircraft in this processes. This type of training also applies to so-called "simulators” exercises for cabin crew. An example is the use of the Aviter system. In Fig. 5, the cadets practice methods of making a proper assessment of the conditions outside the aircraft before opening the door. Fig. 6 presents the procedure of opening the door in an emergency situation.
At this moment, it is not possible to use virtual reality in a full range. It is unenforceable to complete the training and join regular crew right away. The current regulations clearly state that each exercise must be physically performed by the student on real equipment. However, the system allows you to perform specific exercises and play various types of emergency situations, so that everything on the simulator can be performed correctly. Another verification of training effectiveness is the actual emergency situation. The aviation authorities are about to establish international rules to ensure that virtual flight crew training conducted by different organizations will fulfill safety standards.

Similar training is provided for ground handling, where the terminal is an environment. System transfers the user directly to the front desk, his future workplace, allows to get used to the new environment. In addition, the instructor introduces a hypothetical element, situations in which an employee can be found. Practicing this kind of simulation is great experience for the employee. Future worker feels safety, because VR allows him to experience different conditions. Such simulations mimics situations such as finding unidentified baggage at the airport, controlling drills related to changing the gateway, or canceling the connection between flights (Fig. 7).

Next stage of the training is familiarizing with external handling procedures, like the aircraft service. Direct
exposure to the aircraft is a high-risk situation. The noise and traffic occurring during the loading or unloading, especially for new employees, cause a strong dissociation and loss of security. False move can end tragically in such situation. The danger is the aircraft itself because it moves during the parking procedure, and the engines are working. Another type of danger are vehicles presented on taxi ways, fire trucks, passenger transport buses, luggage carrying carts, and catering cars. An intensive rotation, which is 25 minutes for Ryanair airline, all vehicles are on duty at the same time. The wide application of virtual reality is practiced in the training of people directly handling planes in the field of activities such as refueling, de-icing or water replenishment, cargo handling. Fig. 8, presents the procedure of cargo loading.

![Fig. 8 Cargo loading simulation](image)

During the training, apart from the standard situations, you can also practice hypothetical situations and analyze individual versions of real events. VR simulation allows you to create conditions which the crew has not yet met but can always occur. Basing on experience there is possibility of creating situations that have not yet happened but are possible to happen. While analyzing individual cases or events, we can manage our risk in a conscious and effective way. An example is a simulation of big turbulence during the flight or cabin decompression and after a few seconds a fire on board. Another hypothetical situation is the airplane loading procedure with dangerous material outside, in rainfall and strong wind.

Summarizing, the research carried out in 2016, supplemented with data from March 2018 (Fig. 9), indicates that the largest increase in virtual technology is observed in the game industry, but the education sector is already in second place. The gray color indicates the research carried out in 2016, and the red one in 2018. The largest increase is in medical industry, real estate, marketing, sporting events, defense industry and entertainment is placed in the end. 140 respondents took part in the survey.

![Fig. 9 Coie P., Virtual reality development in economy sector survey](image)

### 4. Conclusions

Entertainment industry, especially computer games, had a dominant role in the development and application of virtual reality. Education and Medicine have the leading role in new technologies implementation. However in
medicine, the main role of virtual reality focuses on the medical training for staff.

The limitation of the growth of the virtual reality industry in flight crew training seems to be limited by the computer possibilities, and in some cases the costs. Modern VR tools that training and aviation companies have to bear. Expectations towards modern training systems refer to easier accessibility and lower costs of their implementation. The key is the use of the already available an existing technology like the smartphone applications. Technology users estimate that the growth in the VR industry will take place in the next three years. The demand for technology will also increase the supply, which means that individual IT companies will expand their offer with new applications compatible with VR, AR and in particular with MR [4]. The products of these companies will be gladly bought, they will enjoy the interest of the airline and schools to educate future staff specialized in the aviation industry.

An additional difficulty is the fact that current virtual reality systems focus primarily on individual operations and procedures that are performed in small rooms such as a passenger cabin or cockpit. However, there is a need to build larger systems and more complicated simulations. Future MR solutions, will ensure greater freedom of the user's movements.

Despite the constant development, virtual reality technology is still far from perfect. To create an alternative world a high computing power of computers is required. At this moment images are too easy, and the movement of simulated objects is often unnatural. Also, the equipment is expensive in use and often not enough qantities is possible to buy. The designers from the Silicon Valley are working hard to eliminate all the failuers of technology, so that soon VR becomes a commonly used tool at work.

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Identification of the Efficiency of Extraction Instruments in Special Vehicles in Transport

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Abstract

This research focuses on the issue of current state and development trends in technology and procedures for self-extraction of people from crashed and otherwise damaged special vehicles that use fire brigade units or in mining environments. The experimental part deals with the design of technology for the self-extraction of crews from crashed or damaged vehicles through blocked entrances or glazed openings. The aim is to verify the suitability of the proposed combinations of power saws and cutting blades for cutting structural and armored metal materials and glass armors. The research is carried out for the purpose of increasing the efficiency of transporting the crew of crashed vehicles in the shortest possible time. The reason is the lack of a system for extracting people from specials armored vehicles [2].

KEY WORDS: space steel, armor, glass, extrication, grinders, saws, transport, special vehicles

1. Introduction

It is necessary has unit to monitor, coordinate, and professionally manage the area of discharging people from crashed and otherwise damaged vehicles. This issue is not systematically addressed during the development (production) of vehicles or during their use (in the preparation of drivers, crews, training and rescue teams) [3]. Crews receive only standard training when leaving a stationary vehicle and removing injured persons from vehicles in situations where the vehicle is damaged only to the extent that vehicle exits are not excluded. However, this training does not address the issue of sampling or disembarkation of the crew in situations where the inputs are blocked for various reasons because of their inaccessibility, blocking or mechanical locking caused by deformation of the hinges or locks (it is also necessary to consider the possibility of intentionally blocking the entrances from the outside). Driving training includes practical departure from a vehicle in an emergency. For example, members of fire brigades rescue units are trained in the technique of expelling people from crashed vehicles [4]. This training is, however, carried out in situations where the vehicle is accessible through the entrances or by the use of available technical means in unarmed vehicles.

From the design point of view, unarmed cars and armored cars represent a risk due to the problematic departure of the crew from these vehicles in the event of an accident or injury from fighting. In special protected vehicles used a very difficult situation can arise due to the structure of these vehicles and the use of protective elements designed to increase crew protection, which may limit or block access to the entrances, especially in the event of damage [3, 7]. These vehicles are designed with increased resistance to external stresses that may come from explosive energy, projectile energy, or in various other forms [6, 10]. Due to the specificity of special vehicles and the environment in which they operate, the door and hatch design of these vehicles is designed differently than conventional vehicles. If the vehicle is not equipped with an emergency self-management system when it is produced, it is very difficult to equip this vehicle with a simple device / technology that would allow it to exit the vehicle if the inputs are locked.

Special's cars introduced using of fire brigades rescue are unique in that they are made of metal armor materials of very high strength, with a thickness of several millimeters to tens of millimeters. They are also equipped with an additional armor for the mission, which increases the level of armor protection as well as the thickness of the vehicle walls [8, 9]. Entrances, doors and hatches are used for boarding and crewing; may be blocked as a result of an accident. Drainage techniques used in a regular facility, which mostly focus on cutting civilian crews using hydraulic blades, cannot be effectively used in this case due to stronger and stronger armored vehicle materials.

2. Materials and Methods

Cutting tests of samples of metal materials were carried out in the experimental project, using promising manual cutting tools. With respect to the intended use of the tools for cutting hinges and entrance handles in the extrication of crews from armored vehicles, we have chosen technology and equipment for manual cutting of metal materials with a
thickness of up to 50 mm. The selected technologies are cutting with grinding saws and angle grinders. The technologies of cutting with grinding saws and angle grinders are almost identical. Grinding saws are produced primarily as tools for professional use; they are equipped with a combustion engine drive and have a cutting blade diameter ranging from 250 mm to 400 mm [1, 5]. Angle grinders are supplied as electric or rechargeable for versatile use, with a cutting blade diameter ranging from 100 mm to 230 mm.

Laboratory research has been focused on comparing the 3PA steel-cutting process used for special’s transport vehicles. It was judged how the technology affects the base material. For each of the divisions, what is the quality of the cut area after division and time consuming. The 26 HV5 hardness measurements were made at a distance of 25 mm from the cutting surface for the comparison of selected methods and the results and statistical processing were evaluated by STATGRAPHICS 7.0. The micro-hardness measurement was performed on the ZWICK 3202 at load $F = 5$ kPa and load time $\tau = 15$ seconds.

2.1. Armored Material Cutting Tests with Grinding Saws

We used the hand-held circular saws SACHS DOLMAR, PARTNER and HUSQVARNA, along with abrasive cutting blades and a special diamond blade. In the tests we monitored the time necessary to cut through the material sample and the decrement of the cutting blade, and calculated the parameters of the decrease in the size of the cutting blade and the cutting feed rate (m.min$^{-1}$). The material was structural steel S235JRG2 according to ČSN 41 1375 and ČSN EN 10025-2:2004 [11, 12] the parameters of which correspond to those of materials used in the production of door hinges and hatches of special vehicles, and metal armor material 3PA with martensitic structure. Table 1 lists the chemical composition of S235JRG2 and 3PA steels. Table 2 lists the mechanical properties of these steels [3, 9].

2.2. Cutting Tests of Metal Structure Materials with Angle Grinders

Two cutting tests of metal structural materials with angle grinders were performed. The first test was carried out on a sample of material S235JRG2. The second test, focusing on the emergency opening of the crew’s compartment using an angle grinder and portable source of electricity, was carried out on vehicle BVP-1.

2.3. Cutting Tests on a Sample of Material S235JRG2

For the cutting we used BOSCH and KRESS electric angle grinders together with an abrasive cutting blade and a special diamond blade. The sample material was structural steel S235JRG2, the parameters of which correspond to the materials used in the manufacture of door hinges and hatches of armored vehicles. In the tests we monitored the time necessary to cut through the material sample and the decrement of the cutting blade, and calculated the parameters of the decrease in the size of the cutting blade and the cutting feed rate.

2.4. Laboratory Testing of 3PA Armor Splitting

Devices utilised:
A) BURNING BY A CARBON ELECTRODE
Burning by a carbon electrode was carried out using device ESAB LHF 630 in the length of 160 mm for 35 seconds.

Test conditions:
Current 520 A
Connection to (+) pole

Table 1

<table>
<thead>
<tr>
<th>Steel</th>
<th>Chemical composition (wt.%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td>S235JRG2</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>0.19</td>
</tr>
<tr>
<td>3PA</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>0.30</td>
</tr>
</tbody>
</table>

Table 2

<table>
<thead>
<tr>
<th>Steel</th>
<th>Mechanical properties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rm [MPa]</td>
</tr>
<tr>
<td>S235JRG2</td>
<td>570</td>
</tr>
<tr>
<td>3PA</td>
<td>1600</td>
</tr>
</tbody>
</table>
Air pressure 5 atmospheres
Carbon electrode designation Ø6 ESM 257
Air temperature +25°C

B) BURNING BY AN OXYGEN-ACETYLENE KIT

Test conditions:
Oxygen operating pressure 0.5 MPa
Acetylene operating pressure 100 kPa
Burner type R 6
Air temperature +25°C

The burning was carried out in the length of 160 mm for 40 seconds.

C) BURNING BY PLASMA

The cutting was carried out using a machine of PA-S 20 W-K JELLBERG type. The burning was carried out in the length of 160 mm for 30 seconds.

Test conditions:
Current I 40 A
Burner diameter 1.3 mm (up to 60 A)
Air temperature t +25°C

D) CUTTING BY A DIAMOND WHEEL

The armour material was cut using angle grinder EBU–18–B-A with a diamond wheel in the length of 160 mm for 110 seconds.

Test conditions:
Grinder technical specification:
Grinder input power 2100W
Grinding wheel technical specification:
Type system Gemas
Maximum revolutions 8600 rev.min-1.
Grinding without cooling
Air temperature +25°C

3. Results and Discussion

3.1. The Results of the Cutting Tests of Armor Materials With Grinding Saws are Presented in Tables 3, 4

<table>
<thead>
<tr>
<th>Sample no.</th>
<th>Type of grinding saw</th>
<th>Saw power [cm³.kW⁻¹]</th>
<th>Type of cutting blade</th>
<th>Size of cutting blade [D × T × d]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SACHS DOLMAR 309</td>
<td>70/3.5</td>
<td>HUSQVARNA A30RBF1)</td>
<td>300×3.5×22.2</td>
</tr>
<tr>
<td>2</td>
<td>PARTNER K 1200 MARK II</td>
<td>100/4.4</td>
<td>HUSQVARNA A30RBF1)</td>
<td>300×3.5×22.2</td>
</tr>
<tr>
<td>3</td>
<td>PARTNER K 1200 MARK II</td>
<td>100/4.4</td>
<td>HUSQVARNA A30RBF1)</td>
<td>300×3.5×22.2</td>
</tr>
<tr>
<td>4</td>
<td>HUSQVARNA K760</td>
<td>74/3.7</td>
<td>HUSQVARNA FR-3⁴</td>
<td>350×3.4×25.4</td>
</tr>
<tr>
<td>5</td>
<td>HUSQVARNA K970</td>
<td>94/4.8</td>
<td>PARTNER3) RAIL A30RBF</td>
<td>400×4×25.4</td>
</tr>
<tr>
<td>6</td>
<td>HUSQVARNA K970</td>
<td>94/4.8</td>
<td>PARTNER3) RAIL A30RBF</td>
<td>400×4×25.4</td>
</tr>
<tr>
<td>7</td>
<td>HUSQVARNA K970</td>
<td>94/4.8</td>
<td>PARTNER3) RAIL A30RBF</td>
<td>400×4×25.4</td>
</tr>
<tr>
<td>8</td>
<td>HUSQVARNA K970</td>
<td>94/4.8</td>
<td>PARTNER3) RAIL A30RBF</td>
<td>400×4×25.4</td>
</tr>
<tr>
<td>9</td>
<td>HUSQVARNA K970</td>
<td>94/4.8</td>
<td>PARTNER3) RAIL A30RBF</td>
<td>400×4×25.4</td>
</tr>
<tr>
<td>10</td>
<td>HUSQVARNA K760</td>
<td>74/3.7</td>
<td>HUSQVARNA FR-32)</td>
<td>350×3.4×25.4</td>
</tr>
<tr>
<td>11</td>
<td>HUSQVARNA K760</td>
<td>74/3.7</td>
<td>HUSQVARNA FR-32)</td>
<td>350×3.4×25.4</td>
</tr>
<tr>
<td>12</td>
<td>HUSQVARNA K760</td>
<td>74/3.7</td>
<td>HUSQVARNA FR-32)</td>
<td>350×3.4×25.4</td>
</tr>
<tr>
<td>13</td>
<td>HUSQVARNA K970</td>
<td>94/4.8</td>
<td>PARTNER3) RAIL A30RBF</td>
<td>400×4×25.4</td>
</tr>
</tbody>
</table>

Note:  1) The reference number of blade HUSQVARNA A30RBF is 504 00 04-02;
2) The reference number of blade RESCUE FR-3 is 5748540-01;
3) The alternative to this blade from HUSQVARNA has ref.no. 5040010-03;
Table 4

Material for cutting tests and results

<table>
<thead>
<tr>
<th>Sample no.</th>
<th>Sample material</th>
<th>Area of cut surface $\Omega$, namely Thickness/Width $[\text{mm}]$</th>
<th>Time necessary to cut through sample $[\text{s}]$</th>
<th>Decrease in sawblade diameter $[\text{mm}]$</th>
<th>Decrease in saw blade size $[\text{mm}^3]$</th>
<th>Cutting feed rate $[\text{m.min}^{-1}]$</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S235JRG2 65.6</td>
<td>3 380</td>
<td>523 (8 min 23 s)</td>
<td>12.7</td>
<td>20 503</td>
<td>0.008</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>S235JRG2 30.3/200</td>
<td>6 060</td>
<td>210 (3 min 30 s)</td>
<td>5.2</td>
<td>8 502</td>
<td>0.016</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>S235JRG2 65.6</td>
<td>3 380</td>
<td>279 (4 min 39 s)</td>
<td>N5</td>
<td>N5</td>
<td>0.043</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>S235JRG2 65.6</td>
<td>94 (1 min 34 s)</td>
<td>94 (1 min 34 s)</td>
<td>6</td>
<td>14 967</td>
<td>0.128</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>S235JRG2 65.6</td>
<td>3 380</td>
<td>6060</td>
<td>5.2</td>
<td>8 502</td>
<td>0.016</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>S235JRG2 65.6</td>
<td>3 380</td>
<td>210 (3 min 30 s)</td>
<td>5.2</td>
<td>8 502</td>
<td>0.016</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>S235JRG2 65.6</td>
<td>3 380</td>
<td>279 (4 min 39 s)</td>
<td>N5</td>
<td>N5</td>
<td>0.043</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>3PA 8.4/500</td>
<td>1 680</td>
<td>N5</td>
<td>N5</td>
<td>N5</td>
<td>0.043</td>
<td>-</td>
</tr>
<tr>
<td>9</td>
<td>3PA 8.4/500</td>
<td>840</td>
<td>25 (0 min 25 s)</td>
<td>1.1</td>
<td>2 761</td>
<td>0.24</td>
<td>Cut l=200 mm through center of sample</td>
</tr>
<tr>
<td>10</td>
<td>3PA 8.4/500</td>
<td>840</td>
<td>26 (0 min 26 s)</td>
<td>N5</td>
<td>N5</td>
<td>0.231</td>
<td>Cut through sample 100 mm from the edge</td>
</tr>
<tr>
<td>11</td>
<td>3PA 8.4/500</td>
<td>1 680</td>
<td>101 (1 min 41 s)</td>
<td>N5</td>
<td>N5</td>
<td>0.119</td>
<td>Cut l=200 mm through center of sample</td>
</tr>
<tr>
<td>12</td>
<td>Glass armor 46.6/150</td>
<td>6 990</td>
<td>28 (0 min 28 s)</td>
<td>N5</td>
<td>N5</td>
<td>0.321</td>
<td>-</td>
</tr>
<tr>
<td>13</td>
<td>Glass armor 46.6/150</td>
<td>6 990</td>
<td>61 (1 min 1 s)</td>
<td>6</td>
<td>14 967</td>
<td>0.148</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: 4) 3PA – this is armor material 3PA; 5) N – not evaluated, not measured due to a very low decrease in blade size when cutting (a measurement error exceeded the actual decrease); 6) Glass armor – glued glass armor consisting of 5 layers of 8 mm glass glued with polymer glue attached to a polycarbonate back layer with a thickness of 2.8 mm.

3.2. Cutting Structural Steel Materials

The proposed technology and the tools used allow us to reliably cut material S235JRG2, the parameters of which correspond with the materials used in the manufacture of door hinges and hatches of special vehicles.

The highest cutting feed rate in samples of material S235JRG2 with a 30.3 mm thickness and 200 mm width was achieved using:

- Grinding saw HUSQVARNA K970 and abrasive cutting blade PARTNER RAIL A30RBF, at 0.128 m.min$^{-1}$, i.e. 7 min 50 s.m$^{-1}$;
- The second highest cutting feed rate when cutting the same sample was achieved using grinding saw HUSQVARNA K760 and diamond cutting blade HUSQVARNA FR-3. The cutting feed rate was 0.043 m.min$^{-1}$, i.e. 23 min 15 s.m$^{-1}$.

When we take into account the higher engine output of the HUSQVARNA K970 saw and the larger diameter of its cutting blade PARTNER RAIL A30RBF, its cutting performance compared to the HUSQVARNA K760 saw and cutting blade HUSQVARNA FR-3 is approximately doubled.

A visual comparison of the cut surfaces is shown in Figs. 1 and 2.

![Fig. 1 Cut surfaces of sample no.1 SACHS DOLMAR 309](image-url)
3.3. Cutting Armor Steel Materials

The proposed technology and the tools used allow us to reliably cut the armor steel 3PA, the parameters of which correspond with the materials used in the manufacture of hulls of special vehicles. The highest cutting feed rate in the cutting of a sample of (cut from the edge of the sample to a distance of 200 mm) the material 3PA with a thickness of 8.4 mm and width of 500 mm was achieved using:

- Grinding saw HUSQVARNA K970 and abrasive cutting blade PARTNER RAIL A30RBF, at 0.2 m.min⁻¹, i.e. 5 min.m⁻¹. In the Fig. 3 is a visual comparison cut surfaces.
- The second highest cutting feed rate when cutting the same sample was achieved using grinding saw HUSQVARNA K760 and diamond cutting blade HUSQVARNA FR-3. The cutting feed rate was 0.119 m.min⁻¹, i.e. 8 min 25 s.m⁻¹. In the Fig. 4 a visual comparison cut surfaces.

When we take into account the higher engine output of the HUSQVARNA K970 saw and the larger diameter of its cutting blade PARTNER RAIL A30RBF, its cutting performance compared to the HUSQVARNA K760 saw and cutting blade HUSQVARNA FR-3 is only approximately 10% higher.

3.4. Cutting Transparent Armor Materials (Glass)

The proposed technology and the tools used allow us to reliably cut transparent armor materials (glass armor), the parameters of which correspond with the materials used in the manufacture of armored vehicles. The highest cutting feed rate in samples of glass armor with a 46.6 mm thickness and 200 mm width was achieved using:

- Grinding saw HUSQVARNA K760 and diamond cutting blade HUSQVARNA FR-A30RBF, at 0.321 m.min⁻¹, i.e. 3 min 11 s.m⁻¹. In the Fig. 5 is a visual comparison cut surfaces of sample no.12 HUSQVARNA K760.
- The second highest cutting feed rate when cutting the same sample was achieved using grinding saw HUSQVARNA K970 and abrasive cutting blade HUSQVARNA FR-3. The cutting feed rate was 0.148 m.min⁻¹, i.e. 6 min 8 s.m⁻¹. In the Fig. 6 is a visual comparison cut surfaces of sample no.13 HUSQVARNA K970.

When we take into account the higher engine output of the HUSQVARNA K970 saw and the larger diameter of its cutting blade PARTNER RAIL A30RBF, its cutting performance compared to the HUSQVARNA K760 saw and cutting blade HUSQVARNA FR-3 is approximately 30% higher.
3.5. The Results of the Cutting Tests of Armor Materials With Angle Grinders are Presented in Tables 5 and 6

Table 5

<table>
<thead>
<tr>
<th>Sample no.</th>
<th>Type of angle grinder</th>
<th>Angle grinder output [kW]</th>
<th>Type of cutting blade</th>
<th>Size of cutting blade [D × T × d]</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>BOSCH GWS 19-180J</td>
<td>1.9</td>
<td>DRONCO special AS 30 T-BF</td>
<td>180×2×22.2</td>
</tr>
<tr>
<td>15</td>
<td>KRESS 2200 WS 230</td>
<td>2.2</td>
<td>Pentax Terminator</td>
<td>230×3.3×22.2</td>
</tr>
</tbody>
</table>

Note: 1) The type number of cutting blade Drondo special is 1181055; 2) The reference number of cutting blade Pentax Terminator is P205051 (supplier - COMINVEST); 3) The blade had to be replaced with a new one during the cutting due to wear; 4) N - not evaluated, not measured due to a very low decrease in the saw blade size (a measurement error exceeded the actual decrease in size).

Table 6

<table>
<thead>
<tr>
<th>Sample no.</th>
<th>Sample material Thickness/Width</th>
<th>Area of cut surface [mm²]</th>
<th>Time necessary to cut through sample [s]</th>
<th>Decrease in sawblade diameter [mm]</th>
<th>Decrease in saw blade size [mm³]</th>
<th>Cutting feed rate [m.min⁻¹]</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>S235JRG2 30.3/200</td>
<td>6 060</td>
<td>275³ (4 min 35s)</td>
<td>34 (1.blade)</td>
<td>16 286</td>
<td>0.044</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2 (2.blade)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>650 (10 min 50s)</td>
<td></td>
<td>N³</td>
<td>N⁴</td>
<td>0.019</td>
</tr>
</tbody>
</table>

The proposed technology and the tools used allow us to reliably cut material S235JRG2, the parameters of which correspond with the materials used in the manufacture of door hinges and hatches of armored vehicles.

• The cutting feed rate using angle grinder BOSCH GWS 19-180J and an abrasive cutting blade with a diameter of 180 mm in structural material S235JRG2 with a thickness of 30.3 mm, is 0.044 m.min⁻¹, i.e. 22 min 55 s.m⁻¹.
• The cutting feed rate using angle grinder KRESS 2200 WS 230 and a diamond cutting blade with a diameter of 230 mm in structural material S235JRG2 with a thickness of 30.3 mm, is 0.019 m.min⁻¹, i.e. 54 min 10 s.m⁻¹.

A visual comparison of the cut surfaces is shown in Fig. 7 and 8.
4. Results of the 3PA Armor Splitting Laboratory Tests

For the purpose of comparison of the methods selected, 26 measurements of hardness HV 5 within the distance of 25 mm from the cutting surface were carried out. Their results and statistic processing by STATGRAPHICS 7.0 programme are provided in the following Table 7. and Fig. 9.

Table 7

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Specimen 13</th>
<th>Specimen 14</th>
<th>Specimen 15</th>
<th>Specimen 16</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>X</td>
<td>382.53</td>
<td>364.179</td>
<td>491.753</td>
<td>510.44</td>
</tr>
<tr>
<td>$s^2$</td>
<td>2184.73</td>
<td>1018.86</td>
<td>407.434</td>
<td>38.8972</td>
</tr>
<tr>
<td>s</td>
<td>46.7411</td>
<td>31.9196</td>
<td>20.185</td>
<td>6.22313</td>
</tr>
<tr>
<td>$s_x$</td>
<td>9.16669</td>
<td>6.25995</td>
<td>3.95861</td>
<td>1.22313</td>
</tr>
<tr>
<td>R</td>
<td>219.569</td>
<td>120.858</td>
<td>85.2518</td>
<td>26.8276</td>
</tr>
</tbody>
</table>

Note: $N$-number of measurements, $S$-sample standard deviation, $X$-mean value of hardness, $s_x$-sample standard error, $s^2$-sample variance, $R$-range of variation

Where the cutting is carried out by: a carbonelectrode specimen no. 13; oxygen-acetylene flame specimen no. 14; plasma specimen no. 15; diamond wheel specimen no. 16.

It follows from the hardness measurement results that cutting by a diamond wheel maintains basic mechanical properties of the armour as they had been before the cutting (the variance is comparable to the variance of the original armour). Cutting by plasma shows similar results with partially decreased average value of hardness and increased spread of values. As far as the other methods are concerned, the armour hardness decreases considerably within a great distance from the point of cutting, and there is a large spread of experimental data. From this point of view, cutting armour by a diamond wheel has proved to be the most appropriate method for operative repairs. Moreover, the method does not require further treatment, e.g. grinding off parts of the cutting surface, and although it is slower, leaving out this operation makes the method less time-consuming, and no complex equipment and qualified operators are required. It can also be applied, where thermal cutting would cause the degradation of the next, e.g. composite, layer, or damage to the parts behind the armour which would have to be dismounted. However, there are some restrictions due to the effective thickness of cut approx. up to 15mm and difficulties with cutting shaped areas.

![Fig. 9 Diagram of the course of hardness HV 5 and the probability density](image)

5. Conclusion

We can derive the following conclusions from the results of the cutting tests of armor materials using grinding saws:

- As the output power of the grinding saw and the diameter of the selected cutting blade increases, the cutting power also increases.

- Abrasive cutting blade PARTNER RAIL A30RBF is suitable for cutting structural steel armor materials; it produces high levels of dust when cutting glass armor in comparison with diamond blade HUSQVARNA RESCUE FR-3.

- The abrasive cutting blade had a high decrease in diameter due to wear, reducing its durability; moreover, it is susceptible to moisture absorption during storage.

The diameter decrease of diamond blade HUSQVARNA RESCUE FR-3 was minimal, and the estimated operational life is up to 5 m² of cutting.
We can derive the following conclusions from the results of the cutting tests of armor materials using angle grinders:

- With the diameters of cutting blades used, the abrasive blade had a 2x higher cutting feed rate than the diamond blade.
- The abrasive cutting blade had a high decrease in diameter due to wear, reducing its durability; moreover, it is susceptible to moisture absorption during storage.
- The diamond blade had a minimal diameter decrease.

We can further conclude from the manufacturer's information that the diamond blade is not as prone to storage conditions (especially humidity) as the abrasive cutting blade. Laboratory results steel 3PA

It follows from the hardness measurement results that cutting by a diamond wheel maintains basic mechanical properties of the armour as they had been before the cutting (the variance is comparable to the variance of the original armour). Cutting by plasma shows similar results with partially decreased average value of hardness and increased spread of values. As far as the other methods are concerned, the armour hardness decreases considerably within a great distance from the point of cutting, and there is a large spread of experimental data.

From this point of view, cutting armour by a diamond wheel has proved to be the most appropriate method for operative repairs. Moreover, the method does not require further treatment, e.g. grinding off parts of the cutting surface, and although it is slower, leaving out this operation makes the method less time-consuming, and no complex equipment and qualified operators are required. It can also be applied, where thermal cutting would cause the degradation of the next, e.g. composite, layer, or damage to the parts behind the armour which would have to be dismounted.

Acknowledgement

The work was supported by the Ministry of Defence of the Czech Republic, project No. DZRO K-109 and project No. OFVVU20130003

The research has been supported by the project TP 4/2014: Analysis of degradation processes of modern materials used in agricultural technology; financed by IGA AF MENDELU.

References

Taxation of Income from Dependent Activity of Transport Company’s Employees in the Czech Republic in Accordance with Upcoming Changes from 1 January 2019

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Abstract

The contribution focuses on the taxation of personal income with a focus on the dependent activity of transport company’s employees in the Czech Republic. The tax system in the area of direct taxes, especially income taxes, accepts the process of globalization of the ZDP economy. The common or similar and unifying procedures of the member states reflect the ongoing implementation of EU regulations and directives into national tax systems. Personal income tax schemes are diverse in EU countries, both in terms of considering social aspects of the taxpayer (number of dependent children, invalidity) when calculating the tax liability, either in the form of non-taxable parts of the tax base, deductible items from the tax base or direct tax credit, and in terms of tax bands and tax rates in them and the progressiveness of the tax rate. Frequent changes in tax laws therefore cause uncertainty for taxpayers in their implementation into practice. The contribution also deals with this issue because of the upcoming changes in personal taxation in the Czech Republic from 2019.

KEY WORDS: income, dependent activity, tax, tax system, employee, transport company

1. Introduction

This contribution focuses on income from dependent activity mainly because the tax revenue from this type of income accounts for 88% of the total tax revenue from personal income tax in the Czech Republic. In most countries, personal income taxes are considered to be the most important. They are attributed the highest degree of complexity, fairness and economic efficiency. There are several types of personal income, and each of them has its own specifics. Income from the dependent activity of employees, not only of those who work in transport companies in the Czech Republic, is usually taxed at the source, either in the form of a monthly tax prepayments or withholding tax. In both cases, the calculation is made by the employer within the deadline set in the Act on Income Tax. Unfortunately, the act does not recognize the concept of dependent activity. The exact definition of this concept can be found in the instruction of the Ministry of Finance of the Czech Republic. It is based on the judicial decision of the Supreme Administrative Court and defines the dependent activity as follows: the payer of income directly or indirectly assigns tasks, manages and controls the individuals (natural persons) and bears responsibility related to their activities. In relation to the payer, the individual has a similar status as an employee. Labour remuneration is calculated on the basis of working hours or in the same way as the remuneration of a person in an employment relationship.

2. Income from Dependent Activity

The subject of tax on income from dependent activity is regulated by Section 6 of the Act No. 586/1992 Sb., On Income Tax (hereafter only ITA). For dependent activity, it is important that the tax entity is not only one entity but two entities: a taxpayer and a payer (entity paying the tax) [1, 2]. A taxpayer is referred to as an employee, the one whose income, assets or transactions are taxed. A payer is referred to as an employer, and it is an entity with registered office or permanent residence in the Czech Republic which, on its own account and responsibility, pays the tax or a tax prepayment on the taxpayer's income to the tax administrator. Personal income tax is described as the most complex direct tax in the Czech Republic, for which there are many options of tax exemptions, non-taxable parts and tax credits. Any income, both monetary and non-monetary, is subject to the personal income tax [3, 9]. Income is understood as everything that increases the taxpayer's assets. Under the Income Tax Act, the following are subject to tax:

- income from dependent activity;
- income from independent activity;
- capital assets income;
- rental income;
- other income.
Each section of the Income Tax Act is used for a particular type of income and precisely defines the regulated income. An income from dependent activity is considered to be income of cooperative’s members for their work for the cooperative, incomes of associates and managing director of the limited liability company and limited partners of limited partnerships for their work in these companies, income for the work of liquidators or remuneration of members of statutory bodies and other bodies of legal persons. The subject of income tax from dependent activity is not only income in the form of money but also a non-monetary income [2, 7]. The income can be either regular or one-time, and it is not essential whether or not there is a legal claim for such income. Emoluments are salaries and benefits provided in connection with the current or previous performance of the office, the amount of which is determined in accordance with the act governing salaries in connection with executing duties of state officials, certain state bodies and judges, and the performance provided in connection with the current or former execution of a duty in the bodies of municipalities and other bodies of territorial self-governments, state authorities, associations and interest associations, union organizations, chambers, other bodies [5, 11].

The tax base (partial tax base) equals to the income from dependent activity increased by the amount corresponding to the social security, state employment policy and public health insurance contribution, which the employer is obliged to pay from the income. The employee's income increased in this way is referred to as the super-gross wage. The principle of super-gross wage means that the assessment base for the tax on personal income from dependent activity is the gross wage increased by the social security and health insurance, which the employer is obliged to pay for the employee [10]. Income that is exempt from the tax is not part of the income tax base. Examples include various scholarships, some free-of-charge supplies, inheritance, subsidies, sickness and retirement benefits, payments of insurance claims, lottery winnings, and income from the sale of a family house. The so-called non-taxable parts of the tax base are also deducted from the calculated tax base, which will reduce the tax base significantly. The non-taxable part of the tax base is considered to be the value of free-of-charge supplies provided to social benefit organizations if the overall value exceeds 2% of the tax base or is at least 1,000 CZK, for the value of blood donation and its components 3,000 CZK or the value of organ removal 20,000 CZK. The tax base can be also reduced by interest paid on building savings or mortgage loan up to 300,000 CZK per household, and by contributions paid to supplementary pension insurance or private life insurance up to 24,000 CZK, trade union contributions up to 3,000 CZK or contributions to cover further education up to 10,000 CZK for a taxpayer without health disability, 13,000 CZK for a taxpayer with health disability and up to 15,000 CZK for a taxpayer with severe health disability.

The deductible items from the tax base under Sec. 34 to 34 h of the ITA are:
- tax loss from past years at the latest in five taxable periods immediately following the period for which the loss is assessed;
- deduction for the support of research and development;
- deduction to support vocational education.

After deducting non-taxable parts of the tax base and deductible items from the tax base, the tax base is rounded down to whole hundred CZK and then multiplied by a tax rate, which for individuals in the Czech Republic amounts to 15%. The result is a tax before tax credits claims. The calculated tax can be increased by so-called solidarity tax, which is 7% of the positive difference between the sum of income from dependent activity and the partial tax base from the dependent activity and 48 times the average wage (48 times the average wage amounts to 1,438,922 CZK in 2018) [12]. From the calculated tax, the taxpayer has the option to claim tax credits, which pursuant to Section 35 ba) through Section 35 bc) are:
- basic tax credit for a taxpayer at the amount of 24,840 CZK;
- spouse/registered partner tax credit at the amount of 24,840 CZK (living in the common household, if their income does not exceed 68,000 CZK for the taxable period);
- disability tax credit at the amount of 2,520 CZK (extended credit at the amount of 5,040 CZK);
- a credit of 16,140 CZK if the taxpayer holds a ZTP/P card (for severe health disability requiring special care);
- a student credit of 4,020 CZK if the taxpayer is under 26 or is doctoral student up to 28 years of age;
- a credit for the placement of a child in pre-school facility up to the minimum wage (since 2018 the minimum wage is 12,200 CZK).

After deducting tax credits, the taxpayer may claim tax benefit for a child, which lives with the taxpayer in the common household, pursuant to Section 35c. The tax benefit in 2018 amounts to 15,204 CZK for the first child, 19,404 CZK for the second child and 24,204 CZK for the third and every other child. If the child is a holder of the ZTP/P card, the amount is doubled. If the amount is higher than the calculated tax, the difference is a tax bonus. The tax bonus must be at least 100 CZK, but no more than 60,300 CZK per year. In addition to deductible items, tax credits can be used as another form of tax relief. Tax credits, as opposed to deductible items, reduce the calculated tax liability [8]. An overview of tax benefits for children in 2018 is shown in the Table 1.

The amendment of the act on income tax since 2018 specifies that the employee's income also means the performance provided by the employer for a family member of the employee [4, 15].

This includes mainly non-monetary performance provided by the employer to the employee or family member from the cultural and social needs fund, from the social fund in the form of delivery of health, medical, hygienic and similar goods and services from medical facilities, the purchase of prescription medical devices and the use of educational or recreational facilities. When providing recreation or tour, the value of the non-monetary benefit for the employee is exempt from the tax up to the amount of 20,000 CZK for the taxable period. Economic benefit from interest-free loans
up to the principal of 300,000 CZK is also exempt from taxation. Economic benefit from interest-free loans exceeding the principal of 300,000 CZK is calculated for each calendar month. The calculated amount will then be included in the tax base at least once for the tax period, no later than during the settlement of wage for December. If the employer provides employees free of charge with a motor vehicle for both business and private purposes, the employee's income is considered to be 1% of the acquisition price of the vehicle for each commenced calendar month when the vehicle is provided. If the vehicle is acquired under finance leasing arrangement, the acquisition price of the vehicle from the original owner is used, even in the event of a subsequent purchase of the vehicle [4, 6]. Assessment of the income tax from dependent activity for employees is shown in Table 2.

Table 1

<table>
<thead>
<tr>
<th>Number of children</th>
<th>CZK per year</th>
<th>CZK per month</th>
</tr>
</thead>
<tbody>
<tr>
<td>the first child</td>
<td>15,204</td>
<td>1,267</td>
</tr>
<tr>
<td>the second child</td>
<td>19,404</td>
<td>1,617</td>
</tr>
<tr>
<td>the third and every other child</td>
<td>24,204</td>
<td>2,017</td>
</tr>
</tbody>
</table>

Table 2

Assessment of income tax from dependent activity of employees (Pšenková, Y. [10])

<table>
<thead>
<tr>
<th>Gross wage (salary and its components)</th>
<th>Super-gross wage</th>
<th>Tax prepayment at the amount of 15%</th>
<th>Tax before tax credit claims</th>
<th>Tax credits</th>
<th>Tax after tax credit claims</th>
<th>Tax benefits</th>
<th>Tax liability or tax bonus</th>
</tr>
</thead>
<tbody>
<tr>
<td>(gross wage increased by insurance paid by the employer)</td>
<td>(gross wage x 1.34) or (gross wage x 1.09)</td>
<td>Base rounded up to whole hundreds</td>
<td>Tax before tax credit claims</td>
<td>Tax credits</td>
<td>Tax after tax credit claims</td>
<td>Tax benefits</td>
<td>Tax liability or tax bonus</td>
</tr>
</tbody>
</table>

The annual settlement of tax prepayments and benefits is performed by the employer for an employee if the employee:
- in the taxable period received wage from one or more employers gradually, and
- for the relevant tax period signed with all these employers the Tax Declaration and requested in writing the annual settlement of tax prepayments and benefits with the last employer, no later than 15 February of the following year.

For an employee who submits a personal income tax return, the employer will not make an annual settlement of tax prepayments and benefits and will only issue “Potvrzení o zdanitelných příjmech ze závislé činnosti, sražených zálohách na daň a daňovém zvýhodnění” (a certificate of taxable income from dependent activity). From 2018, there are also changes in withholding tax for agreements to complete a job and income up to 2,500 CZK per month. Income settled or paid by the taxpayer are a separate tax base for the tax withheld at a special tax rate under the following conditions: the employee did not sign tax declaration with the payer, and at the same time the income is paid based on agreements to complete a job, the total amount of which for the same payer of the tax does not exceed 10,000 CZK per calendar month, or income for the same payer of the tax the total amount of which does not exceed 2,500 CZK per calendar month. An employee, who is a resident in the Czech Republic, may then include the withheld tax in the tax return [8, 15].

Taxpayers with income from dependent activity are obliged to file a tax return if they have income from multiple payers of the tax at the same time, or if they have other income than income from dependent activity, which exceeds 15,000 CZK/year. Tax-exempt income and income from which the tax is withheld are not included. The Income Tax Act also regulates other events when the taxpayer is required to file a tax return. Under certain conditions, it might be advantageous for the taxpayer to file a tax return. For example, if the taxpayer is employed for only half a year, and the income is so high that a tax prepayment is paid each month (that is the tax credit is lower than the calculated prepayment), and the second half of the year the taxpayer is unemployed, it is worthwhile to file a tax return. The taxpayer has so the opportunity to claim the total amount of the tax credit per a taxpayer, and the unused portion of the paid amount is reimbursed to the taxpayer.

3. Calculation of Wages in the Czech Republic in 2018

Model taxpayer with various incomes (from the minimum wage in the Czech Republic at the amount of 12,200 CZK in 2018, or average wage which is set in accordance with the act governing social security premiums and amounts to 29,979 CZK for 2018, up to the above-standard income which is more than 4 times the average wage in the Czech Republic) is a resident of the Czech Republic, with income only from dependent activity. The taxpayer is not entitled to
any deductible items. As for the tax credit, the taxpayer is only entitled to a basic credit for a taxpayer as the taxpayer signed the Tax Declaration with his sole employer.

**Employee 1** with minimum monthly gross wage of 12,200 CZK. Calculation of the net wage for employee 1.

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount (CZK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross wage</td>
<td>12,200</td>
</tr>
<tr>
<td>Super-gross wage (134% rounded up to whole hundreds)</td>
<td>16,400</td>
</tr>
<tr>
<td>Super-gross wage tax 15%</td>
<td>2,460</td>
</tr>
<tr>
<td>Tax credit per a taxpayer</td>
<td>- 2,070</td>
</tr>
<tr>
<td>Tax after tax credit claim</td>
<td>- 390</td>
</tr>
<tr>
<td>Social insurance 6,5%</td>
<td>- 793</td>
</tr>
<tr>
<td>Health insurance 4,5%</td>
<td>- 549</td>
</tr>
<tr>
<td><strong>Net wage to be paid</strong></td>
<td>10,468</td>
</tr>
<tr>
<td>Employers' contributions 34%</td>
<td>4,148</td>
</tr>
<tr>
<td>Total costs of the company</td>
<td>16,348</td>
</tr>
</tbody>
</table>

**Employee 2** with average monthly gross wage of 29,979 CZK. Calculation of the net wage for employee 2.

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount (CZK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross wage</td>
<td>29,979</td>
</tr>
<tr>
<td>Super-gross wage (134% rounded up to whole hundreds)</td>
<td>40,200</td>
</tr>
<tr>
<td>Super-gross wage tax 15%</td>
<td>6,030</td>
</tr>
<tr>
<td>Tax credit per a taxpayer</td>
<td>- 2,070</td>
</tr>
<tr>
<td>Tax after tax credit claim</td>
<td>- 3,960</td>
</tr>
<tr>
<td>Social insurance 6,5%</td>
<td>- 1,949</td>
</tr>
<tr>
<td>Health insurance 4,5%</td>
<td>- 1,350</td>
</tr>
<tr>
<td><strong>Net wage to be paid</strong></td>
<td>22,720</td>
</tr>
<tr>
<td>Employers' contributions 34%</td>
<td>10,193</td>
</tr>
<tr>
<td>Total costs of the company</td>
<td>40,172</td>
</tr>
</tbody>
</table>

**Employee 3** with above-standard monthly gross wage of 130,000 CZK (more than 4 times the monthly average wage). The cap for social security contributions was not exceeded. Calculation of the net wage for employee 3.

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount (CZK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross wage (January)</td>
<td>130,000</td>
</tr>
<tr>
<td>Super-gross wage</td>
<td>174,200</td>
</tr>
<tr>
<td>Super-gross wage tax 15%</td>
<td>- 26,130</td>
</tr>
<tr>
<td>Solidarity tax 130,000 – 4 x 29,979 = 10,084 x 7%</td>
<td>705.88</td>
</tr>
<tr>
<td>Total tax rounded up to whole hundred</td>
<td>26,836</td>
</tr>
<tr>
<td>Tax credit per a taxpayer</td>
<td>- 2,070</td>
</tr>
<tr>
<td>Tax after tax credit claim</td>
<td>- 24,766</td>
</tr>
<tr>
<td>Social insurance 6,5%</td>
<td>- 8,450</td>
</tr>
<tr>
<td>Health insurance 4,5%</td>
<td>- 5,850</td>
</tr>
<tr>
<td><strong>Net wage to be paid</strong></td>
<td>90,934</td>
</tr>
<tr>
<td>Employers' contributions 34%</td>
<td>44,200</td>
</tr>
<tr>
<td>Total costs of the company</td>
<td>174,200</td>
</tr>
</tbody>
</table>

**Employee 3** with above-standard monthly gross wage of 130,000 CZK (more than 4 times the monthly average wage). The cap for social security contributions was exceeded. Calculation of the net wage for employee 3.

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount (CZK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross wage (December)</td>
<td>130,000</td>
</tr>
<tr>
<td>Super-gross wage</td>
<td>141,700</td>
</tr>
<tr>
<td>Super-gross wage tax 15%</td>
<td>- 21,255</td>
</tr>
<tr>
<td>Solidarity tax 130,000 – 4 x 29,979 = 10,084 x 7%</td>
<td>705.88</td>
</tr>
<tr>
<td>Total tax rounded up to whole hundred</td>
<td>21,961</td>
</tr>
<tr>
<td>Tax credit per a taxpayer</td>
<td>- 2,070</td>
</tr>
<tr>
<td>Tax after tax credit claim</td>
<td>- 19,891</td>
</tr>
<tr>
<td>Social insurance 6,5%</td>
<td>- 8,450</td>
</tr>
<tr>
<td>Health insurance 4,5%</td>
<td>- 5,850</td>
</tr>
<tr>
<td><strong>Net wage to be paid</strong></td>
<td>95,809</td>
</tr>
<tr>
<td>Employers' contributions 34%</td>
<td>41,700</td>
</tr>
<tr>
<td>Total costs of the company</td>
<td>141,700</td>
</tr>
</tbody>
</table>

The calculation of the net wage of employees shows that the highest tax burden is on the employee with above-standard income, which is also subject to 7% solidarity tax, and the lowest tax burden on the employee with the minimum
wage. However, the taxation of employee wages in the Czech Republic is lower for wages exceeding 48 times the average wage which is set by the act governing social security premiums, as can be seen from the calculation for the employee 3 in January and then in December when the cap for the payment of social security premiums was exceeded since the basis for calculating the tax, i.e. the super-gross wage, is no longer 1.34 times the gross wage but only 1.09 times. The basis for assessing the income tax is lower than for wages that do not exceed the limit. To determine the real tax burden, effective tax calculations are used to better document the real impact of taxes and social security contributions on the gross earnings of employees. Effective rates help us to reveal the real tax rates and statutory payments that actually affect employees [9].

4. Upcoming Changes in Personal Taxation in the Czech Republic in 2019

The year 2019 could be a turning point for wages and personal taxation in the Czech Republic, given that the Ministry of Finance of the Czech Republic submitted a so-called “new tax package for 2019” to the external commentary procedure. Because of this package, the possible cancellation of super-gross wage and solidarity tax is being prepared. According to the Ministry of Finance of the Czech Republic, these non-systemic institutes make the tax system in the Czech Republic unclear and at the same time obscure the real rate of taxation. With the current method for calculating the income tax liability, there is an artificial increase of the tax base, and this is why the tax rate, which is 15%, does not correspond with the real rate. The newly proposed income tax rate should be 19%. This decision would reduce the tax burden by 1.1% as the current real rate is 20.1%. As it has already been mentioned, the Ministry of Finance of the Czech Republic plans to abolish the solidarity tax and introduce another tax rate of 23% for income exceeding four times the average wage. This rate corresponds approximately to the same burden with the current system [16]. The income tax reduction after the possible cancellation of the super-gross wage is shown in Table 3.

<table>
<thead>
<tr>
<th>Gross income of the employee</th>
<th>Tax assessed from super-gross wage</th>
<th>Tax assessed from gross wage</th>
<th>Tax liability difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>15,000</td>
<td>945</td>
<td>780</td>
<td>-165</td>
</tr>
<tr>
<td>20,000</td>
<td>1,950</td>
<td>1,730</td>
<td>-220</td>
</tr>
<tr>
<td>25,000</td>
<td>2,955</td>
<td>2,680</td>
<td>-275</td>
</tr>
<tr>
<td>50,000</td>
<td>7,980</td>
<td>7,430</td>
<td>-550</td>
</tr>
<tr>
<td>75,000</td>
<td>13,005</td>
<td>12,180</td>
<td>-825</td>
</tr>
<tr>
<td>100,000</td>
<td>18,030</td>
<td>16,930</td>
<td>-1,100</td>
</tr>
<tr>
<td>125,000</td>
<td>23,210</td>
<td>21,680</td>
<td>-1,530</td>
</tr>
<tr>
<td>150,000</td>
<td>29,055</td>
<td>27,430</td>
<td>-1,625</td>
</tr>
<tr>
<td>175,000</td>
<td>34,885</td>
<td>33,180</td>
<td>-1,705</td>
</tr>
<tr>
<td>200,000</td>
<td>40,730</td>
<td>38,930</td>
<td>-1,800</td>
</tr>
</tbody>
</table>

Since the change in the tax rate for self-employed individuals from 15 % to 19 % would imply an increase in the tax liability, the proposal also comes with the option to deduct ¾ of the insurance contributions paid from the tax base, which would result in reduction of the total contribution burden for the vast majority of self-employed individuals who pay non-zero tax. The total impact of the proposed tax changes on state budget revenues is estimated at -15.2 billion CZK (for public budgets - 22.3 billion CZK), which will remain in taxpayers' wallets [16].

5. Conclusions

The basic structure of income tax calculation is almost the same in all developed countries – the overall tax base from all taxable income is reduced by tax reliefs (non-taxable parts of the tax base, deductible items), and the tax, from which tax credits can be deducted, is calculated from the adjusted tax base. Given that the tax base for the calculation of income tax from dependent activity is artificially increased in the Czech Republic, it is not possible to say that the 15% tax rate corresponds to the real rate of taxation [2, 13].

In this context, the contribution deals with the calculation of the overall tax rate of income from dependent activity, which includes insurance contributions, capping for social security premiums, tax credit per a taxpayer and solidarity surcharge. In view of all these factors, it is not possible to say the exact value of the overall rate of taxation of the income from dependent activity since its value varies depending on the size of the income. In recent years, major tax revenue reforms have taken place around the world. They were driven by the fact that tax revenue must be able to predict and adapt to changes in the business environment, globalization and innovations in communication and information technology [14]. One of the key goals of most modern tax revenue systems was the ability to collect revenue both efficiently and effectively. Like governments in many countries, the Czech government was looking for ways to improve the revenue collection system while making voluntary compliance with regulations for taxpayers and payers of contributions more attractive.
References

The Introduction and Impact of Tachographs on Road Freight Transport

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Abstract

The European Union and the AETR have created a single system through recording devices (tachographs) to record drivers' work activities. Throughout the 21st century, all prerequisites for the introduction of digital technology have been created in Europe in the field of tachographs. One of the main reasons for introducing digital tachographs in the EU was to increase the protection against analogue tachograph manipulation. The article discusses the conditions for the introduction of tachographs and their impact on road carrier.

KEY WORDS: transport, tachographs, manipulation, carrier

1. Introduction

The control of driver activities has started after the AETR has been recognized and created. This agreement was recognized in 1970, and the control of drivers' activities began in the same year. For our area, it can be said that the monitoring of activities started only in 1976, as this year Czechoslovakia joined the AETR agreement. Recording of driver activities was performed manually in writing form and without the help of recording equipment. The driver wrote the details of his activity in the book. He wrote them manually, which did not prevent manipulation of time data in particular. It is the driver's responsibility to keep the check book true and to prove it to the authorities that have been used to control them. It was the responsibility of the company to keep records of issued control books and archiving them for one year. The recorded data included the driver's name, vehicle registration number, date and basic route data (from where – to where). Consequently, the driver wrote his activity on a given day, from midnight to midnight. Pictograms were used for unification and for better understanding of activities. Similar control books can also be found today. They are used to monitor the work of drivers of N1 vehicles category with a total mass greater than 2.8 tonnes. They are mainly used in Germany, the driver manually writes the data. The driver writes the route and the time of his mode of work on that day [3]. In particular, due to the possibility of deliberate data manipulation and false writing, it was necessary to improve the systems used to check the drivers. It was necessary to avoid handwriting, that's why the mechanical analogue tachographs were created.

2. Analogue Tachographs

Most tachographs produced prior to 1 May 2006 were of the analogue type (Fig. 1). Later analogue tachograph head models are of a modular design, enabling the head to fit into a standard DIN slot in the vehicle dashboard. This would enable a relatively easy upgrade to the forthcoming digital models, which were manufactured to the same physical dimensions.

![Fig. 1 The tachograph chart [1]](image-url)

The analogue tachograph head uses styli to trace lines on a wax coated paper disc that rotates throughout the day, where one rotation encompasses a 24-hour period. If the disc is left in the head over 24 hours, a second trace will be written onto the first, and so on until the disc is removed. It is an infringement of EU Regulation 561/2006 to use a disc for a period longer than it is designed for. Multiple overlapping traces may still be deciphered in the speed and distance fields, but it is far more difficult for the activity field where one trace can easily be obliterated by another. Analogue
tachograph heads provide no indication to the driver of the need to change the disc.

At the beginning of every shift, the driver would manually write their details in the centre of the paper sheet, such as:

- the driver's name and surname;
- the vehicle registration number;
- the place and date of insertion of the paper disc and
- the initial mileage.

They would then physically put the paper disc into the back of the machine. After this is done they can then begin their working day. They will select their work mode. There are 3 modes available; Other work, Availability and Break/Rest:

- Other work – Jobs included in job role that don’t involve driving this could be duties such as loading and unloading goods.
- Availability – This mode is used for when there is a delay in production so you are waiting for the goods to become available to load and drive away.
- Break/Rest – Taking a break from driving for example, pulling in at the motorway services for a sleep or having something to eat.

Once the vehicle is turned on and moving, the tachograph will recognise the change in mode automatically and start to record the distance and time. Because the tire treads depth, the rim dimensions, the tire, the tachograph can also work with deviations, for the distance travelled and the speed itself. The tolerance of the distance travelled in relation to the actual distance is 4%, this applies for distances longer than 1 km. The speed may vary from ± 6 km / h. Travel time has a tolerance of ± 2 minutes per day or 10 minutes in 7 days. At the end of the shift the driver would manually remove the paper disc and give the recorded information to their admin team or supervisor to store [4].

**The tachograph chart**

Despite the introduction of measuring instruments, the driver is still required to perform a manual record, but with this type of recording device, the data is not as important as the check book. The driver must write some data on the tachograph disc before insertion (see Fig. 2), but also after removing the tachograph disc. When the disc is removed from the device, the driver writes:

- the disc picking point;
- the date of the disc picking;
- the mileage and
- the mileage difference.

The driver is obliged to have a sufficient number of tachograph discs that are approved for the type of analogue tachograph used. The paper discs used by the driver must not be destroyed immediately, the driver must have the tachographs discs in the last 28 calendar days. Subsequently, the discs are archived in the company for 2 years (for SR) or 1 year (EU).

In practice, it works so that the company has a dedicated room for archiving tachograph discs. However, as it could have been damaged or unreadable, especially due to the sun's radiation, it was advisable if the carriers had discs scanned in the computer, respectively made copies.
2.1. Problems with Analogue Tachographs

Analog tachographs have been very obsolete with today's tachographs. But they were much better than control books. They provided a great deal of useful information to enable the authorities to check the drivers, as they did not report the data themselves but were recorded by the recording equipment. Unfortunately, this recording system has not prevented drivers from manipulating information about their activities. As time goes by, drivers have found a way to "help". Of course, the first and easiest illegal solution was to simply replace the tachograph disk and discard the old one. This fraud is being used today in vehicles with an analogue tachograph. Discrepancies in 28-day activity reporting are issued by the activity certificate to be printed on the day when the disc was thrown out. The possibility of fraud with an analogue tachograph is much more. For example, you can create discs as it suits you. Just pull off the analogue tachograph, plug the power supply and send impulses to the tachograph. This replaces the impulses that would otherwise go from the sensor. In older types, the tachograph wheel could be replaced for larger ones, and the data was written faster for this modification. [9] That the drivers have not done so they will create tachographs, which did not take the information from only one source, but several. Their introduction was such a great deal of difficulty. Especially because of the fraud, it was obvious that a change was necessary. Replace the used system with a newer one, which could not be so easily deceived. Therefore, digital tachographs have been introduced since 1 May 2006.

3. Digital Tachographs

Since analogue tachographs have already been obsolete and drivers have come to terms with how they can be deceived, much more complicated and more precise recording devices have been created. They are used in the same way as analogue tachographs, except that the driver no longer writes any data on digital tachographs. Digital tachographs are in use since May 1, 2006. All vehicles that have been brought into service after this date must already have a digital tachograph. Older vehicles equipped with an analogue tachograph must, in the event of a malfunction, replace the instrument with a digital one. [6] This Regulation represents an increase in the cost of operating older vehicles with an analogue tachograph. The carrier also has to replace the old analogue tachograph for the new one – digital (Fig. 3).

![Fig. 3 The digital tachograph](image)

Digital tachographs consist of the vehicle unit, motion sensor and smart cards. The vehicle unit is the brains of the system. It has a processor, a real-time clock, two card slots (for driver and co-driver), a display, a printer, a download connector and a facility for making manual entries. The vehicle unit is located in the driver’s area of the cab. The motion or speed sensor is located on the gearbox. It signals in an encrypted form the vehicle speed and distance travelled by the vehicle for the vehicle unit to record. The vehicle unit and the motion sensor are paired and the signals from the sensor are fully encrypted. This means any attempt to interfere with them is detected and recorded by the vehicle unit. A driver’s card can store up to 28 days’ worth of data. When it is full, the stored data may be overwritten by new data. The vehicle unit stores data for the previous 365 days before the oldest data is overwritten.

Digital tachograph operates independently of the vehicle battery, it means it has its own power supply. This power supply is regularly checked for calibration and, if necessary, exchanged. The main tasks of this type of tachograph include recording, storing, displaying and printing data related to the driver's activity. However, when the card is inserted into a digital tachograph, the vehicle must be either started or the key in the pre-start position. Data is primarily obtained from the sensor that is attached to the gearbox. In the first generations of the digital tachograph, only the transducer is used, the tachograph now collects data from several independent sensors.

3.1. Problems with Digital Tachographs

Sensors have been attributed, in particular, to fraud in the digital tachograph. Tachograph fraud continued after the introduction of digital tachographs. The most common way drivers deceive a digital tachograph is that they use a magnet. The magnet is based on the sensor that is on the gearbox of the vehicle. In this way, no movement information is received from the motion sensor by the digital tachograph. The tachograph shows that the vehicle is standing, even when it moves. Once the magnet is in place, the driver can also take a safety break while driving. So the driver draws rest while he is still driving. After pumping such a "rest", the driver continues to drive, but now legally. The magnet is removed and the tachograph records its other activities normally as it does. When using a magnet, there is no fault or error in the tachograph. The most serious problem is that some carriers are still trying to force drivers to break the working time. One of the many aspects that a driver can force to do is to pay in € per kilometer. However, such action is unlawful. Especially for the magnet mentioned, data was collected not only from one but from several sensors. These sensors also began to be
produced from non-metallic materials to prevent the magnet from being used.

Problems also arise in the case of drivers using two driver cards. This problem can be avoided by more frequent and more rigorous checks by drivers.

More sophisticated frauds are with double pulse senders, modified pulse senders, build-in devices found in the course of time. If the standard pulse generator - the link between the vehicle and the tachograph - is disconnected; the tachograph does not receive a speed signal and registers a rest period. In principle, the disconnection is automatically reported in the tachograph, but the installation of a so-called dummy in the system can manipulate this function and prevent the report.

There is great concern at a growing wave of tachograph fraud and tampering, by which both drivers' hours and speed regulations are flouted on a large scale. Most of this fraud is motivated by economic pressures on vehicle operators, and might be reduced by better tachograph systems.

4. Roadside Checks in EU

In total over the period of 2013 and 2014 more than 6.6million vehicles and approximately 7.4 million drivers were controlled during checks at the roadside. These values stand for decreases of respectively 23.9% and 15% in relation to the previous reporting period and mark a continuation of the downward trend noted in former reports. The reason for a higher number of drivers checked than a number of vehicles is twofold: the double manning as well as missing data on this matter from Denmark on the number of vehicles checked at roadside.

The drop of 15% in the absolute number of drivers controlled at roadside is not matched by the corresponding increase in the number of drivers controlled at premises and results in the overall decrease in the numbers of drivers checked both at roadside and premises of 13%.

Checks in Member States, involved in the majority, national vehicles and drivers and equalled respectively 65% and 64% of all vehicles or drivers checked at roadside. In six Member States, namely Austria, Belgium, France, Luxembourg, Malta and Slovenia, the pattern is reversed and more non-national vehicles were subject to a control. This in some cases may be explained by the size or geographic position of these Member States. Detailed rates are incorporated in the accompanying document. As non-discrimination is one of the fundamental principles of the EU Treaties and a key requirement for carrying out roadside checks, the Commission may consider taking appropriate measures in order to ensure the equal treatment of drivers and operators in Member States where the checks are performed more frequently in regard to non-resident drivers and operators.

The Table 1 and Fig. 4 below shows that proportions between categories of infringements maintain similar levels compared with the previous reporting periods. The slight decline observed for offences on breaks and driving time is counterbalanced by increases in the offences concerning rest periods, lack of records for other work and recording equipment offences.

Table 1

<table>
<thead>
<tr>
<th>Period</th>
<th>Breaks</th>
<th>Rest periods</th>
<th>Driving time</th>
<th>Driving time records</th>
<th>Recording equipment</th>
<th>Lack/availability of records for other work</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013-2014</td>
<td>23%</td>
<td>25%</td>
<td>16%</td>
<td>17%</td>
<td>10%</td>
<td>8%</td>
</tr>
<tr>
<td>2011-2012</td>
<td>26%</td>
<td>24%</td>
<td>19%</td>
<td>17%</td>
<td>8%</td>
<td>6%</td>
</tr>
<tr>
<td>2009-2010</td>
<td>29%</td>
<td>23%</td>
<td>18%</td>
<td>15%</td>
<td>5%</td>
<td>8%</td>
</tr>
<tr>
<td>2007-2008</td>
<td>30%</td>
<td>25%</td>
<td>20%</td>
<td>14%</td>
<td>10%</td>
<td>1%</td>
</tr>
</tbody>
</table>

Fig. 4 Categories of infringements detected at roadside and premises [8]
4.1. Roadside Checks in Slovak Republic

In Slovakia, the Labor Inspectorate inspects the work regime most frequently in cooperation with the Police Corps of the Slovak Republic. The legal regulation of such controls is enshrined in Act No. 125/2006 Coll. on Labor Inspection. The National Labour Inspectorate is a state administration body with nation-wide competence that oversees tasks concerning labour inspection, and manages and supervises the labour inspectorates, and unites and rationalizes their working methods.

Control of the mode of work can be done directly on the road or in the carrier's business. Among the transporters infringements is mainly badly worked out schedule of drivers' work. Often, the carrier organizes the work of drivers so that they are unable to comply with social legislation. In this case, the Labour Inspectorate may impose a fine on the driver from € 1,659.70 to € 16,596.96 [7].

Another serious violation of carriers is, in particular, that they provide premiums for kilometres driven on that day. This means that the carrier endangers not only the safety of the transported goods or persons, but also the safety of the road.

At present, the greatest difficulty in performing such a control is not the provision of space by the carrier. This means that the carrier will not provide adequate premises where the check could take place, where, in particular, all necessary devices and records would be fitted. This access for transport operators makes the work of inspectors more difficult.

In 2016, a total of 10,122 drivers using the recording equipment were checked in Slovakia. In total, this represents 308,602 checked days. Up to 11 867 offences have been identified (Fig. 5). Of the number of checked drivers, the most frequent infringements include:
- non-compliance with the daily minimum rest period - 4,340 drivers;
- exceeding the driving time of the vehicle - 4 079 drivers;
- exceeding the daily driving time of the vehicle - 1 652 drivers;
- non-compliance with weekly rest - 871 drivers;
- non-performance in 28 calendar days - 562 drivers;
- two-week driving time exceeded - 363 drivers [2].

![The most frequent infringements of drivers in 2016](fig5)

When assessing the infringements detected by labor inspectors at roadside inspections and inspections in transport companies, it can be said that the situation in 2017 was almost the same. A total of 11,526 infringements were found in the inspections carried out, with 295,485 working days checked, representing an infringement of 25.6 working days checked (Fig. 6).

Drivers have often been unable to document their activity during the inspection. This was due, in particular, to inadequate driver training in the field of additions when the digital tachograph evaluated the activity as a change as unknown [2].

![The most frequent infringements of drivers in 2017](fig6)
The most serious infringements identified by the inspectors include:

- Unauthorized manipulation of tachographs in order to exclude the tachograph from activity - with the most frequent fraud done on the tachograph being the installation of a magnet on the sensor located on the vehicle's transmission. This happened in 58 cases.
- The driver drives to another tachograph card than his own.
- Employers do not ensure regular downloading of driver card data and vehicle unit data, respectively do not store used record sheets for the specified time.

The Labor Inspectorate has the right to shut down the vehicle for a period of time necessary to complete a rest period, for example, when not adjusting the daily rest. In these inspections, the Labor Inspectorate strives not only to sanction drivers but also to lead them to better use of the digital tachograph. Drivers should, on their own initiative, control all the activities they can input in the tachograph and the tachograph should be able to operate properly.

5. Conclusion

Tachograph fraud is still a growing issue, probably driven by the vestiges of the economic recession and the scale of competition in the road freight sector. It is a fact that some hauliers are sometimes prepared to gamble on not being caught. However, most also surely do so in the full knowledge that they are potentially putting themselves and other road users in risk. That’s not only due to the increased likelihood of drivers failing to react as quickly as they should, or, worse, failing asleep at the wheel due to tiredness. It’s also because vehicles will be exceeding their inspection and maintenance intervals as a result of unrecorded mileage. I believe that inspectors will continue to control drivers to prevent all of the abovementioned infringements, thereby increasing road safety.

Acknowledgements

This paper was developed under the support of project: MSVVS SR - VEGA: 1/0143/17 - Increasing the competitiveness of Slovak carriers providing transport services in road transport in the common market of the European Union.

Contribution has been prepared on the basis of the grant: - VEGA no. 1/0436/18 - Externalities in road transport, an origin, causes and economic impacts of transport measures.

References

Effect of the Pistons Group Replacement with Discs on the Accuracy of Torsional Oscillations Calculations

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Abstract

Limitation of torsional vibration is vitally important in order to avoid damage or even fracture of the crankshaft or other propulsion system components [1, 2]. In calculation scheme usually the internal combustion engine piston and clutch mass are replaced by equivalent discs. Such a scheme is a very rough approximation [3], however, it allows for a significant simplification of critical speed calculations. The aim of the work was to evaluate the impact of such a simplified calculation scheme on the results of calculations in two simplest cases.

KEY WORDS: torsional oscillations, twisting angle, critical frequencies

1. Piston and Connecting-Rod Reduction on Crankshaft

Displacement of piston 3 (Fig. 1):

\[ s = r \left( 1 - \cos \varphi + \frac{r}{2l} \sin^2 \varphi \right), \]

here \( r \) – length of crank 1; \( l \) – length of connecting-rod 2.

![Fig. 1 Simplified engine cylinder scheme](image)

Velocity of piston:

\[ v = r \omega \left( 1 + \frac{r}{2l} \sin 2\varphi \right). \]

The connecting-rod mass is replaced by two point masses \( m_{21} \) and \( m_{23} \) added to its ends. In this case, the kinetic energy of the piston mechanism will be:

\[ \frac{1}{2} J_1 \omega^2 + \frac{1}{2} m_{21} (r\omega)^2 + \frac{1}{2} (m_{23} + m_3) v^2, \]

here \( J_1 \) – moment of inertia of crank with flywheel; \( m_3 \) – mass of piston, \( m_{21} \); \( m_{23} \) – added to crank and to piston mass of connecting-rod.

This mechanism will be replaced by an equivalent disk whose kinetic energy equals the kinetic energy of the whole mechanism:

\[ \frac{1}{2} J_{eq} \omega^2 = \frac{1}{2} J_1 \omega^2 + \frac{1}{2} m_{21} (r\omega)^2 + \frac{1}{2} (m_{23} + m_3) v^2. \]

Consequently:
2. Single-Cylinder Engine with Propeller

The calculation scheme is shown in Fig. 2, where 1 – equivalent disc with moment of inertia \( J_{\text{eq}} \) corresponding to engine; 2 – propeller with moment of inertia \( J_2 \); \( c \) – stiffness of propeller shaft.

Let’s just look at the torsional oscillations of the discs caused by the harmoniously variable torque with the amplitude \( M_0 \) applied to disc 1.

Equations of discs motion:

\[
J_{\text{eq}} \dot{\varepsilon}_1 = M_0 \sin pt - \mu (\omega_1 - \omega_2) - c (\varphi_1 - \varphi_2);
\]

\[
J_2 \dot{\varepsilon}_2 = \mu (\omega_1 - \omega_2) + c (\varphi_1 - \varphi_2),
\]

here \( p \) – cyclic frequency of the torque; \( \mu \) – damping coefficient; \( \varphi_1, \varphi_2 \) – the turning angles of the discs 1 and 2.

\[
\omega_1 = \frac{d\varphi_1}{dt}, \quad \omega_2 = \frac{d\varphi_2}{dt}, \quad \varepsilon_1 = \frac{d\omega_1}{dt}, \quad \varepsilon_2 = \frac{d\omega_2}{dt}.
\]

Dividing the upper equation with \( J_1 \), lower - by \( J_2 \) and subtracting from the upper division the lower, we obtain the differential equation:

\[
\varepsilon_{1,2} = \frac{M_0}{J_1} \sin pt - \frac{\mu}{J_{1,2}} \omega_{1,2} - \frac{c}{J_{1,2}} \varphi_{1,2}.
\]

In Eq. (1): \( \varepsilon_{1,2} = \varepsilon_1 - \varepsilon_2; \quad \omega_{1,2} = \omega_1 - \omega_2; \quad \varphi_{1,2} = \varphi_1 - \varphi_2; \quad J_{1,2} = \frac{J_1 J_2}{J_1 + J_2}.

At the chosen frequency \( p \) and zero start rules, with the small step \( \Delta t \) we numerically integrate the differential Eq. (1) and find the angle of twist \( \varphi_{1,2} \) as a function of time. We continue to integrate so long as the oscillation amplitude stabilizes. By calculating various values of \( p \), we find the critical frequency \( p_{cr} \) at which the amplitude of the oscillation is greatest.
In an example, let's look at a system for which masses, inertia moments and stiffness are found at work [4):

\[ J_1 = J_{eq} = 2.08 \cdot (\sin \varphi + 0.1667 \cdot \sin^2 \varphi)^2 + 28.3 \text{ kgm}^2, \quad J_2 = 88.7 \text{ kgm}^2, \quad c = 50200 \text{ Nm/rad}, \quad \mu = 100 \text{ Nm s}, \quad M_0 / J_1 = 1 \text{ s}^2. \]

Digitally integrating with step \( dt = 0.001 \text{ s} \) found that the \( p_{cr} = 48.5 \text{ s}^{-1} \), and diagram of twisting angle at that frequency is shown in Fig. 3. The oscillation amplitude is 0.000604 rad.

If piston and clutch mass are replaced by equivalent discs with constant moment of inertia \( J_{eq} \), then with the methodology described in work [3], found that \( p_{cr} = 47.5 \text{ s}^{-1} \) and amplitude is 0.00367 rad. Comparing the results obtained shows that in the case under consideration in the scheme with constant disk inertia moments, we obtain a 2% reduction in critical frequency and a 39% decrease in the oscillation amplitude at critical frequencies.

### 3. Two-Cylinder Engine with Propeller

The calculation scheme is shown in Fig. 4, where

1. \( 1, 2 \) – equivalent discs with moments of inertia \( J_1, J_2 \) corresponding to engine, 3 – propeller with moment of inertia \( J_3 \), \( c_1 \) – stiffness of shaft between discs 1 and 2, \( c_2 \) – stiffness of propeller shaft.

#### Fig. 4 Calculation scheme

Let's just look at the torsional oscillations of the discs caused by the harmoniously variable torque with the amplitude \( M_0 \) applied to disc 2.

**Equations of discs motion:**

\[ J_1 \varphi_1 = -\mu_1 (\omega_1 - \omega_2) - c_1 (\varphi_1 - \varphi_2); \]  
\[ J_2 \varphi_2 = M_0 \sin pt - \mu_2 (\omega_2 - \omega_3) - c_2 (\varphi_2 - \varphi_3) + \mu_4 (\omega_4 - \omega_2) + c_1 (\varphi_1 - \varphi_2); \]  
\[ J_3 \varphi_3 = \mu_2 (\omega_2 - \omega_3) + c_2 (\varphi_2 - \varphi_3), \]

here \( \mu_1, \mu_2 \) – damping coefficients of shaft between discs 1 and 2 and of propeller shaft; \( \varphi_1, \varphi_2, \varphi_3 \) – the turning angles of the discs 1, 2 and 3 around the shaft axis.

\[ \omega_1 = \frac{d\varphi_1}{dt}; \quad \omega_2 = \frac{d\varphi_2}{dt}; \quad \omega_3 = \frac{d\varphi_3}{dt}; \quad \varphi_1 = \frac{d\varphi_1}{dt}; \quad \varphi_2 = \frac{d\varphi_2}{dt}; \quad \varphi_3 = \frac{d\varphi_3}{dt}. \]

By dividing the Eq. (2) with \( J_1 \), the Eq. 3) with \( J_2 \), the Eq. 4) with \( J_3 \) and subtracting the second from the first division, and subtracting the third from the second division, we obtain the system of differential equations:

\[ \begin{align*}
\epsilon_{1,2} &= \frac{M_0}{J_2} \sin pt - \frac{\mu_1}{J_1} \omega_{1,2} - \frac{c_1}{J_1} \varphi_{1,2} + \frac{\mu_2}{J_2} \omega_{2,3} + \frac{c_2}{J_2} \varphi_{2,3} \\
\epsilon_{2,3} &= \frac{M_0}{J_2} \sin pt + \frac{\mu_2}{J_2} \omega_{2,3} + \frac{c_1}{J_2} \varphi_{2,3} - \frac{\mu_1}{J_2} \omega_{1,2} - \frac{c_2}{J_2} \varphi_{1,2}. 
\end{align*} \]

In system (5):

\[ \begin{align*}
\epsilon_{1,2} &= \varphi_1 - \varphi_2; \quad \epsilon_{2,3} = \varphi_2 - \varphi_3; \quad \omega_{1,2} = \omega_1 - \omega_2; \quad \omega_{2,3} = \omega_2 - \omega_3 \\
\varphi_{1,2} &= \varphi_1 - \varphi_2; \quad \varphi_{2,3} = \varphi_2 - \varphi_3; \quad J_{1,2} = \frac{J_1 J_2}{J_1 + J_2}; \quad J_{2,3} = \frac{J_2 J_3}{J_2 + J_3}. 
\end{align*} \]

In an example assume that [4]:

\[ J_1 = 2.08 \cdot (\sin \varphi + 0.1667 \cdot \sin^2 \varphi)^2 + 9.69 \text{ kgm}^2; \]
\[ J_2 = 2.08 \cdot \sin(\varphi + \pi) + 0.1667 \cdot \sin2(\varphi + \pi) \] \[ c_1 = 378000 \text{ Nm/rad}; \ c_2 = 50200 \text{ Nm/rad}; \ \mu = 200 \text{ Nm/s}; \ M_0 / J_2 = 1 \text{ s}^{-2}. \]

Numerically integrate with step \( \Delta t = 0.0005 \text{ s} \) system (5) at zero-start conditions by searching for the lowest frequency at which the motion stabilizes to the highest torsional oscillation amplitudes.

It was found that the \( p_{cr1} = 41.9 \text{ s}^{-1}, \ max \phi_{1,2} = 3.1 \cdot 10^6 \text{ rad}, \ max \phi_{2,3} = 92 \cdot 10^6 \text{ rad} \). Diagram of twisting angle is shown in Fig. 5.

If piston and clutch mass are replaced by equivalent discs with constant moment of inertia \( J_1 = 10.74 \text{ kgm}^2, \ J_2 = 29.3 \text{ kgm}^2 \), then was found that \( p_{cr1} = 42.2 \text{ s}^{-1}, \ max \phi_{1,2} = 3.25 \cdot 10^6 \text{ rad}, \ max \phi_{2,3} = 89.4 \cdot 10^6 \text{ rad} \).

Similar integrate with step \( \Delta t = 0.0002 \text{ s} \) was found the highest critical frequency \( p_{cr2} = 219 \text{ s}^{-1}, \ max \phi_{1,2} = 9.5 \cdot 10^6 \text{ rad}, \ max \phi_{2,3} = 3.4 \cdot 10^6 \text{ rad} \) and diagram of twisting angle at these frequency is shown Fig. 6.

Comparing the results obtained by assuming that the inertia moments of the discs are constant and also considering the variance of inertia momentum of the disc, we find that the resonance frequencies differ by less than 1\%, but the oscillation amplitudes vary significantly – at the lowest critical frequency amplitude varying by 3–5\%, but at the higher frequency, the difference is even 35–63\%.

4. Conclusions

Replacing a piston group with a hard disk in single cylinder and two-cylinder engines does not practically affect on calculated critical frequency size.

In single cylinder engines, such a substitution significantly affects (more than 30\%) the calculated amplitude at resonance.

In two-cylinder engines, this substitution has little effect on the calculated amplitude at the lowest critical frequency and has a significant effect (more than 30 – 60\%) at the highest critical frequency.

References

Parameter Optimization of the Locomotive Running Gear

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Abstract

In principle all railway vehicles exhibit lateral oscillations, also called a hunting motion. Stability of hunting motion usually decreases with increasing running velocity and the speed at which hunting motion becomes unstable limits the maximal permissible speed of railway vehicle. When designing a new rolling stock, it is necessary to tune the parameters of a vehicle suspension so that the critical velocity is higher than the maximum operational vehicle speed. In the paper the Nelder-Mead optimization is proposed as the method useful for finding the optimal vehicle parameters at which the maximum critical velocity is reached. This optimization method was applied to the locomotive DS3. The results are presented and discussed in the paper.

KEY WORDS: railway vehicle, stability, high speed, optimization

1. Introduction

High speed is one of the most important today’s requirements for the rail transport [1, 2]. However, the increasing the maximum speed brings also the problem of vehicle stability. Therefore, the parameters of the vehicle suspension should be tuned in order to achieve a vehicle stability in the entire speed range. Taking into the account number of tuned suspension parameters and number of variable parameters like a track condition, wheel profile wear, vehicle loading, etc., the finding of the optimal suspension parameters is a complex and demanding task [3-7]. Tuning the parameters of a vehicle suspension by a trial-error method is inefficient and never leads the optimal solution. In order to find optimal suspension parameters, it is necessary to build reliable and effective algorithms and implement them in computer based optimization methods.

2. Methodology

Optimization methods are effectively applied in various fields of human activity. Particularly significant progress has been made in the design and analysis of large technical systems. When solving a particular optimization problem, it is essential to choose the mathematical method that would lead to desired results with minimal computation cost. The choice of the optimization method is determined both by the formulation of the optimization problem and by the mathematical model of the optimized object. Any single optimization method cannot be applied to solve all optimization problems that arise in practice. Some methods are more, some less general, some methods are specially designed for solving optimization problems with mathematical models of a specific type. The choice suitable optimization method depends on the complexity of optimized object, on the criterion of optimization, on the number of variable parameters and the complexity of the boundary conditions, on the required accuracy of the solution, on the available CPU power, and so on. An important characteristic of any optimization problem is its dimension \( n \), which is equal to the number of variable parameters. Solving high-dimensional problems requires to perform large amount of calculations. Because direct enumeration of the solution is usually complicated and not always possible, the iteration methods are preferably used. To solve the problem of minimizing the function \( f(x) \) downhill methods are used. They are based on constructing a sequence of vectors

\[ x[0], x[1], \ldots, x[n] \]

such that

\[ f(x[0]) > f(x[1]) > f(x[n]) > \ldots \]

An arbitrary point can be chosen as the starting point \( x[0] \), however it is beneficial when \( x[0] \) is located as close as possible to the searched minimum point. The iteration from the point \( x[k] \) to the point \( x[k+1] \), \( k = 0, 1, 2, \ldots \), consists of two stages: the choice of the direction of motion from the point \( x[k] \) and the determination of the step length along this
direction. The downhill methods vary in the way of calculating of those two parameters.

The exact solution of the problem is theoretically obtained after an infinite number of iterations. In practice, the calculation is terminated when certain criteria is met. Such criteria could be for example the step length

\[ |x[k] - x[k-1]| < \varepsilon \]

or the magnitude of the function change

\[ |f(x[k]) - f(x[k-1])| < \gamma \],

where \( k \) is the iteration number and \( \varepsilon, \gamma \) are required values of the accuracy of the solution.

A number of optimization methods exists. For each particular problem it is necessary to choose the method that brings the solution within a required accuracy in the shortest possible CPU time. The quality of the numerical method could be characterized by many factors: the rate of convergence, the CPU time needed for one iteration, the amount of computer memory necessary for the implementation of the method, the class of solved problems, etc.

3. Formulation of the Problem.

At the Dnipropetrovsk Electric Locomotive Plant (NPO DEVZ) in cooperation with German company Siemens, the development and production of the cargo and passenger electric locomotive DS3 (Fig. 1) was carried out [8-10]. The theoretical research, which preceded the production of the new locomotive, was carried out at the Dnipropetrovsk National University of Railway Transport [11-15] and for this purpose the mathematical model of this locomotive has been built. Based on the simulation model the critical velocity, i.e. the speed at which this locomotive becomes unstable, of 175 km/h was calculated.

In this paper the Nelder-Mead [16] method was applied in order to find the optimal suspension parameters and increase the critical velocity of the locomotive DS3. As variable parameters were chosen:

- \( k_{bx} \) [kN/m] stiffness of the primary suspension in the longitudinal direction;
- \( k_{by} \) [kN/m] stiffness of the primary suspension in the lateral direction;
- \( k_{sx} \) [kN/m] stiffness of the secondary suspension in the longitudinal direction;
- \( k_{sy} \) [kN/m] stiffness of the secondary suspension in the lateral direction;
- \( \beta_{bx} \) [kNs/m] viscous coefficient of the hydraulic dampers in the primary suspension;
- \( \beta_{by} \) [kNs/m] viscous coefficient of the hydraulic dampers in the secondary suspension.

The goal of the optimization is to tune the variable suspension parameters in order to achieve the maximal value of the critical velocity. Table 1 summarizes the variable suspension parameters; their actual values; limits and values after the optimization.

![Fig. 1 Locomotive DS3 operated by Ukrzaliznytsia](image)

In this paper the Nelder-Mead method was applied in order to find the optimal suspension parameters and increase the critical velocity of the locomotive DS3. As variable parameters were chosen:

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- \( k_{by} \) [kN/m] stiffness of the primary suspension in the lateral direction;
- \( k_{sx} \) [kN/m] stiffness of the secondary suspension in the longitudinal direction;
- \( k_{sy} \) [kN/m] stiffness of the secondary suspension in the lateral direction;
- \( \beta_{bx} \) [kNs/m] viscous coefficient of the hydraulic dampers in the primary suspension;
- \( \beta_{by} \) [kNs/m] viscous coefficient of the hydraulic dampers in the secondary suspension.

The goal of the optimization is to tune the variable suspension parameters in order to achieve the maximal value of the critical velocity. Table 1 summarizes the variable suspension parameters; their actual values; limits and values after the optimization.

The analysis showed that some of the coefficients tend to the lower limit of the value range \((k_{bx}; k_{by}; \beta_{bx})\); and some to the upper limit \((k_{sx}; k_{sy})\). The decreasing of the longitudinal and lateral stiffness of the wheelset and the bogie frame connection can lead to the increase in the dynamic displacements of the bogie frame relative to the wheelsets; which adversely affects the traction drive operation. The lines of critical velocity level as the functions of coefficients \(k_{bx}\) and \(k_{by}\) were constructed (see Fig. 2). Analysis of the level lines shows that it is quite reasonable to vary the values of \(k_{bx}\) in the range from 40 to 57 MN/m and \(k_{by}\) in the range from 4 to 4.6 MN/m. For this range of primary suspension stiffness; the optimal parameters of the locomotive were calculated as follows: \(k_{bx} = 40\) MN/m; \(k_{by} = 4\) MN/m; \(k_{sx} = 150\) kN/m; \(k_{sy} = 200\) kN/m; \(\beta_{bx} = 0\) kNs/m; \(\beta_{by} = 10\) kNs/m. Its’ critical speed decreased to from 258 to 237 km/h.
Table 1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Actual Value</th>
<th>Parameter limits</th>
<th>Step of Change</th>
<th>Optimal Value</th>
<th>Param. Change %</th>
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<tr>
<td>Primary susp. stiffness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$k_{bx}$ [kN/m]</td>
<td>70000</td>
<td>30000</td>
<td>80000</td>
<td>1000</td>
<td>30000</td>
</tr>
<tr>
<td>$k_{by}$ [kN/m]</td>
<td>5000</td>
<td>3000</td>
<td>6000</td>
<td>100</td>
<td>30000</td>
</tr>
<tr>
<td>Secondary susp. stiffness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$k_{sx}$ [kN/m]</td>
<td>91</td>
<td>50</td>
<td>150</td>
<td>10</td>
<td>150</td>
</tr>
<tr>
<td>$k_{sy}$ [kN/m]</td>
<td>155</td>
<td>100</td>
<td>200</td>
<td>10</td>
<td>200</td>
</tr>
<tr>
<td>Coeff. of primary susp. dampers</td>
<td>$\beta_{bx}$ [kNS/m]</td>
<td>5</td>
<td>0</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Coeff. of secondary susp. dampers</td>
<td>$\beta_{by}$ [kNS/m]</td>
<td>35;8</td>
<td>10</td>
<td>80</td>
<td>10</td>
</tr>
<tr>
<td>Critical velocity</td>
<td>$v_{crit}$ [km/h]</td>
<td>175</td>
<td></td>
<td></td>
<td>258</td>
</tr>
</tbody>
</table>

Fig. 2 The critical velocity level plots with respect to the suspension parameters: a - $k_{bx}$; $k_{by}$; b - $k_{sx}$; $k_{sy}$

Consequently, two more sets of locomotive parameters were defined so finally 5 variant of locomotive suspension parameters were analyzed (Table 2):

1 – data corresponding to a real electric locomotive DS3;
2 – data obtained by Nelder-Mead optimization;
3 – data obtained by Nelder-Mead optimization within limits defined by the level lines analysis;
4; 5 – additional data.

Table 2

<table>
<thead>
<tr>
<th>Variant</th>
<th>$k_{bx}$ [kN/m]</th>
<th>$k_{by}$ [kN/m]</th>
<th>$\beta_{bx}$ [kNS/m]</th>
<th>$k_{sx}$ [kN/m]</th>
<th>$k_{sy}$ [kN/m]</th>
<th>$\beta_{by}$ [kNS/m]</th>
<th>$v_{crit}$ [km/h]</th>
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<td>70 000</td>
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<td>5</td>
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<td>35;8</td>
<td>175</td>
</tr>
<tr>
<td>2</td>
<td>30 000</td>
<td>3 000</td>
<td>0</td>
<td>150</td>
<td>200</td>
<td>10</td>
<td>258</td>
</tr>
<tr>
<td>3</td>
<td>40 000</td>
<td>4 000</td>
<td>0</td>
<td>150</td>
<td>200</td>
<td>10</td>
<td>237</td>
</tr>
<tr>
<td>4</td>
<td>60 000</td>
<td>4 000</td>
<td>5</td>
<td>300</td>
<td>220</td>
<td>10</td>
<td>246</td>
</tr>
<tr>
<td>5</td>
<td>40 000</td>
<td>4 000</td>
<td>0</td>
<td>200</td>
<td>300</td>
<td>12</td>
<td>258</td>
</tr>
</tbody>
</table>

Fig. 3 Dependence graphs of the horizontal lateral displacements of the axle-box $\Delta_{by}$ relative to the bogie frame on the running speed of the locomotive
The graph on the Fig. 3 shows the dependence of the amplitude of dynamic lateral displacements of the bogie frame relative to the wheelsets \( A_{\text{bog}} \) on the running speed. The line number corresponds to the number of variant in Table 2.

The graph on the Fig. 3 shows that starting from the running speed of 160 km/h (and 140 km/h for the line 2) the lateral displacements of the axle-box relative to the bogie frame increase faster than that below this value. This indicates that after the locomotive exceeds the speed of 160 km/h on the straight track section high amplitudes of bogie frame lateral motion may arise. As can be seen from the Fig. 3; the locomotive DS3 with the parameters corresponding to the variant 5 has the smallest values of the lateral displacements of the axle-box relative to the bogie frame. Its critical speed with such parameters is 258 km/h.

4. Conclusions

In order to establish the maximum critical velocity of the mainline electric locomotive DS3; parameters of its running gear were optimized using the Nelder-Mead method. The parameters that mostly influence the magnitude of the critical velocity were revealed and tuned and thus a significant increase in the critical velocity was achieved. The Nelder-Mead optimization method has been found applicable and useful for tuning and optimizing suspension parameters of railway running gears. This optimization method and obtained results could be applied by designers of railway vehicles.

References

Security Research and Safety Aspects of Natural Gas Facilities in Slovak Republic

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Abstract

Currently the security of energy supplies has become an inherent issue. The consumption of natural gas increased worldwide, European import dependence is reaching the record levels and many geopolitical conflicts are based on this growing dependency. Due to those aspects, many countries started various security research to find out the optimal solution for this arising problem. Enormous dependency on natural gas shows that it is necessary not only to diversify, but also to protect gas infrastructure, which is completed from various facilities and objects, from destruction or damage that would have serious consequences for the surrounding area and the population.

This article addresses the above listed problems and offers some recommendations to increase the security level of gas infrastructure of the Slovak Republic.

KEY WORDS: security, safety, natural gas facilities, natural gas infrastructure

1. Introduction

Despite the global development of modern technologies that enable the active use of innovative energy sources, the gas industry remains a dominant part of the smooth functioning of households and of various manufacturing plants and factories. Without hydrocarbons, the world energy system cannot exist. Natural gas also serves as a fuel and is actively used in the automotive and aviation industry.

It is generally known that natural gas, even if it is not poisonous, has properties that pose an enormous risk. Natural gas is unbreathable and, with greater leakage, it could push oxygen out of closed premises, and thus cause suffocation of people being there. Another risk is its explosiveness. When mixed with air, natural gas is a highly flammable mixture, and a small spark is enough for explosion.

The use of natural gas inevitably forces explosions, burning clouds, fires or even accidents; this affects the availability of natural gas and the smooth operation not only of natural gas enterprises, but also of households and other industrial facilities that are dependent on natural gas supply and their breakdown could have technological or economic consequences.

2. Gas Industry in the Slovak Republic

Gas industry is one of the four sub-sectors of the Energy sector within the critical infrastructure of the Slovak Republic (hereinafter referred to as SR), and it is an inseparable part of it. The Gas Industry sub-sector mainly includes the import, mining, transportation, distribution and storage of natural gas. The elements of this sub-sector are primarily the objects of mining network, the distribution network including the control stations, the transmission network, in particular transit pipelines, direct gas pipelines, compressor stations and national valve stations, gas storage facilities, and domestic deposits from which natural gas is being extracted. The Gas Industry subsector includes the provision of the heating industry with energy sources. It is made up of objects of central heating units, connections supplying the energy and water units, and transmission and distribution networks [1].

The structure of the Natural Gas sub-sector can also be referred to as a Gas Infrastructure (hereinafter referred to as GI). The GI consists of interconnected pipeline networks (gas pipelines) and other gas facilities that serve primarily to transport, store, and distribute the natural gas to its final consumers.

The basic components are defined in the source [2] as follows:

- transmission pipelines for the transport of natural gas and bio gas that form part of a network, which mainly contains high-pressure pipelines, excluding high-pressure pipelines used for upstream or local distribution of natural gas;
- underground storage facilities connected to the above-mentioned high-pressure gas pipelines;
- reception, storage and regasification or decompression facilities for liquefied natural gas (LNG) or compressed natural gas (CNG);
- any equipment or installation essential for the system to operate safely, securely and efficiently or to enable bi-directional capacity including compressor stations.
3. Crisis Situations and Emergencies in the Gas Industry of the Slovak Republic

Emergency in the gas sector and its level in the defined territory or on part of defined territory is declared and recalled by the distribution network operator, which is based on a decision of the ministry fulfilling tasks of the gas dispatching in the defined territory, in public mass media and by means of dispatching management.

Crisis situation in the natural gas industry can be caused by:
- **Natural disasters**: depending on the territorial scope and severity of natural disasters, natural gas transport between the producer, the transmission system operator, the distribution system operators, the underground storage facility operators. These are particularly threats to upper layers of watercourses caused by gale-force winds and floods in places where soil is washed away or landslides occur. Implementation of consistent measures to secure those critical areas considerably reduces the level of risk they bear. Natural disasters can cause both direct damage to the gas company (damaging or destroying the facility) and an indirect damage caused by a subsequent power outages concerning natural gas customers affected by the disaster [3].
- **Anthropogenic threats**: in normal operation, the extent of these risks can be eliminated by strict adherence to the safety regulations, technological procedures, preventative controls and training of the attending staff. In the case of international tensions, natural gas industry can be under a serious risk of terrorism. Depending on the nature of the terrorist threat or the completed terrorist act, natural gas supplies may be limited or interrupted [3].
- **Technogenic threats**: in the natural gas industry, there can be following technogenic threats:
  - external & internal corrosion;
  - stress corrosion cracking;
  - manufacturing production errors;
  - welding defects;
  - defects of technical equipment;
  - mechanical damage from third party intrusion;
  - operational errors;
  - external environmental impacts [3].

The destruction of the natural gas system operational facilities has a direct impact on the reliability of gas supply in the SR. The higher the pressure level of the natural gas pipelines affected, the greater is its general impact on natural gas supply. In the case of the transit pipelines there is a rule that the closer to the East the accident site is, the larger territory will be affected by the limitation or interruption of the natural gas supply. Thus, an accident at the underground storage has a major impact on the national natural gas supply during the winter months.

In the case of a gas supply disruption, a state of emergency (hereinafter referred to as SoE) in the gas industry may be declared on the territory of the Slovak Republic that is considered as an extraordinary situation in the energy sector. Threshold for the SoE declaration in the gas industry is the difference between the sources and the offtake of natural gas that is a situation where there are insufficient resources to meet the requirements of the baseline offtake rate [10]. In the defined area or its part, depending on the extent of the emergency event, dispatching management implements restrictive measures that aim to eliminate the difference between the sources and the offtake of natural gas.

They are:
- a) limiting offtake rates;
- b) emergency offtake rates;
- c) limiting heating curves.

The baseline natural gas offtake rate is a situation when the natural gas offtake fully corresponds to a contractually agreed amount. Limiting offtake rates are derived from the baseline offtake rate and represent a daily percentage reduction of the contractually agreed amount of natural gas. The emergency offtake rate is rate no.10, when the level of natural gas offtake is zero. Under its implementation, the natural gas supply is interrupted for all customers. The limiting heating curves are derived from the baseline heating curve and represent a reduction in the daily gas offtake compared to the baseline heating curve, they determine the amount of the daily natural gas offtake in relation to the contractually agreed quantity of natural gas [4].

When the state of emergency is being terminated, the natural gas companies are obliged to proceed according to the approved emergency plans and according to the instructions of the natural gas dispatching management, or respectively to their own dispatching. State of emergency termination measures are implemented as separate technical procedures aimed to restore the proper operation of the transmission and distribution network in the shortest possible period. Ministry of Economics of the SR does not intervene in emergency termination measures; it can only request the feedback from the gas dispatching management on the implementation of these measures and the termination of the state of emergency. Ministry of Economy informs on the feedback request informally through public means of notification [4].

4. Risk Assessment in the Gas Industry of the Slovak Republic

In the area of risk assessment in gas industry, the Pipeline Integrity Management (PIMS) methodology, among others, is implemented using risk theory as a tool for assessing the safety and reliability of its operations including the consequences of pipeline integrity failure, property, population safety, the environment, and so on. [5].

In order to ensure the integrity, reliability, security and efficient operation of the transmission network, Slovak
transmission system operator - Eustream, a.s. - performs inspections, preventive repairs and maintenance of natural gas facilities according to established criteria. Maintenance is performed on the basis of the results of diagnostic works at the level of the compressor stations as well as on the linear part of the pipeline network with a quality level corresponding to the European standards. Removal of deficiencies detected by external and internal gas pipeline inspections is also implemented by the means of repairs or reconstructions of natural gas facilities. The transmission system operator plans to carry out repairs to the extent necessary for the required level of serviceability of the transmission network.

Inspections, preventive repairs, and maintenance of gas facilities have been carried out within the framework of the largest distribution network of natural gas operated by the SPP company, which consists of a complex of natural gas distribution facilities including the pipeline system and technological facilities under the stipulated criteria that ensure its integrity, reliability and security. The elimination of damages detected by external and internal gas pipeline inspections has been implemented by the means of repairs or reconstructions of gas facilities. Damages were detected primarily during the execution of earthworks, which are their most frequent source and represent an important security risk.

For the safe and efficient operation of the control stations, these stations have a monitoring system allowing the transmission of data to the natural gas dispatching. The monitoring system enables immediate intervention with optimization of the network management in the case of a breakdown or accident until the problem is rectified.

In order to prevent accidents and emergencies in the natural gas industry, it is necessary to observe the legislative and technical standards and organizational measures, to evaluate operating conditions, to re-evaluate all events, to assess the state of technical facilities, i.e. carry out the risk assessment. However, it is not enough to assess the risk, it needs to be reduced.

The company NAFTA, a. s. sought a methodology providing consistent rules for assessment of the risk of a major operational accident. It has opted for an Accidental Risk Assessment Methodology for Industries (ARAMIS) special methodology that assesses the risks of industrial accidents and combines the strengths of determinism and other approaches to risk assessment. The ARAMIS methodology was developed as a general methodology designed to establish a single risk assessment process in all companies acting under the Seveso II directive. The generic nature of methodology also makes it possible to establish a mutual comparison of the "riskiness" of enterprises regardless of the sector to which they belong. In order to achieve a relevant risk analysis, it is therefore necessary to specify it for use in the gas sector facilities. For this reason, the methodology described below corresponds to the specifications of the ARAMIS methodology in the Natural Gas sub-sector [6].

ARAMIS methodology has been optimised for the needs of NAFTA, a. s., in particular there were modified the parameters and criteria used in the general methodology in order to meet the conditions of the technological facilities used for the storage of natural gas. The outcome of the assessment of the risks of an industrial accident is the determination the risk level, suggestion of the appropriate measures, and thus priority definition for the company's eventual investment plans in the area of enhancing its operational safety [6].

In the gas industry, we may also meet the implementation of the residual risk maps. In the case of such industrial facilities as natural gas ones, it is not possible to achieve a zero risk. Therefore, the natural gas network operator must also know the level of the residual risk.

The social acceptability of the risk of a major industrial accident in terms of assessing the potential threat to the life of one or more persons is defined by the acceptable likelihood or the frequency of the occurrence of a major industrial accident. The conclusions of the assessment of the social acceptability of risk are reflected in the draft measures, in particular in the area of organisational measures, technical and technological changes, and the emergency plan. The emergency plan is also the basis of communication with the state administration and local self-government bodies about the potential risks of a major industrial accident, its impact and measures to protect the population and the environment [6].

At present, a system for the assessment of the technical condition of the natural gas facilities, named HTS, is used in Slovakia. This system is aimed to assess facilities based on the risk factors grouped in 12 categories according to the type of facility. The principle of this system lays in the assessment of facilities based on the assigned weighed value identifying the real state and the position of the analysed facility under operating conditions. This system enables the network operator to record, generate statistics and individual data on the technical and operational state of the natural gas facilities. The methodology used by this system is grounded on the precautionary principle, which means that in case of concern about occurrence of the emergency, the evaluator has the opportunity to assess the natural gas facility as if the emergency were real. To improve the prediction of the technical state, the methodology provides the calculation of the projected HTS index [7].

The natural gas facilities are evaluated by the operating technologist once a year in five categories: high-pressure gas pipelines (HPGP), medium pressure gas pipelines (MPGP) and low-pressure gas pipelines (LPGP), control stations, anti-corrosion protection systems and regulating systems. Each category of gas equipment has its set of segments created by the function it performs and a set of other specific parameters, for example, a local network in a village or city area, a maintenance area, a HPGP route, a control station. Outputs of this kind of qualification rating are:

- a list of natural gas facilities under the HTS index;
- the HTS assessment form of the natural gas facility according to the defined output in the SAP PM HTS system;
- the frequency of selected activities for the Maintenance and Technical Control Plan;
- a list of the assets cards of the relevant technical facility;
- a list of leaks and failures from the reporting database;
- request to develop a ZP [7].

The regular assessment of the technical condition of natural gas facilities and correction of anomalies in the distribution network through the means of modern asset management are an important part of various standards and internal regulations. The HTS methodology is designed to improve management and analytical processes, to integrate all available data and information related to the integrity of the distribution network and to assess the risk factors of the pipeline segments that may have a negative impact on its reliability and safety. Managing the process with the help of the HTS methodology allows to develop the damage prevention programs through the more detailed monitoring of individual risk factors, highlights the possibility to improve the diagnostics programs that are aimed at corrosion, material errors, third party activities and other negative manifestations and include operational and maintenance activities. The introduction of the HTS quality management system has provided a powerful tool to monitor the economic benefits of the HTS methodology, the effectiveness of elimination measures aimed at network integrity and the prolongation of the productive age of the natural gas facilities in the distribution network [7]. The results of the technical condition evaluation are once a year inserted into the GIS system - Fig. 1.
the risk of intentional human intervention.

Currently, the security of the natural gas infrastructure as part of the Energy Sector within the Critical Infrastructure System is playing an important role in environmental change and emerging threats. It should be kept in mind that the risk assessment process is difficult to apply to the system as large as the natural infrastructure, so it is appropriate to focus on the elements of this infrastructure, which are the natural gas facilities. From the point of view of the integrity and security of the overall system constituted by a system of interconnected networks and nodes, it is necessary to assess the elements of this system from the point of view of their significance, which may vary significantly. The importance of the elements of the natural gas infrastructure may depend on a number of factors, such as the size of the element, the size of the territory on which the element is functioning, the number of other elements which functionality and reliability are directly dependent on the element under consideration, etc. Damage or complete destruction of the more significant element will logically lead to more significant consequences and damage.

5. Conclusions

The explosion of the natural gas terminal which occurred at the end of 2017 in the Eastern Austria near the Slovak border caused a chain of consequences. Natural gas supplies to Italy, Slovenia, and Croatia have been interrupted temporarily, Italy has declared a state of emergency due to a lack of gas supplies. Prices for natural gas in Italy rocketed almost by 100%. This accident also affected the prices of the natural gas in Great Britain, where prices of this commodity increased by 35%. This accident highlights the importance of security in the natural gas sector. Taking into account the current situation on the natural gas market and the enormous dependence on natural gas imports not only in Slovakia but also globally, I consider the issue of assessing the risks and resilience of the natural gas facilities to be very topical and requiring the public attention.

It is therefore necessary to develop not only the procedures and tools to define the most important elements of the gas infrastructure but also the effective procedures for risk assessment and evaluation of the resilience level to relevant threats for individual typological objects and systems, regardless which part of the natural gas infrastructure system they are located in.

I plan to address the issues of risk assessment in the natural gas industry in Slovakia in my dissertation thesis, which focuses on the risks of natural gas facilities and increase of the resilience of critical infrastructure in the natural gas subsector. The main goal of the dissertation is to propose a way to assess the significance of individual typological objects of natural gas infrastructure. The proposed evaluation procedure (methodology) should include all steps implemented in the process of assessing the safety risks of individual typological units of gas infrastructure.

The expected result of the dissertation is a complex system for evaluating the risks of natural gas facilities and linear units of natural gas infrastructure that will allow to reveal the significance of the individual elements and its most vulnerable locations, the damage or outage of which would have an impact on other sectors of critical infrastructure, industry and population.

It is necessary to develop procedures and tools not only to identify the most important elements of the gas infrastructure but also effective procedures for risk assessment and evaluation of the resilience level to relevant threats for individual typological objects and systems, regardless which part of the natural gas infrastructure system they are located in. The outcome of the risk assessment process should be solutions such as the need to monitor the natural gas facilities, to increase the current level of physical protection, or to eliminate the risk factors affecting the natural gas facility.

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Pilots’ Performance in Changing from Analogue to Glass Cockpits

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Abstract

This article discusses the problems of pilots’ performance when displaying the flight and navigation data changes from an analogue to a glass cockpit depiction. We have focused the research activities on the performance of pilots who have flown less flight hours (approx. up to 100 flight hours) only with an analogue display, in their short aviation career, or who were absolute beginners and had only basic experience with instrument flying. The task of the research is to confirm a hypothesis that display changes will have less negative impact on pilots’ performance if a new training and practice method using flight simulators precede the changes. For measuring the performance of pilots we have created two methods: precision of the piloting techniques and power load level. Research flights were conducted on a flight simulator and on a real aircraft. During the research, two groups of pilots were being compared. The first group of pilots completed the display changes according to current procedures and the second group of pilots according to the new training method. This article presents the research methodology and the results of measurements.

KEY WORDS: pilot, pilotage, human performance, aircraft, cockpit, simulator, stress, workload

1. Introduction

This paper is considered for an output of a project named as “Research on pilots training methods by utilization of flight simulators”. ITSN project code is 2622022016. The project was cosponsored by EU funds and carried out by Education training & consulting company (ET&Cc) in cooperation with The Faculty of Aeronautics of Technical University in Kosice (LF Tuke).

A strategic goal of the project was characterized as a research of the security increase in civil aviation realized by ET&Cc. The research process utilized an effective cooperation with a research and development institution of LF Tuke and a follow-up implementation of the findings into commercial environment [9].

After analysing current simulation trainings for pilots it proves that the display transmission of basic flight data, navigation data and engine outputs on a cockpit displays have an influence on pilots performance. There are piloting techniques effected and those are introduced in forms of deviations on an actual airplane position and actual flight trajectory off standard flight and navigation parameters [10]. Current trends in display of core flight, navigation and engine data on airplanes instrument board is heading to a consistent switch from the standard analog ones to glass cockpits. On principle, later ones can considerably change the display concept of outputs needed for pilotage and aircraft navigation.

It was anticipated that data display has different influence on various pilot categories and depends on pilots trainings, number of flight hours, career time and etc. Some the most significant influence on pilots performance resulting from data displays transformation were hypothesized for following combinations:

− switch from analog to glass cockpits and its influence on analog cockpit flown pilots;

− switch from glass cockpits to analog and its influence on glass cockpits flown pilots;

− cockpits desk switch to any of above displays and their influence on any cockpit flown pilots. However, the switch is enforced with some long term perspective.

Following up analysed outputs, hypothesis were designed for the project research. The hypothesis represents new knowledge in below areas:

“Following up analysed outputs we anticipate that transformation of an airplane cockpit from analog to glass one has a negative influence on pilots performance. This refers to pilots who during a short pilot career had analog cockpit experience only, flew less flight hours (app. up to 100 flight hours) or they are novice and have only basic experience with instrument flights”

This pilots category will form 1st test sample and called as beginners. We assume, prior to the display change, the new training method will be passed then the switch will allow for less negative impact on the pilots performance [10].
During the research, the influence on pilots’ performance after the transmission of flight and navigation data display was assessed by measuring the precision on pilotage technique and pilots’ workload. The pilot workload level was defined for the project use as a deviation of defined psycho-physiological pilot parameters off earlier defined designator parameters for the same pilot.

Measuring pilots’ performance by measuring of workload level and stress factors on pilots has already been attracting time long attention. Most of studies in this research area have been dealing with a psychological load on a flight crew. Various studies admitted that increasing the workload level might result in a faulty perception, lack of attention or weak output data processing. Mentioned workload factors gives a negative influence on the safety in civil aviation. Today’s statistics show a fact that the human factor plays a key role for airplane crashes.

One of 1st studies were carried out at an air base in Arizona in 1977. The study was focused on stress producing factors and their influence on pilots training. Their experiment followed up studies which confirms the stress factor on pilots behaviour changes and culminates in faulty pilot decisions. Some similar studies proved evocation and presence of a stress in piloting, respectively in simulator training. [1, 3, 6, 7].

Another study focused on evaluation of stress and its factors on any professional duty performance. A variety of daily life factors were considered among others interpersonal relations, family matters, life style etc. Research findings proved an urgency for programmes of the stress control and stress resistance which will lead to operational improvements of crew performance [8]. In Wilson and Fisher study we find measurements variety of pilots physiological parameters which define stress load at certain flight sequences. The study was dedicated to forming appropriate physiological parameters and their combinations for detecting pilot conditions at certain flight phases (a level of pilots workload).

Most studies applied a couple of different parameters for the measurement of psychological and physical load among others heart rate, breath rate, eye blinks, myopotential temperature, blood pressure etc. [2-5, 8, 11-14]. Parameter outputs were evaluated by different methods of data collections and evaluation by various sensors types application.

Nowadays, there is no stable method for evaluation of the physical and psychical load although the issue of a stress load evaluation in aviation seems to be quite elaborated. Above all, an abstention of methods applicable on different types of aviation positions that can eliminate stress load and performance increase factors is notable.

2. Methodology

The tested pilots group for the research was completed of pilots with a short flying career path, experienced in analog cockpit displays and flew less flight hours (app. up to 100 flight hours), or there were novice only with a basis instrument flight experience.

The sample group represented 20 pilots. The half of the group passed a conversion from analog to glass cockpits after an implementation of the current training standards recommended for the switch of analog to glass cockpits displays.

Another half of the tested group passed the conversion to glass cockpits displays after an implementation of the new training standards recommended for the switch of analog to glass cockpits displays.

Mentioned the new methodology was exclusively designed for this project research. While relocating pilots to the Groups A and B, a special attention must have been paid to an equal separation according pilots’ past flying experience and their performance, the measured findings from previous experiments applied here.

In this paper an influence of flight and navigation data display switch was reviewed by measuring of the precision of pilotage technique and level of pilots workload. The precision of pilotage was in this project defined as a divergence between real flight parameters at certain flight phases off standard flight parameters.

The workload level in this project was defined as a divergence of selected psycho-physiological pilots parameters off defined assumed level of those parameters for the same pilot.

For this research all flight phases practiced by airplanes and flight simulators (pilotage in working zone) were arranged like instrument flights involving some partial utilization of a normal horizon flight. (proportionally app. 80% instrument flight and 20% normal horizontal flight)

At the beginning of the research, a theoretical lesson in basis of pilotage was given for the novice group (the lesson time was 1 hour). Next, the group was familiarized with a simple pilotage technique by an analog display flight simulator (the lesson time was 1 flight hour).

The 1st measuring of pilots’ performance was arranged upon completing the first practice on the flight simulator:
- Through deviations identified in real flight parameters at defined flight phases off standard parameters during a simulator flight equipped with analog display (the lesson time 1 flight hour). Deviations were recognized during:
  ➢ rectilinear horizontal flight – a deviation measured in height and flight track;
  ➢ horizontal turn – a deviation measured in height, slope, and flight track;
  ➢ increasing and decreasing turn – a deviation measured in speed, slope and flight track.
- Contemporaneously by a measurement of the precision of pilotage technique, there were recorded defined psycho-physiological pilots parameters utilized in quantification of pilots workload:
  ➢ Heart rate;
  ➢ Breath rate;
  ➢ Body temperature;
  ➢ Body activity (3D actogram);
Research Findings

The chapter deals with a performance measured findings definite for the precision pilotage technique for a pilot/individual number 1 out of the Group A as well as overall findings out of the Group A and B and their comparison.

Below reported data came from a flight instructor and formed in an absolute deviation off defined flight parameters namely a magnetic course (Km), height (H), vertical speed (Vv) and slope (β). Instructor’s data recorded were compared with flight records and meets criteria for an evaluation of the pilotage precision. Each measurement had 3 manoeuvre series. And every serie included following manoeuvres: rectilinear horizontal flight (a derivation verification off defined a course Km and height H); horizontal 360° turn by β 30° slope (a derivation verification off defined slope β and height H); ascending 180° turn by 15° slope and vertical speed of 500ft/min (a deviation verification off defined slope β and vertical speed Vv); 180° descending turn by a slope of 15°and a vertical speed 500 ft/min (a deviation verification off defined slope β and vertical speed Vv).

The hypothesis number 1 affirmation or negation has been explained in the Fig. 1. The Fig. 1 shows a comparison of the pilot number 1 performance – a comparison of an adaptation period by the simulator training focused on the switch from analog to glass cockpit displays by application of the current training standards (a comparison of deviations measured during 2nd and 5th measurement of the performance).

The hypothesis number 1 affirmation or negation has been explained in the Fig. 2. This represents a comparison of pilot performance number 1 – a comparison of adaptation period during live flying from the analog display to glass cockpit display by applying the current training methods (a comparison of deviations measured during the 4th and 6th performance measuring).
Green background reflects a lower deviation – performance increase
Red background reflects a higher deviation – performance decrease
Blue background reflects a standard deviation – stable performance

Table 1

<table>
<thead>
<tr>
<th>Pilot number 1 precision pilotage – simulator flights</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Serie</td>
</tr>
<tr>
<td>HPL</td>
</tr>
<tr>
<td>360</td>
</tr>
<tr>
<td>s180</td>
</tr>
<tr>
<td>k180</td>
</tr>
<tr>
<td>2. Serie</td>
</tr>
<tr>
<td>HPL</td>
</tr>
<tr>
<td>360</td>
</tr>
<tr>
<td>s360</td>
</tr>
<tr>
<td>s180</td>
</tr>
</tbody>
</table>

Table 2

<table>
<thead>
<tr>
<th>Pilot number 1 precision pilotage – live flights</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Serie</td>
</tr>
<tr>
<td>HPL</td>
</tr>
<tr>
<td>360</td>
</tr>
<tr>
<td>s180</td>
</tr>
<tr>
<td>k180</td>
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<td>2. Serie</td>
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<tr>
<td>HPL</td>
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<tr>
<td>360</td>
</tr>
<tr>
<td>s180</td>
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<tr>
<td>k180</td>
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<tr>
<td>360</td>
</tr>
<tr>
<td>s180</td>
</tr>
<tr>
<td>k180</td>
</tr>
</tbody>
</table>

A conclusion on the pilotage precision technique for the pilot number 1:

A performance in the comparison in the Fig. 1 decreased 10x, balanced 5x and increased 9x.

The performance shows full decrease in this comparison.

A performance in a comparison in the Fig. 2 decreased 12x, balanced 4x and 8x increased.

The overall performance in this comparison was decreased.

The measurement applied on the subject number 1 affirms the first part of the hypothesis number 1 – the pilot performance teamed up to the Group A (after the switch from analog to glass cockpit display by applying the current procedures dedicated for such transmission) decreased in case of a simulator practice as well as live flying.

Tables 3 and 4 report final data for the Group A achieved during the simulator and live flying.

The performance of 7 pilots out of 10 teamed up in the Group A decreased, 1 pilot achieved balanced performance and 2 pilots achieved increased performance. Regarding evaluated the Group A manoeuvres during the simulator practice, the performance decreased in 103 manoeuvres (42,92%), balanced in 54 manoeuvres (22,50%) and increased in 83 maneuvers (34,58%) (Fig. 1).

The performance of 7 pilots out of 10 teamed up in the Group A decreased, 1 pilot achieved balanced performance and 2 pilots achieved increased performance. The current training procedures applied. Regarding evaluated Group A manoeuvres during the live flights, the performance decreased in 126 manoeuvres (52,50%), balanced in 18 manoeuvres (7,50%) and increased in 96 manoeuvres (40,00%) (Fig. 2).

The overall Group A performance during the switch from analog to glass cockpit display by the simulator practice as well as live flights while applying the current training standards, decreased and affirms the first part of the hypothesis number 1 – the performance of the Group A pilots (during the switch from analog to glass cockpit display by the simulator practice as well as live flights while applying current training standards) decreased.

The Tables 5 and 6 reports summary data for the Group B during the simulator practice and live flights.

The performance of 3 pilots out of 10 teamed up in the Group B decreased, no pilot achieved balanced performance and 7 pilots achieved increased performance. Regarding evaluated Group B manoeuvres during the simulator practice, the performance decreased in 58 manoeuvres (24,17%), balanced in 73 manoeuvres (30,41%) and increased in 109 manoeuvres (45,42%) (Fig. 3).
### Table 3: Group A performance – simulator flights

<table>
<thead>
<tr>
<th>Subject number</th>
<th>Performance decrease</th>
<th>Balanced performance</th>
<th>Increased performance</th>
<th>Summary of performance evaluation</th>
</tr>
</thead>
<tbody>
<tr>
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<td>10</td>
<td>5</td>
<td>9</td>
<td>Decrease</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
<td>3</td>
<td>10</td>
<td>Decrease</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
<td>8</td>
<td>5</td>
<td>Decrease</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>9</td>
<td>9</td>
<td>Increase</td>
</tr>
<tr>
<td>5</td>
<td>12</td>
<td>3</td>
<td>9</td>
<td>Decrease</td>
</tr>
<tr>
<td>6</td>
<td>12</td>
<td>5</td>
<td>7</td>
<td>Decrease</td>
</tr>
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<td>5</td>
<td>3</td>
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<td>Increase</td>
</tr>
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<td>5</td>
<td>3</td>
<td>Decrease</td>
</tr>
<tr>
<td>9</td>
<td>13</td>
<td>3</td>
<td>8</td>
<td>Decrease</td>
</tr>
<tr>
<td>10</td>
<td>7</td>
<td>10</td>
<td>7</td>
<td>Balanced</td>
</tr>
<tr>
<td><strong>Total</strong></td>
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<td><strong>54</strong></td>
<td><strong>83</strong></td>
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</tr>
<tr>
<td><strong>%</strong></td>
<td><strong>42.92%</strong></td>
<td><strong>22.50%</strong></td>
<td><strong>34.58%</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 1** The Group A, performance on simulator flights

- Decreasing performance: 35%
- Balanced performance: 22%
- Increase performance: 4%

### Table 4: Group A performance – live flights

<table>
<thead>
<tr>
<th>Subject number</th>
<th>Decreasing performance</th>
<th>Balanced performance</th>
<th>Increasing performance</th>
<th>Overall performance evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12</td>
<td>4</td>
<td>8</td>
<td>Decrease</td>
</tr>
<tr>
<td>2</td>
<td>17</td>
<td>2</td>
<td>5</td>
<td>Decrease</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>2</td>
<td>7</td>
<td>Decrease</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>2</td>
<td>10</td>
<td>Decrease</td>
</tr>
<tr>
<td>5</td>
<td>15</td>
<td>1</td>
<td>8</td>
<td>Decrease</td>
</tr>
<tr>
<td>6</td>
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<td>2</td>
<td>11</td>
<td>Balanced</td>
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<td>2</td>
<td>10</td>
<td>Decrease</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>126</strong></td>
<td><strong>18</strong></td>
<td><strong>96</strong></td>
<td></td>
</tr>
<tr>
<td><strong>%</strong></td>
<td><strong>52.50%</strong></td>
<td><strong>7.50%</strong></td>
<td><strong>40.00%</strong></td>
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</tr>
</tbody>
</table>

**Fig. 2** The Group A, performance on live flights

- Decreasing performance: 52.50%
- Balanced performance: 7.50%
- Increase performance: 40.00%

### Table 5: Group B performance – simulator flights

<table>
<thead>
<tr>
<th>Subject number</th>
<th>Decreasing performance</th>
<th>Balanced performance</th>
<th>Increasing performance</th>
<th>Overall performance evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
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<td>4</td>
<td>16</td>
<td>Increase</td>
</tr>
<tr>
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<td>7</td>
<td>5</td>
<td>12</td>
<td>Increase</td>
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<td>14</td>
<td>Increase</td>
</tr>
<tr>
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<td>15</td>
<td>Increase</td>
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<td>7</td>
<td>11</td>
<td>Increase</td>
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<tr>
<td>16</td>
<td>3</td>
<td>12</td>
<td>9</td>
<td>Increase</td>
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<tr>
<td>17</td>
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<td>Increase</td>
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<td>11</td>
<td>5</td>
<td>Decrease</td>
</tr>
<tr>
<td>19</td>
<td>12</td>
<td>7</td>
<td>5</td>
<td>Decrease</td>
</tr>
<tr>
<td>20</td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>Decrease</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>58</strong></td>
<td><strong>73</strong></td>
<td><strong>109</strong></td>
<td></td>
</tr>
<tr>
<td><strong>%</strong></td>
<td><strong>24.17%</strong></td>
<td><strong>30.41%</strong></td>
<td><strong>45.42%</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 3** The Group B, performance on simulator flights

- Decreasing performance: 24.17%
- Balanced performance: 30.41%
- Increase performance: 45.42%

### Table 6: Group B performance – live flights

<table>
<thead>
<tr>
<th>Subject number</th>
<th>Decreasing performance</th>
<th>Balanced performance</th>
<th>Increasing performance</th>
<th>Overall performance evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
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<td>1</td>
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<td>Increase</td>
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<tr>
<td>12</td>
<td>1</td>
<td>3</td>
<td>20</td>
<td>Increase</td>
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<td>6</td>
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<td>Increase</td>
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<td>Increase</td>
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<td>Increase</td>
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<td>11</td>
<td>Increase</td>
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<td>6</td>
<td>2</td>
<td>16</td>
<td>Increase</td>
</tr>
<tr>
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<td>1</td>
<td>4</td>
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<td>Increase</td>
</tr>
<tr>
<td>20</td>
<td>3</td>
<td>1</td>
<td>20</td>
<td>Increase</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>38</strong></td>
<td><strong>32</strong></td>
<td><strong>170</strong></td>
<td></td>
</tr>
<tr>
<td><strong>%</strong></td>
<td><strong>15.83%</strong></td>
<td><strong>13.33%</strong></td>
<td><strong>70.83%</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 4** The Group B, performance on live flights

- Decreasing performance: 15.83%
- Balanced performance: 13.33%
- Increase performance: 70.83%
The performance of 10 pilots teamed up in the Group B during the switch from analog display to glass cockpit displays by the live flights and by application of the new training procedures, was reported as increased.

Regarding evaluated the Group B manoeuvres during the live flights, the performance decreased in 38 manoeuvres (15,83%), balanced in 32 manoeuvres (13,33%) and increased in 170 manoeuvres (70,83%) (Fig. 4).

The overall Group B performance during the switch from analog to glass cockpit displays by the simulator practice as well as the live flights while applying the new training standards, increased and affirms the hypothesis number 1 – the performance of the pilots teamed up in the Group B (during the switch from analog to glass cockpit display by the simulator practice as well as live flights while applying the new training procedures) increased.

4. Conclusion

The comparison results of pilots performance achieved by a tool of the precision of pilotage fully affirms the hypothesis number 1 – For pilots who experience in a practice the conversion from analog to glass cockpit displays by applying the new training methods, the change reports less negative performance.

After a comparison of the achieved results as reported in the figures above, we can proclaim following change of performance:

- **simulator practice**
  - decreasing performance: group A 43%  group B 24%
  - balanced performance: group A 22%  group B 30%
  - increasing performance: group A 35%  group B 46%

- **live flights**
  - decreasing performance: group A 52%  group B 16%
  - balanced performance: group A 8%  group B 13%
  - increasing performance: group A 40%  group B 71%

The conversion from analog to glass cockpit display had the negative impact on the pilots performance. This fact concerns only those pilots who passed the conversion by applying the current training standards (their performance decreased). Before the display conversion they had passed only an elementary theoretical training in glass cockpit pilotage which lasted only 1 hour.

Those pilots who had passed the theoretical training by applying the new training methods reported less negative researched results (their performance even increased). It means that before the display conversion they had passed 3 hour detailed theoretical training in glass cockpit pilotage and 5 hour simulator training in glass cockpit pilotage.

References

Research of Influence of Obstacles Shape on the Radial Characteristics of the Pneumatic Wheel

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Abstract

The tires properties of the road wheels influence on the comfort during driving and the level of loads transferred to the suspension and further on the vehicles body. The tires, as the only element in the vehicle, directly cooperate with the ground and are characterized smoothing-absorbing properties of the ground unevenness, which affect the dynamic loads of the road wheels and suspension. Mentioned properties are closely related to the stiffness of the tire. The aim of this work was to determine the influence of the shape of small-sized obstacles (the length of the obstacle is much smaller than the length of the contact patch) on the radial characteristics of a modern passenger car tire. The research was carried out at the Military University of Technology in Warsaw (Poland). Obstacles with cross-section: triangle, rectangular and hemisphere were selected for the tests. In order to extend the identification of changes in the intensity of the obstacle's influence, the tests were carried out at different values of the tire inflation pressure.

KEY WORDS: pneumatic tire, quasi static research, radial stiffness, shape of obstacles

1. Introduction

Contemporary constructions of passenger cars are a collection of many advanced components affecting on a safety of their users. The following systems can be included, such as passive safety systems (e.g. seat belts, airbags) and active safety systems (e.g. ABS, tires) [20]. Pneumatic tires are the only one vehicle components which are in direct contact with a road surface. Their design (constriction) and materials used during production process affect on the vehicle's movement (e.g. ability to accelerate and brake, as well as to maintain a chosen direction of movement). The incorrect condition of tires, as well as the failures of the braking system, the steering system and the deficiencies found in the vehicle lighting, are the most common vehicle defects. Fig. 1 presents comparison of road accidents numbers caused by technical disability of the vehicle, including identified deficiencies in tires. In the analyzed period, the improper condition of tires was the reason for 16 – 25% of accidents resulting from vehicles malfunctions.

![Fig. 1 The share of accidents caused by improper tires conditions in the total numbers of accidents resulting from vehicle malfunctions [5-15]](image)

This comparison gives only a general view on the significance level of improper tire conditions’ influence on the vehicle's malfunction, because the number of accidents is not the same as the number of identified irregularities resulting from the technical condition (several failures can be identified in a single accident).
The materials properties of the pneumatic tires and the value of inflation pressure can affect on the steering and stability of the vehicle. Decreasing of the tire inflation pressure primarily reduces a directional and angular stiffnesses of the tires. It may be the reason for unpredictable behavior of the vehicle during riding on the turning at high speed (e.g. changing of vehicle trajectory in relation to the expected trajectory [17], extension of the braking distance) and during overcoming single road obstacle. The action to improve security in this area is, e.g. the obligatory equipping all new cars manufactured and intended for sale in the EU (after November 1, 2014) with TPMS sensors [19]. The incorrect condition of the road surface is another threat to road safety. Fig. 2 shows the share of this threat against the number of all accidents caused by other causes in Poland. In the analyzed period, the improper in the roads surfaces caused about 1,3 – 4,7% of all accidents resulting by other reasons. It is worth noting that small obstacles often occur on the roads surfaces, for example crossing by a railway tracks, stones or road ruggedness resulting from surface repairs. They can affect e.g. on the value of driving (braking) force transmitted by the driving wheel and the distribution of forces in the tire contact area with the ground. The analysis of influence short-length obstacles (in comparison to the length of the tire contact path) on changes in a wheel radial stiffness was carried out based on the results of quasi-static pneumatic tire research.

Fig. 2 The share of accidents caused by improper roads surfaces conditions in the total number of accidents resulting from other causes [5-15]

2. Object and Test Conditions

Tire for passenger cars with the most widespread size 205/55 R 16V were selected for the research. Basic information about research object construction are summarized in Table 1. Test conditions were determined based on typical loads acting on the wheels of the passengers cars D-segment. Taking into account the range of variability of passengers' numbers and an amount of luggage, values of two normal load were determined, i.e. 3,6 kN and 4,5 kN. Similar assumptions were made during choosing the value of inflation pressures in the tire. Recommended values of inflation pressure (by producer) and the case when the vehicle is driving at a low pressure values are also taken into account. Finally, the following values were selected for the research [kPa]: 100, 150, 200, 230, 280. Test conditions are summarized in Table 2.

### Table 1

<table>
<thead>
<tr>
<th>Tire size / construction</th>
<th>Maximum value of the tire inflation pressure [kPa]</th>
<th>Maximum load [kN]</th>
<th>Internal construction</th>
</tr>
</thead>
</table>
| 205/55 R 16 91 V / radial tire  
(summer) | 350                                              | 6,15              | Polyester Steel Polyamide |
| Material | Plies numbers | Material | Plies numbers |
| Polyester | 1 | Polyester | 1 |
| Steel | 2 | Polyamide | 2 |

### Table 2

<table>
<thead>
<tr>
<th>Normal loads [kN]</th>
<th>Inflation pressure [kPa]</th>
<th>Surface type</th>
<th>Shape of the obstacles</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,6</td>
<td>100</td>
<td>Flat steel plate</td>
<td>Triangular</td>
</tr>
<tr>
<td>150</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>200</td>
<td></td>
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<td>230</td>
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<td></td>
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<tr>
<td>280</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4,5</td>
<td>150</td>
<td>Flat steel plate</td>
<td>Rectangular</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>230</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>280</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>half-round</td>
</tr>
</tbody>
</table>
The quasi-static research of radial stiffness determination were divided into two stages. In the first stage of the research, the characteristics of radial stiffness on the flat surface were determined. In the second stage, the radial stiffness characteristics using the single obstacle were determined. Selected shapes of obstacles (Fig. 3) are typical road irregularities, which can be met during driving by the car, for example, changing the height of the road surface caused by the repair of its defects, drain pits, railway crossing, etc. The obstacles covered the entire width of the tested tire contact area and their length (identical for each obstacles) was significantly smaller than the length of the tire contact patch. Their low height (about 10 mm) was also dictated by the possibility of their use on a drum station (the next stage of research - dynamic tests). During quasi-static studies, the plane of longitudinal symmetry of each obstacles and the plane passing through the axis of rotation of the wheel had the following geometrical relations: vertical and common (Fig. 4). This relations made it possible to measure the radial stiffness at the top of the each obstacles.

During the research, the measurements were made for four places evenly distributed around the circumference of the tire. The research in given conditions were repeated three times for each selected tire cross-section. During the research, the ambient temperature was controlled, which was $20^\circ\text{C} \pm 2$ and the relative humidity, which was $60\% \pm 10$.

3. Test-Bench and Research Methodology

Experimental research were carried out on the test -bench located in the Institute Motor Vehicles and Transport laboratory (Fig. 5), Faculty of Mechanical Engineering of the Military University of Technology in Warsaw (Poland). Detailed descriptions of the test-bench and its measuring capabilities can be found in [1, 2, 4, 16].

![Test-bench for quasi-static research](image)
During determination the radial stiffness characteristics, the tire was loaded until 125% of normal load and then unloaded (Fig. 6). The data recording of force as a function of tire deflections (Fig. 7) allows to draw a hysteresis loop on the basis of which the values of the hysteresis coefficient $F_H$ and radial stiffness values $k_R$ of the tire were calculated. The hysteresis loop factor, which is a measure of energy losses as a result of tire deflection, is expressed by the formula [3]:

$$F_H = \frac{L_U - L_O}{L_U},$$

(1)

where $L_U$ – the area under the curve which expresses the work during loading (bending) the tire; $L_O$ – the area under the curve which expresses the work during unloading the tire.

The value of the radial stiffness coefficient $k_R$ was determined as the directional coefficient of the line tangent to the center line of the hysteresis loop (Fig. 8), according to the equation [18]:

$$k_R = \frac{\Delta F}{\Delta z} \mid_{F_s \rightarrow F_{s\,\text{stat}}} = \tan \alpha.$$

(2)
4. Research Results

Due to the differences in the shape of obstacles and research on a flat surface, the obtained results were analyzed in terms of similarities and differences that could affect the vehicle's movement. Research results, i.e. values of radial stiffness coefficients, are presented in Table 3.

Table 3

<table>
<thead>
<tr>
<th>Tire inflation pressure [kPa]</th>
<th>Normal load 3,6 kN</th>
<th>Normal load 4,5 kN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat steel plate [kN/m]</td>
<td>Triangular obstacle [kN/m]</td>
<td>Rectangular obstacle [kN/m]</td>
</tr>
<tr>
<td>100</td>
<td>130,60 ± 0,870</td>
<td>108,81 ± 1,164</td>
</tr>
<tr>
<td>150</td>
<td>172,70 ± 0,390</td>
<td>126,71 ± 1,167</td>
</tr>
<tr>
<td>200</td>
<td>207,50 ± 0,820</td>
<td>152,87 ± 1,190</td>
</tr>
<tr>
<td>230</td>
<td>224,80 ± 1,970</td>
<td>181,63 ± 1,522</td>
</tr>
<tr>
<td>280</td>
<td>259,30 ± 2,560</td>
<td>208,08 ± 0,981</td>
</tr>
</tbody>
</table>

Fig. 9 Influence of obstacles shape on the radial stiffness coefficient $k_R$ values ($F_Z = 3,6$ kN)

Fig. 10 Radial stiffness characteristics ($p_h = 100$ kPa, $F_Z = 3,6$ kN)
Increase of inflation pressure causes almost proportional increase of the radial stiffness values ($k_R$), observed on the flat surface (stage 1) and with the obstacles (stage 2) (Fig. 9). The research revealed that the small size obstacles may cause a radial stiffness reduction of 17-32% in the adopted range of tire inflation pressures. Mentioned above phenomenon is shown in Fig. 11, where the value 100% corresponds to the radial stiffness coefficients registered for the tire researched on a flat surface without the single obstacles. This changes in radial stiffness is the result of the increased deflections of the tire (compared to the flat surface) and the reduction of the internal forces in the tire resulting from the resistance of the layers (plies) to bending (forces are also dependent on the value of the inflation pressure). Decreasing the radial stiffness of the tire may affect on the substitutive vertical stiffness of the vehicle's support system (suspension). The registered characteristics in the second stage of the research were characterized by similar courses (Fig. 10) regardless of the value tire’s internal pressure. However, it is worth to pay attention to the characteristics recorded in the range of 18 - 32 mm of tire deflections. The effect of the obstacles curvature on the tire deformations were noticeable there.

![Graph showing percentage changes of radial stiffness coefficients](image)

**Fig. 11 Comparison of the percentage changes of the radial stiffness coefficient values**

**Table 4**

<table>
<thead>
<tr>
<th>Tire inflation pressure [kPa]</th>
<th>Flat steel plate</th>
<th>Triangular obstacle</th>
<th>Rectangular obstacle</th>
<th>Half-round obstacle</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>0.114 ± 0.0018</td>
<td>0.110 ± 0.0029</td>
<td>0.098 ± 0.0025</td>
<td>0.108 ± 0.0019</td>
</tr>
<tr>
<td>150</td>
<td>0.115 ± 0.0034</td>
<td>0.106 ± 0.0044</td>
<td>0.095 ± 0.0039</td>
<td>0.106 ± 0.0022</td>
</tr>
<tr>
<td>200</td>
<td>0.119 ± 0.0023</td>
<td>0.113 ± 0.0026</td>
<td>0.099 ± 0.0020</td>
<td>0.113 ± 0.0026</td>
</tr>
<tr>
<td>230</td>
<td>0.122 ± 0.0057</td>
<td>0.122 ± 0.0023</td>
<td>0.111 ± 0.0032</td>
<td>0.117 ± 0.0021</td>
</tr>
<tr>
<td>280</td>
<td>0.128 ± 0.0031</td>
<td>0.131 ± 0.0035</td>
<td>0.117 ± 0.0032</td>
<td>0.127 ± 0.0041</td>
</tr>
</tbody>
</table>

The received hysteresis loop provides mainly information about energy losses related to material damping. The
values of $F_T$ factors are shown in Table 4. The lower value of energy losses recorded for research with the obstacle is the effect of reducing the length of the contact path (with the ground) and the size of the tire deformation. As a consequence, it will affect to reduce the value of the traction force which is achieved on the co-operation between tire and flat ground (outside the tire contact area with the obstacle), also it will increase value of slip in mentioned area and will accelerate wearing of the tread (especially when this co-operation with the obstacle will be repeated cyclically).

Additionally, comparing the obtained results of the hysteresis loop, which is measurement of energy losses, it can be noticed that obstacles with a larger curvature generate greater energy losses (triangular and half-round obstacles) than short flat obstacles.

5. Conclusions

The conducted research allowed to observe the changes of radial stiffness and energy losses of tire in the conditions of its co-operation with the flat surface and with the single different shape obstacle. The selected shapes and the dimensions of the obstacles reflected the most common roads irregularity (e.g. railways crossing, surface repairs). The research indicated a significant (even to about 20 - 30%) decrease of tire radial stiffness, during test conditions with the single obstacle, even though its height is relatively small compared to the tire profile and much shorter than the length of tire contact area. The largest decrease of the mentioned values was observed for tire internal pressures of 150 kPa and 200 kPa. The recorded tire radial stiffness characteristics, regardless of the shapes of the obstacles, reached similar courses independently of tire inflation pressures. Use of the obstacles also caused a reduction of the length of the contact path (with the ground) and the size of the tire deformation. As a consequence, it will affect to reduce the value of the traction force which is achieved on the co-operation between tire and flat ground (outside the tire contact area with the obstacle), also it will increase value of slip in mentioned area and will accelerate wearing of the tread (especially when this co-operation with the obstacle will be repeated cyclically).

References

19. Rozporządzenie Parlamentu Europejskiego I Rady (We) Nr 661/2009 z dnia 13 lipca 2009 r. w sprawie wymagań technicznych w zakresie homologacji typu pojazdów silnikowych dotyczących ich bezpieczeństwa ogólnego, ich przyczep oraz przeznaczonych dla nich układów, części i oddzielnych zespołów technicznych.
Theory and Practice of the Innovative Spring Suspension Design for Locomotive to Improve its Traction and Dynamic Characteristics

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Abstract

This paper deals with the methods and techniques of the locomotive dynamic characteristics improvement, decrease in force impact on the track, minimizing tire and rail wear by secondary suspension improvement. Based on the calculations carried out using the created mathematical models and experimental research, there are proposed series of construction solutions of the supporting and returning devices with rational characteristics, which allow improving traction characteristics of the locomotive and reducing its dynamic impact on the track in vertical as well as in horizontal planes, on the straight track as well as on the curved track. Moreover, the proposed solution can provide the locomotive body with the centering function relative to the bogie. The proposed body to bogie connection was tested using a special test stand and in operating conditions. According to the test results, the proposed construction of body to bogie connection can ensure the required rigidity and damping characteristics due to the design optimization.

KEY WORDS: secondary suspension, static deflection, rubber-metal parts, bogie swivel angle

1. Introduction

Analysis of the research relevance has shown that the most expensive and problematic is creation and technical implementation of the locomotive undercarriage, which largely determines its technical and economic efficiency as a traction vehicle. At the same time, evaluation of this efficiency is contradictory, caused by complex and ambiguous dependencies of traction and coupling, dynamic, ergonomic and other characteristics of the locomotive [1-3]. The change in characteristics of the supporting and returning devices makes it possible to provide: an increase in traction characteristics of the locomotive; a decrease in the maximum dynamic impact on the track in vertical as well as in horizontal planes, on the straight track as well as on the curved track; centering the locomotive body relative to the bogie, etc [4]. Due to this, research of the characteristics of the body to bogie connection and further improvement of its design, aimed at improving the dynamic characteristics of the locomotive and, as a result, reducing force impact on the track and wear of tires and rails, is a topical task [5, 7, 8].

The supporting and returning devices of most locomotives are a combination of a rolling support and a block of the rubber-metal parts (RMP). The support simultaneously ensures the bogie swivel, lateral motion and vertical oscillations of the body relative to the bogies. Roller supporting and returning devices are mounted on the frame of the bogie in such a way that the relative motion of the bogies and the body in the horizontal and lateral direction takes place due to the elastic rubber-metal parts. The bogie swivel relative to the body is provided by deforming the RMP and rolling the rollers along the inclined surfaces.

As studies of diesel locomotives of the 2TE116 and TE121 series have shown, such a spring suspension does not ensure centering the body relative to the bogies with its lateral motion in the pivot gap, motion of the body from the middle position causes a one-sided overload of the wheel sets, which in its turn causes an increase in the slip of its axles when the traction force is realized, the body’s non-centering results in a shift of the point of the traction force transfer from the bogie to the body from the central position, which causes yaw moment between them, and as a result, the bogie skew in the rail track, thereby increasing the lateral slip of the wheel sets [6]. The body’s non-centering is obviously a consequence of the lack of lateral rigidity of the body to bogie connection.

2. Fluidic Muscle Parameters Research

To determine the parameters of effective operation of the supporting and returning devices, a technique for determining the characteristics of the shift of the rubber-metal parts has been developed.

In the locomotive body supports, the blocks of rubber-metal parts perceive the vertical load \(Q_o\) and the lateral horizontal force \(P_{ho}\) (Fig. 1). The support plates of the end RMP remain parallel to each other, regardless of the relative lateral motions of the body and the bogie. Taking into account this fact, the existing methods for calculating the elastic characteristics of a rubber shock absorber are unreasonably used to calculate the characteristics of blocks of several shock absorbers installed on each other [9]. At the same time, it is assumed that the remaining plates of the rubber-metal parts remain parallel to the support surfaces, regardless of the relative shift of the bogies under the body.
More precise ways of solving the problems of theory of elasticity with reference to one rubber part lie in establishing the value of stresses and motions that satisfy the equilibrium conditions and the boundary conditions, and in case of solving the system of equations they satisfy the compatibility conditions of deformations. The calculation method presented in the work [9, 10] is based on the application of the Ritz energy method, in which the expressions for motions corresponding to the conditions of the problem are given. They satisfy the condition of constancy of the volume. The deformation components and invariants are calculated based on motions; the deformation energy is calculated by integrating the expression of the specific energy in the whole volume; the potential of external forces is calculated and the expression of the total energy of the system is made; the coefficients are determined by the conditions of the energy minimum; the directions and values of the main deformations are determined; the main stresses in the sites of interest are determined.

The work presents a technique for calculating the compression characteristics of a column of flat rubber disks placed on the top of each other, vulcanized to steel plates. In this case, each of the rubber parts of the whole block is subjected to the same loads and deformations.

As experiments have shown, under real conditions, under the action of the returning force \( P_{th} \) and the vertical load \( Q_0 \) along with the lateral and vertical relative motions of the steel plates different in position in the RMP block the relative turn of the plates around the longitudinal horizontal axis is observed, which is explained by the different additional moments of forces \( M_i \). Thus, while determining the elastic characteristics of the block of the rubber-metal parts, not only characteristics of one RMP and its quantity in the block should be taken into account, but also the vertical and horizontal loads creating bending moments of forces, differing in value, affecting each RMP block, i.e. their angular motions.

The solution of the problem of determining one of the elastic characteristics of the block of rubber-metal parts—rigidity on the lateral shear—is advisable to begin with the statement that the returning force \( P_{th} \) is known, and then to find the value of the lateral motion of the support surfaces \( \delta_s \). Particular interest is in determination of the horizontal and vertical deformations of an average rubber-metal part when the support surfaces of the RMP block are laterally shifted to \( \delta_s \), taking into account the turn to the angle \( \rho \) (Fig. 1).

Let us assume that the vertical force \( Q_0 \) and the horizontal force \( P_{th} \) are applied to the middle rubber-metal part. Parallelism of these plates indicates that the rubber packing does not perceive any bending moments. Then the resultant of the forces \( Q_0 \) and \( P_{th} \) can be replaced by the normal pressure \( N \) and the shear force \( P_{th}' \):

\[
N = Q_0 \cdot \cos \rho - P_{th} \cdot \sin \rho ;
\]

\[
P_{th}' = P_{th} \cdot \cos \rho + Q_0 \sin \rho .
\]

With an increase in the angle of inclination \( \rho \) of the rubber-metal part, the compression force decreases by the value \( \Delta Q_0 \):

\[
N = Q_0 \cdot \cos \rho - P_{th} \cdot \sin \rho ;
\]

\[
P_{th}' = P_{th} \cdot \cos \rho + Q_0 \sin \rho .
\]
\[ \Delta Q_0 = Q_0 - Q_0 \cdot \cos \rho + P \cdot \sin \rho. \]  

(3)

Respectively, deformation of the rubber part thickness will decrease by the value:

\[ \delta_{zc} = \frac{\Delta Q_0}{S_c}, \]  

(4)

where \( S_c \) is rigidity of the rubber part compression, the value of which is determined as:

\[ S_c = \frac{\pi (R^2 - r^2) E_c}{h_0}, \]  

(5)

where \( R \) - the radius of the rubber part; \( h_0 \) - thickness of the rubber part; \( k \) - the coefficient of the rubber part shape; \( E_c \) - elasticity module on compression of the rubber part, the value of which can be determined by the formula [10]:

\[ E_c = 6 \cdot G \left(1 + k^2\right), \]  

(6)

where \( G \) is the modulus of elasticity on the shear of the rubber part.

For the rubber part that is a hollow packing with the internal diameter \( d \), the form coefficient \( k \) will be [11]:

\[ k = \frac{D - d}{4h}. \]  

(7)

At the same time, the shear deformation along the plate becomes equal to:

\[ \delta_{sh} = \frac{P_{sh}^*}{S_{sh}}; \]  

(8)

\[ S_{sh} = \frac{\pi (R^2 - r^2) G}{h_r}; \]  

(9)

\[ h_r = h_0 \left(1 - \frac{Q_0}{S_{sh}}\right), \]  

(10)

where \( S_{sh} \) is the shear rigidity of the rubber part; \( G \) - the modulus of elasticity on the shift of the rubber part; \( h_r \) - thickness of the rubber part under the load.

The total vertical deformation of the inclined rubber part is equal to:

\[ \delta_z = - \delta_{zc}^* \cdot \cos \rho + \delta_{sh}^* \cdot \sin \rho. \]  

(11)

The horizontal deformation of the inclined rubber part is:

\[ \delta_y = - \delta_{zc}^* \cdot \sin \rho + \delta_{sh}^* \cdot \cos \rho. \]  

(12)

The value of the lateral motion of other rubber-metal parts in the support block can be determined with sufficient accuracy according to the angle of inclination of the steel plates of this RMP:

\[ \delta_{y,i} = - \delta_{zc}^* \cdot \sin \rho_i + \delta_{sh}^* \cdot \cos \rho_i \]  

(13)

\[ \rho_i = \frac{\rho^*_{1,i} + \rho^*_{2,i}}{2} \]  

(14)

where \( \rho^*_{1,i} \) - the angle of inclination of the outer (respectively to the block center) plate of the \( i \)-th RMP; \( \rho^*_{2,i} \) - the angle of inclination of the inner plate of the \( i \)-th RMP.

To find the angle of inclination of the RMP, we will consider the rubber packing as a deformed rod, which is under the action of the lateral force \( P_{sh} \) and the moment of the forces \( M_i \) under conditions of rigid mounting to the fixed
surface at one end. According to the formulas of small deformations, it follows from Hooke’s law that the calculated value of the angle of inclination of one steel plate regarding the other one can be determined by the formula:

$$\rho = \frac{P_h h^2}{2EI} + \frac{M_h h}{EI} = \frac{h}{2EI} \left( \frac{P_h h}{2} + M_h \right), \quad (15)$$

where $I_x$ - the moment of inertia of the rubber packing regarding the axis $OX$ passing through its geometric center; $M_i$ - the moment of force affecting the rubber-metal part and depending on its location in the rubber column, the value of which can be determined by the formula:

$$M_i = P_i I + Q_i \frac{\delta_i}{h_{max}} = \left( P_i + Q_i \frac{\delta_i}{h_{max}} \right) \left( h_i + 2t \right) i; \quad (16)$$

$$h_{max} = (h_i + 2t) n, \quad (17)$$

where $n$ - amount of the RMP in the block; $t$ - thickness of the steel plate; $i$ - amount of the RMP from the center of the block.

Then the relative angular motion of the steel plates of one RMP is:

$$\rho_i = \frac{h}{EI} \left[ \frac{P_h h}{2} + \left( P_i + Q_i \frac{\delta_i}{h_{max}} \right) \left( h_i + 2t \right) i \right]. \quad (18)$$

It should also be taken into account that deformation of the rubber column increases in the lateral direction by a value equal to:

$$\delta_i = \frac{P_i h^3}{3EI} + \frac{M_i h^2}{2EI} = \frac{h_i}{2EI} \left[ \frac{2P_i h_i}{3} + \left( P_i + Q_i \frac{\delta_i}{h_{max}} \right) \left( h_i + 2t \right) i \right]. \quad (19)$$

The value of the total lateral motion of the supporting surfaces, caused by the forces $P_i$ and $Q_i$ affecting one body support, consists of angles of turn and lateral motion of all the rubber-metal parts of the block. So, as for the support, the total lateral motion of the supporting surfaces is determined by the formula:

$$\delta = \sum_{i=1}^{n} \delta_i + \sum_{i=1}^{m} \delta_i. \quad (20)$$

The shear rigidity of the RMP block is determined as the result of dividing the value of the returning lateral force $P_i$ by the lateral motion of its support surfaces:

$$S_{shs} = \frac{P_i}{\delta_i} \quad (21)$$

In the same way, the formulas were obtained for calculating rigidity for the blocks consisting of different amount of the RMP. Comparing the values of the elastic characteristics of the RMP block obtained by the proposed method with the values obtained by the existing technique [10, 12], when $S_{shs} = S_{shs} / n$, where $n$ is the amount of the RMP in the block, we determine that the difference among the values of the shear rigidity of the RMP block can reach 10%-40%. At the same time, with an increase in the horizontal force $P_i$, the values of the static deflection may differ by 19%, in case of absence of the horizontal force this difference practically does not exist. With an increase in the vertical load on the support $Q_o$, the difference in the values of $S_{shs}$ obtained by both techniques increases, in case of absence of the vertical load, this difference practically does not exist. Thus, the shear rigidity of the block of the rubber-metal parts, determined by the existing technique, differs from the proposed one as it does not take into account the differences in the conditions of deformations of the individual RMP, then, as experimental research shows, it introduces a significant error in the results obtained. Thus calculation of the shear rigidity of the block of seven RMP according to the developed technique allows increasing the accuracy of the calculation by 9 ... 10 times in comparison with the existing technique, that is, the difference between the calculated and experimental values of $S_{shs}$ decreases from 17 ... 40% to 1.65 ... 4%.

The advantage of the developed technique for calculating rigidity of the support shear with the RMP block is that its usage makes it possible to more accurately determine the elastic characteristics of the block with any predetermined
number of the RMP and the value of the vertical load on the support. According to the calculations performed, with an increase in the vertical load on the support and the number of the RMP in the block, the returning force in connection of the body to the locomotive bogies is expected to decrease as well as the stability of the body on the bogies. Thus, when designing the undercarriage, attention should be paid to the fact that to increase the dynamic qualities it is necessary to increase the static deflection, but at the same time to ensure stability of the supports by optimizing rigidity, thereby ensuring high traction and safe entry into the curved sections of the track.

3. Experiment

Experiments to determine elastic deformations of the RMP supports of various configurations in the horizontal plane; the choice of the rational design of the body side support on the bogie was carried out at the test stand of OJSC Holding Company “Luhaskteplovoz” [9].

The test stand allows simulating the real operating conditions of the locomotive returning devices. Fig. 2 shows the appearance of the test stand and the layout of the test stand (side view).

![Fig. 2 General view and diagram (side view) of the test stand for static tests of the RMP. 1 - carriage; 2 - RMP; 3 - base; 4 - vertical load screw; 5 - frame post; 6 - dynamometer; 7 - horizontal load screw](image)

The test stand consists of fixed base 3 on which movable carriage 1 simulating the bogie is disposed. On fixed base 1 there is installed frame post 5 with the vertical load screw, and the frame post of the horizontal load screw is fixed. Horizontal load screw 7 is connected with movable carriage 1 by dynamometer 6. The tested RMP of the support is mounted between movable carriage 6 and vertical load unit 4 simulating the bogie and the body.

Prior to the beginning of the tests, all the RMP were checked for compliance with the requirements of the drawing. Under the static load of 110 kN, the vertical deflection of the RME and the support as a whole were measured. The test stand works as follows.

In accordance with the test program, RMP set 2 is mounted to movable carriage 1 of the stand, the maximum motion of which is 140 mm. The vertical load was created by screw 4 by means of closed space frame 5 and base 3. Horizontal motions of the support were carried out by screw 7, the force measurements were made by dynamometer 6 of Dor 3-5 type.

A middle longitudinal line was drawn on each RMP support along its perimeter; for the RMP set, a vertical middle line was drawn. The intersections of these lines were used to measure both vertical and horizontal motions.

After loading the support with the static load of 110 kN, which was monitored by the deflection of the RMP, the horizontal force registered by the dynamometer was applied to the support; obtained horizontal and vertical motions of the RMP were measured with a ruler of 150 GOST 427-75.

Before rating the support performance, cyclic load was applied to the RMP set in the horizontal direction until stable characteristics were obtained.

The test results show that when combined vertical and horizontal forces are applied the RMP of series-produced support are not loaded equally, and the support configuration acquires a curved S-shape, which indicates the uneven stress condition of the support elements and possible loss of its stability. On the test stand, various designs of the supporting and returning devices with the RMP holes in different parts of the support were tested. The most effective solution was the support design, successfully implemented on the TEP150 diesel locomotive [13].

Comparison of the results of weighing wheel by wheel showed that after installation of experimental supports, the centering of the locomotive body on the bogies was improved. Thus, the maximum actual difference in the loads of the wheels of one axis in the initial state reached more than 5%, which exceeds the permissible value of 4%. After re-equipping the section with experimental supports, the difference was 2%.

4. Construction Solution

The purpose of the design is high traction and dynamic, and brake qualities of the high-speed rolling stock,
centering the body relative to the bogies during entry into curved sections of the track. The side support consists of eight rubber-metal parts (RMP), working on compression in the vertical direction and on twisting around the vertical axis (Fig. 3), the body, the lower support plate of which is connected by pins with the bearer and mounted in the pallet; the upper support with a lock, on which a set of rubber-metal parts is mounted. Each element consists of a rubber shock absorber, vulcanized to the metal plates. The interaction of the guide with the lock as well as the annular corrugations of the plates excludes the lateral shift of the rubber-metal parts in the sets and in the connections with the supports. The height of the set of the rubber-metal parts on the support is regulated by washers. There are two parallel rollers in the body, which are connected by clips. Movable parts of the support, moving in the body parallel to the lateral axis of the bogie, are guided by welded steel bars [Declarative patents for utility model №№ 8060, 50938, 46011, 45011].

When the locomotive moves along the straight section of the track, the rollers occupy the middle position between the inclined surfaces of the supports. When entering the curves, the body shifts relative to the bogies due to motion of the support on the rollers (Fig. 4). In this case, the rollers, rolling on the inclined surfaces of the supports, create horizontal forces that tend to return the body into its initial position. A polymer plate (fluoroplast-4) is mounted on the lower plate of the roller; sliding friction of this plate along the steel plate ensures swiveling the bogies relative to the body in the horizontal plane. The bearer moves along the straight line perpendicular to the radius connecting the center of the support to the pivot.

When the vehicle is moving in the traction and braking mode, the upper part of lock 14 interacts with the lower part of lock 12 on the surface “A”, the gap “B” is reduced, eliminating compliance of the RMP block in the longitudinal direction of the vehicle axis. It helps to ensure parallelism of the upper and lower supporting surfaces of the RMP, and, accordingly, to redistribute the vertical load along the axes of the wheel sets, thereby providing better utilization of the adhesive weight, improving the traction and brake characteristics of the locomotive.

When entering curved sections of the track, the RMP block is blocked, eliminating skewing of the body in the longitudinal direction. A covering is installed in the internal cavity of the support to protect it from dust and moisture. The cavity of the support is filled with oil.

The proposed design can be used for both high-speed rolling stock, and for cargo, shunting.

Full-scale tests of this support have shown that in the straight sections of the track at the speed of 100 km/h for
the locomotive in the initial state, the maximum amplitudes of oscillations were 34 mm, for the locomotive with the experimental supports – 19 mm, the maximum swivel angles were respectively $13.2 \cdot 10^{-2}$ rad and $3.6 \cdot 10^{-2}$ rad.

5. Conclusions

In accordance with the purpose of the work, as a result of theoretical and experimental research, recommendations have been developed to improve adhesion of the body with the locomotive bogies. The developed technologies for calculating the shear rigidity of the support with the RMP block allows us to more accurately determine elastic characteristics of the block with any predetermined amount of the RMP and the value of the vertical load on the support. The proposed adhesions of the body with the bogies are tested on the test stand, and some of the proposed versions of the supports on a real locomotive. The developed with the participation of the author design of the side body support on the bogies, which allows providing the required elastic characteristics, was tested and introduced on the diesel locomotive TEP150. Installation of the experimental supports allowed improving the body centering of the locomotive on the bogies. The maximum actual load difference of the wheels of one axis in the initial state reached more than 5%, which exceeds the permissible value of 4%. After re-equipping the section with the experimental supports the difference was 2%.

Acknowledgement

The research was held on the basis of the scientific Joint Ukrainian- Lithuanian Project "Development of science-intensive methods of engineering the surfaces of a highly loaded wheel-rail contact to ensure the competitiveness, environmental friendliness and energy efficiency of rail transport".

References

Conception of Protecting Civil Aircrafts from Man-Portable Air-Defence System

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Abstract

Terrorism is a asymmetrical danger which is constantly present in various dimensions of everyday life of international community. Nowadays, terrorism is not only defined as a ideological or ethni cal conflict, it has become widespread, advanced, and unpredictable. As a result, it can be divided into numerous categories. The article describes real threats for civil aircrafts passengers’ safety, such as terrorist attacks carried out with use of man- portable air-defence systems.

There is a lot of systems of protecting the aircraft from the most popular MANPADS attack schemes. They differ in ways of operating, possible uses for the system, complexity, and price. The last one plays a major role in choosing the system by an air carrier. The article presents one of the proven systems which may help solve problems with MANPADS.

KEY WORDS: MANPADS, civil aircraft protection, terrorism

1. Introduction

Flying has become the most common and safest way of travelling, especially when it comes to long distance travels. This type of transport comes in handy to the modern, usually busy, man. Because it has so many advantages, flying attracts a high number of people, resulting in gathering multicultural, or quite the opposite, nationalist crowds. As a result, such crowds gathered either in terminals or in aircrafts have become a great target for terrorist groups which support terrorist groupings. Because of the constantly growing number of illegal inference acts providing efficient protection from terrorists is crucial in civil aviation. All countries which ratified Convention on International Civil Aviation signed in Chicago 7 December 1944 have dealt with it. Appointed in 1944, International Civil Aviation Organisation (ICAO), has taken care of the coordination of activities carried out by countries signatories, and creating international safety and protection of flights [3].

Technological progress, informatisation of life, knowledge and research advancement, as well as availability to mass destruction weapons has led to the development of postmodern terrorism. The wave of terrorist attacks has proven that this type of activity is transnational and has an asymmetrical nature by not having any borders or ethical principles. A few characteristics of postmodern terrorism can be enumerated [4]:

- terrorist groupings are transnational and the range of their actions is global;
- refined working methods, as the result of better trainings for member of the terrorist organisations;
- new sources of endowments;
- network structure, impeding searching our other members;
- terrorist actions aim at mass death now more than ever before;
- terrorists make good use of new technology and information;
- deeply-rooted religious attitude and motivation.

Terrorism in the air, which includes violence acts aimed at the safety of air navigation, has emerged with the advancement of air transport in the 20th century. Since 1930, numerous cases of illegal aircraft seizures have been noted all around the world. In 1960’s number of such acts has gradually increased. According to data collected by A.E. Evans, about 47 hijackings took place only in 1948-67, the following year, 1968 the number raised to 46 [1]. Fundamental to the international society were the 9/11 terrorist attacks which have shown a new face of the air terrorism. It was then when ICAO determined changes essential in international safety standards. As the result, the tragic events from 2001 were the foundation of the safety of civil aviation, which is one of the most restricted area of aviation to this day.

In aviation there are specified safety standards which are strictly obtained. Every unit of air transport, ranging from ICAO, through aviation authorities to civil and military aviation has its own safety system.

For this idea of the model of air accident development the responsibility for arising of the accident distributes on whole teams correlated to aviation management: from the highest to the lowest level and all men engaged in the realisation of the task. The ones responsible for managing safety try to minimise the possibility of accidents, and if they were unable to avoid such accidents, they do their best to prevent similar situations taking place.

The active managing of safety strategy’s main aim is focusing on active permanent monitoring and acquiring knowledge based on various information which may point the threat area and signalise arising of first symptoms of potential problems significant for safety. Extensively compiled systems of reporting about threats and accidents serve
this purpose. Therefore, functional system should enable full identification of conditions posing a potential threat of safety [2].

Safety of modern aircrafts is without a doubt at a much more advanced level than it was 1940-70’s. However, the degree of complexity of the technical instrumentation is increasing. Nowadays, pilots, especially in civil aviation, steer the aircraft passively most of the time, almost everything relies on the on-board computers. It is often said that modern pilot is a reserve for the automatics of conducting an open flight. For a layman this may be surprising, but for a professional, this is just a confirmation of the possibilities of the modern technology. But what does this mean for the pilotage practice? Whenever a factor, not applying to the pilot’s algorithm, shows up, an alarm goes off and that is when the pilot takes over the yoke. The pilot’s job is to be the main operator and to monitor information in the fully automated cabin. Based on that information, he/she makes a decision only if he/she thinks that the information differs from the norm. The number of information about the external situation the pilots receive is increasing, but simultaneously the time intended for analysing such information, making optimal decisions, and carrying out actions is shrinking. Despite using the most advanced technology, the reality surprises with unforeseeable circumstances. In such cases, the mistakes made by the pilot may lead to an accident, which usually is a consequence of a complex sequence of events, an unexpected combination of various circumstances and conditions. Experience in safety gained by the aviation industry can raise the safety levels, and also may be used in managing safety systems not only in other transport facilities, but also in all operations including men-modern technology contact.

2. MANPADS – Simple, Yet Dangerous Weapon

Man-portable air-defence system (MANPADS) is a light rocket system against aircraft, intended to shoot down targets in the air which are visible to the eye, e.g. aircrafts, helicopters and other machines emitting electromagnetic spectrum. Because of the risk such weapons constitute to civil aviation, possession and sale of MANPADS is strictly controlled. The progress of technics and technology has made it possible to engineer MANPADS to be manned by a single soldier. Nowadays, these weapons are used on every level of air safety and are able to combat targets over the distances from hundreds of metres up to tens of kilometres and over the heights from tens of metres to tens of kilometres. Thus it is undeniable that man-portable air-defence aircrafts pose an enormous threat for civil aircrafts when in hands of terrorists or random individuals.

What is the origin of MANPADS? At the time of WWII, the Third Reich was losing its capacity during the mass raids, and Luftwaffe was defenceless towards more numerous and better armed military aviation units of the United Nations. Troops were being devastated by low flying battle aircrafts and fighter aircrafts. Because of having no time and limited funds the German authorities required the Armament Office to come up with a simple, but at the same time cheap solution. The authorities came to the conclusion that Luftpfaust will be able to combat aircraft, just as Panzerfaust (man-portable, single shot, recoilless weapons) have combated tanks in the East. Finally, the name Luftpfaust has been changed to Fliegerfaust. Being modelled on Panzerfaust, Fliegerfaust was also intended to be manned by one soldier. The construction had to be maximally simplified because of the economic and training aspects. The weapon which was about to meet the authorities’ expectations was devised and tested in a short period of time. This is how the man-portable anti-aircraft rocket system Fliegerfaust was invented (Fig. 1) [11].

![Fig. 1 FLIEGERFAUST – German progenitor of man-portable anti-aircraft rocket systems](image)

It consisted of nine barrels (connected to each other by clamping rings), two hilts, and a straight sight. Missiles of 20 mm calibre, 25 cm length with electronic ballasts. The whole machine weighed about 6.5 kilogrammes at length of 1.4 metres. Pressing shutter button would start electric induction generation which would release four missiles at once, after 0.1 second lag, the rest of five missiles were released. This sequence was to, theoretically, eliminate the interaction of exhaust gases with the missiles’ trajectory. Two salvos, fired one after the other, were to guarantee bigger chances of striking the target. The theoretical range of Fliegerfaust was expected to reach about 500 metres. However, it was impossible to achieve such range in practice, as the bullet dispersion was too big. Despite the difficulties, it has been decided to introduce the weapon into the armament in vast numbers. Sample batch was planned to total 10
thousand launchers and 4 million rockets. In reality, the number of weapons did not exceed more than several thousand items. There is no reliable data about the effectiveness the weapons had on combating aircraft, however there is proof that they were largely used for fights taking place on the streets of Berlin, where the victims were mostly infantrymen.

Fliegerfausts, which was found by Russians, were examined and formed a base for a RSFSR-made set of weapons known as Kolos, which were intended for Viet Cong. The North Vietnam’s army was at that time fighting with the USA supported South Vietnam’s army. Kolos weighed 9.2 kilogrammes and had 7 barrels of 30 mm calibre. The maximal striking range estimates 500 metres. The Kolos set has never been introduced to the market due to promising results of then tested homing rocket set. Russians were also elaborating on SA-7A Grail, equipped with thermal-homing missiles.

The Soviet army, at the time, had technology which allowed them to build infrared guided rockets. It was decided that this set should combat targets flying with speed of 220 m/s and height of 50 to 1500 metres. Technology of the time enabled shooting only from the back hemisphere, because aircrafts, especially jets, emitted hot gases from their rear.

In 1970 the improved version of the system, SA-7A Grail, was developed. Up to the 80’s, hundreds of thousands of these rockets have been produced. Some countries, including Poland, Romania and Yugoslavia, bought the license for producing this set. Other countries, for example China, have copied the design. The Chinese sold the copies as HN-5.

The western equivalents of the soviet sets were, and still are, FIM-43 Red Eve, its descendant FIM-92 Stinger, French Mistral, British HVM, and Swedish RBS-70 and RBS-70NG. FIM-92 Stinger was introduced into armament in 1979. Firstly, it was used by the USA Army, later by the Allies.

Despite of constant development of aircrafts and the aviation strategies, man-portable air-defence systems still pose a real threat to aircrafts. MANPADS are wanted by armies and, what is worse, terrorist groupings, which is proven by frequent thefts of the sets from servicemen magazines and constant demand for them on the under-the-counter trade.

MANPAD is a system intended for a one-men use. They were used repeatedly during different armed conflicts since 1969, that is from border fights between Egypt and Israel. MANPADS main element is an anti-aircraft rocket put in the tubular launcher which is independently guiding itself to the strongest sources of the heat radiation where the aircraft’s engine is. It is meant to be a cheap system, that is why it is simplified in any way possible. For instance, the rocket itself does not have a proximity fuse, but a impact action fuse, that is why it explodes when it touches the warmest spot of the aircraft. Moreover, there are no external detection systems, the detection of the target takes place by using the head of the guiding rocket located in a tubular launcher. Also, the release device is disconnected and it is possible to exploit it repeatedly after the exchange of a worn-off launcher.

The simplicity of MANPADS results in its ease of use. There are no special calibration systems, no tests and aiming, everything is rather durable, sometimes even crude and “idiot-resistant”. The procedure of soaring, in case of terrorist operations consists only of installing the starting mechanism and the container with coolant on the launcher, removing it from its covers, raising to the shoulder and aiming it towards the aircraft. Intercepting the target by the rocket is being signalled to the operator with a light signal or a sound. Soaring consists of only in pulling the trigger. Later the empty pipe of the launcher is being thrown away - of course after dismantling the starting mechanism, which is reusable. MANPADS does not need a specialist to operate it. That is why it has gained so much popularity within Russians, during fights in Afghanistan, and now Syrian Arab Armed Forces.

The simplicity of the system does not mean it is not efficient. At first, mostly easily available Russian rockets were a success. For example, the Vietnamese, only in 1972-1975, launched 589 SA-7A Grail and SA-7A Grail rockets, hitting 204 American aircrafts. They were also used in Africa, South and Central America, in Asia and in the Middle East.

Moreover, also Stinger rockets, which Afghans received from the Americans (supposedly in the 1 000 amount of pieces), were a success. Those rockets forced Russians to change their tactics of operating in Afghanistan, however it did not change the fact that Afghans lost over 250 aircrafts there. MANPADS were also used in Chechenia, Georgia, and now are more and more desired by terrorists.

Terrorists are acting by surprise, mostly where nobody is expecting the attack and there is no chance of counteraction. The terrorist moreover does not feel a pressure that if he doesn't fire he will die, since it is him who is choosing the time and the place of the attack.

During last 80 years, air terrorists developed a lot of methods of action which let them conduct an unlawful acts of violence. Since the 9/11 attack, terrorism has become a real threat for civil aviation, and has become an object of interest. The increasing number of violence acts forces the international community to take up action in order to modernize the level of civil aviation safety. According to data collected by The United States Department of State, one of the main reasons of increase of air terrorism acts is proliferation of MANPADS. Only in 1970-2002, those actions contributed to shooting down more than 40 aircrafts and death of innocent people. Not before 2003, with close multilateral cooperation of the US government with other countries, it was possible to effectively limit spreading of anti-aircraft weapons and to destroy almost 32.5 thousand of rockets in over 30 countries all over the world [5].

That is why, despite not being new to the modern world, MANPADS are now the newest threat for civil aviation. Some information state, that there is about half of millions of those rocket systems all over the globe. Some models of that weapon are available for all, and they can be found on the black market. Information as for the MANPADS number in non-national or terrorist groups may differ, but according to one of the estimates, over 20 such groups has this weapon in Africa, Asia, Europe, in the Middle East and in South America.
and the possibility of hiding MANPADS makes the weapon leading in use for carrying out terrorist attacks. Attacks conducted about 15 years ago with missiles of the short reach guided by the infrared induced aircraft manufacturers and organs of the supervision to think, whether one should not equip commercial planes with antimissile protection systems. At the time, it was considered to be too expensive, unreliable and dangerous for civil aircrafts. Also, it created new hazards for the pilot, as radiation is damaging for the eye, and other ways of protection might be toxic.

Only Israel decided to introduce the system to its civil aircrafts, after the incident in 2002, when Arkia aircraft, taking off in Mombasa, was shot at. Fortunately, the missile missed. According to the Sky Shield government program, jets and aircraft of Elas’ nationalist carrier Al Israel Airlines, as well as Arkia Israel Airlines and Israir Airlines are being equipped with such systems produced in the Elbit Systems local firm. Israel acknowledged that benefits were greater than costs and anxieties about the safety.

The majority of antimissile systems intended for planes and helicopters is supposed to fight bullets of the short reach and the ones shot from shoulder harquebuses. The USA equipped majority of its units of transport and servicemen, and also protection devices into the systems, having Great Britain and Australia follow in their footsteps after short period of time. Systems produced by the Northrop Grumman company equip planes of presidents, e.g. Air Force of the US President, Germany also implemented the system into the plane of the chancellor.

The most important effect of installing the protection system on aircraft’s board is increasing the situational awareness for pilots which are being kept informed about threats posed by MANPADS.

3. “Adros” - One of the Solutions for Aircrafts Safety

ADRON Research and Development Company (R&D Ltd.), a Ukrainian company based in Kiev, in collaboration with NPK Progress in Nieżyn, has developed such machines which they have produced since 1982. The first machine, L-166W1AE, was initially used to protect the Mi-24 helicopters from missiles with warhead guided thermally. It generates an apparent source of infrared radiation. KT-01AWJe “ADROS” is a more modern version of L-166W1AE. Laser beams can be used interchangeably for both machines on Mi-24 W helicopters. Adron R&D Ltd. designed equipment which protects helicopters and aircrafts from all dangers connected to infrared radiation, including MANPAD. Such equipment is able to do so by fooling the guidance system, and as the result changing the rocket’s trajectory.

“ADROS” prevents helicopters from being directly hit by different types of rockets with warheads guided by infrared radiation working in:

- amplitude-phase modulation mode;
- frequency-phase modulation mode;
- time-impulsive modulation mode [6].

3.1. The Way it Works

Radiation interfering station is designed to protects the aircraft from missiles with warheads guided thermally. Such station generates an apparent source of infrared radiation.

Infrared radiation emitted by a radiation lamp with help of electro-mechanic modulator is converted into different thermal impulses, shown in Fig. 2. Those impulses provide false information about the aircraft’s location in relation to the optical axis of the missile. Disruptions in the rocket’s control channel leads to disturbing its trajectory, making it spiral until it is out of sight. The system has no work-ready mode, it works in a stable way during the whole mission, granting safety for an aircraft or a helicopter. System "fools" all IR seeking missiles in the area of its reach, making calculating coordinates of the attacking bullet unnecessary. The software is designed in the code of the Assembler programming and is flexible for reprogramming and future updates of the system.

Basic technical parameters of KT-01AWJe „ADROS” station:

- zone of securing the helicopter in the azimuth 30 - 330°;
- zone of securing the helicopter in the elevation +20 - -30°;
- time needed for the station to start working max. 5 min;
- time of uninterrupted work max. 4 h;
- length of the break before next operation min. 30 min;
- blocking range at least 5 km;
- power taken from the 208 V/400 Hz electricity network ≤ 4 000 VA;
The devices of the aircraft is provided by multipole extractor of gas as it shields the direct visibility warmed element and the KUV 26-50 E are used with the KT-02ACE station "Adros" covers of the outlet of the engine (EES) "Adros" ASh-01V (shown in Fig. 3) and the flares storage container "Adros" EES wire, with help of special materials which are reducing emission of the infrared. Reducing aerodynamic and (of flares or dipoles) of calibre of 26 mm and 50 mm and flares in order to protect the aircraft against rocket attacks. Part of the flow.

Dynamic losses takes place through the change of the EES configuration and the optimization of the geometry of the part. Of the flow.

Technical characteristic of IRCM station:

The station works in three modes: APM - amplitude-phase modulation; FPM - frequency-phase modulation; PLM - time-impulsive modulation.

Main advantages of "Adros" KT-01AVE station:

- it does not require information about the kind and frequencies of missiles approaching the aircraft;
- it works without bullet approach warning system;
- it doesn't require bullet approach tracking system;
- it guarantees permanent all around protection;
- it has a simple construction, and as a result, a high dependability and affordable price point.

Another similar, but newer and slightly modified device of this type produced by the recalled company is IRCM "Adros" KT-02ACE Station, shown in Table 1. It is destined for the active protection of planes equipped with two turbojet engines against missiles equipped with infrared guiding heads. The majority of stations is muffling the signal of infrared guided heads g with the amplitude-phase modulation fundamentally (APM). Its disrupting signal must then bev 1.5 - 2 times bigger than the signal from aircraft engines, and in some cases even up to 20 times stronger. IRCM "Adros" KT-02ACE station does not require such amount of surplus of the energy of the interferential signal. It is able to muffle signals of infrared guided heads with the increased immunity for other types of the modulation disturbance, for instance, frequency-phase modulation (FPM), time-impulsive modulation (PLM). That ability enables full blockade of guided missiles, such us FIM-92 Stinger, SA-18 Grouse, SA-16 Gimlet, R-60, М, AA-11 Archer, and many more. The functioning of the system depends on the new optoelectronic method of deafening. The applied technology includes newly designed electronically controlled modulator with programmable processors. The Ukrainian technology, unlike its foreign equivalents, does not demand big intensity of the electronic signal of the counteraction in order much to surpass the signal which emits real target. Research and production capacity of Ukrainian company, along with past experience in protection systems, allows to adapt the current system to the equipment of the serviceman and their installation, or civilian aircraft of different type.

The position provides the continuous interference for the trajectory of guided missiles, resulting in the increasing mistake of the targeting the thermal track of aircraft engines. The station doesn't require information about parameters of the type and modulation frequencies of infrared guided heads of missiles and the missile approach warning system.

Technical characteristic of IRCM station:

- probability of overpowering Stinger type missiles: 0.7 - 0.8 s;
- time needed for changing the trajectory of the Stinger type missile: 0.5 - 0.8 s;
- spectral range of the radiation: 1.8 - 5.5 μm;
- protection zone: 180°;
- mass of the station: up to 35 kg.

To improve the effectiveness of the protection and lowering the thermal visibility of aircraft, special screens, covers of the outlet of the engine (EES) "Adros" Ash-01V (shown in Fig. 3) and the flares storage container "Adros" KUV 26-50 E are used with the KT-02ACE station "Adros". The needed level of lowering the thermal visibility of engines of the aircraft is provided by multipole extractor of gas as it shields the direct visibility warmed element and the EES wire, with help of special materials which are reducing emission of the infrared. Reducing aerodynamic and dynamic losses takes place through the change of the EES configuration and the optimization of the geometry of the part of the flow.

Storage container "Adros" KUV 26-50, shown in Fig. 4, is intended to locate the target and the thrust of decoys (of flares or dipoles) of calibre of 26 mm and 50 mm and flares in order to protect the aircraft against rocket attacks. The device is using flares in specially programmed sequences to create a complicated situation of drowning bullets out with infrared guided heads, even if they have a system of the counteraction. Universal programs of using flares are being designed for a specific type of the aircraft. Aircraft with flares of two calibres with different and specially

<table>
<thead>
<tr>
<th>Year of production</th>
<th>Wave's length [μm]</th>
<th>Power [kW]</th>
<th>Work in the modulation mode</th>
<th>The possibility of fooling the bullet</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>1.8 - 5.5</td>
<td>3/6</td>
<td>APM, FPM, PLM</td>
<td>0.7 ÷ 0.8</td>
</tr>
<tr>
<td>1982</td>
<td>1.8 - 4.2</td>
<td>3</td>
<td>APM</td>
<td>0.3</td>
</tr>
<tr>
<td>1995</td>
<td>1.5 - 5.0</td>
<td>3</td>
<td>APM</td>
<td>0.4</td>
</tr>
<tr>
<td>1997</td>
<td>3 - 5, 6 - 12</td>
<td>no data</td>
<td>APM</td>
<td>0.55</td>
</tr>
</tbody>
</table>

Table 1

Comparison of parameters of the station disrupting in the infrared
calculated periods of launching them are providing bullets coming near with false information about the location of the aircraft and cause deviating of missiles from the trajectory of the attack.

Fig. 3 „Adros” ASH-01V special monitors of the engine’s exit [9]

Fig. 4 The infrared illuminator and the flares storage container „Adros” KUV 26-50E with IRCM „Adros” KT-02ACE station [8]

Technical characteristic of a flare storage container:
- caliber of installed flares 26 mm and 50 mm;
- number of flares in the device:
  - caliber of 26 mm 20;
  - caliber of 50 mm 10;
- number of devices controlled by one control unit 2 - 20;
- time needed to be ready for operation 30 s.;
- strength of consumables not more than 250 W;
- test and self-control built in yes.

"Adros” KUV 26-50 can be applied at all stages of the flight under the manual or automatic procedure (including the rocket approach warning system) and can be installed on every type of the aircraft. For the KUV storage container 26-50 Adron R&D Ltd company designed special skyrockets "ADROS" PIK-26, PIK-50, PIK-50V (Fig. 5) which serve for the protection of planes against guided missiles equipped with infrared searchers. Launched flares then build false cells for the infrared, and then move missiles away to a safe distance from the protected aircraft afterwards.

Table 2

<table>
<thead>
<tr>
<th>Type of flare</th>
<th>&quot;Adros&quot; PIK-26</th>
<th>&quot;Adros&quot; PIK-50</th>
<th>&quot;Adros&quot; PIK-50V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caliber [mm]</td>
<td>26,6</td>
<td>50,2</td>
<td>50,2</td>
</tr>
<tr>
<td>Length [mm]</td>
<td>85</td>
<td>200</td>
<td>105</td>
</tr>
<tr>
<td>Weight [kg]</td>
<td>0,09</td>
<td>0,85</td>
<td>0,45</td>
</tr>
<tr>
<td>Speed of the thrust [m/s]</td>
<td>30 ± 5</td>
<td>30 ± 5</td>
<td>30 ± 5</td>
</tr>
<tr>
<td>Time of burning [s]</td>
<td>4-6</td>
<td>6-8</td>
<td>4-6</td>
</tr>
<tr>
<td>Temperatures in which they can work [°C]</td>
<td>± 50</td>
<td>± 50</td>
<td>± 50</td>
</tr>
</tbody>
</table>

Two stations Adros KT-02ACE in special containers with flares storage container Adros KUV 26-50 E installed on both sides of the plane are sufficient enough for ensuring its full protection.

4. Warning Device

Warning devices are intended to inform the pilot about radiation of the aircraft through radar stations of intercepting planes. It works on its abilities to reflect electromagnetic waves from objects about commensurate dimensions and greater than these waves, and uses the fact that inside homogeneous waves are undergo refraction.1 The radio signal made as the result of the reflection is called the radar echo (Fig. 6).

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1 Refraction - reversal of the propagation of electromagnetic or acoustic waves, refraction of the wave connected to its speed change (see: speed of light, speed of sound), when it goes over to other center. The change of the speed is connected with change of the wavelength, while the frequency remains fixed.
4.1. Active Method with the Passive Reply - Bases of Radiolocation

First radars worked on the principle of radiating constant electromagnetic waves, and the energy reflected from objects indicated their presence in the space. Separate aerials were applied for emission and the receipt of electromagnetic waves. However, everyone very often associates the modern radar with the device sending short, strong impulses of electromagnetic wave energy in certain direction, and next picking up very weak impulses reflected from objects. This association is justified, since in radiolocation such method has found the widest application.

In this method, the source of “enlightening” energy is the radar’s transmitter. The transmitter receives reflected signals (echoes) which are a base for determining space coordinates of these purposes by the output device (Fig. 6). Optical indicator is the most often used output device. Not so long ago, the radar’s operator made the decision about the target’s presence and determined its coordinates. Nowadays, the so called “human factor” is often dismissed from performing these activities, e.g. arrangements of automatic tracking targets provide radar data directly to the computer which is performing two functions - of the output device and of the operator. The active method with passive reply, because of its versatility, is the most useful one, since the process of the detection of objects is dependent only on its ability to reflect waves.

The aerial radiates energy of impulses provided from the transmitter in the form of the narrow beam of the electromagnetic radiation. It forms a beam of circular cross-section, that is in the shape of the cone and of small angle width (the beam is preferred to be of the smallest angle width - such a bundle is called the pencil beam). The aerial moves around its own pivot - simultaneously sounding the space (sending impulses of the electromagnetic radiation), shown in Fig. 7. When the aerial beam reaches direction, on which the object is located, the receiver will start picking another impulses of the echo - each with the same delay (that is in the same distance). While the aerial rotates, time impulses of the echo are current, until the object is in the beam.

![Fig. 6 Scheme of the active method with passive reply (own elaboration)](image)

![Fig. 7 Azimuth and elevation (own elaboration)](image)

System of horizontal coordinates is a system of astronomical coordinates, in which local direction of the division constitutes the main pivot, and the surface of the horizon is a basic plain. Zenith and a nadir are poles of the system. Its position on the celestial sphere depends on geographic coordinates of the observer and the moment of observation, so horizontal coordinates are describing only temporary location of heavenly bodies. In such system location of the given body is determined giving two coordinates: azimuth and elevation, defined in the following manner:

- **azimuth** $\beta$ - straight angle between the north part of the geographical meridian and the given horizontal direction. counted according to the direction of movement of hands of the clock in the scope of $0 - 360^\circ$;
- **elevation** $\varepsilon$ - straight angle between the surface of the horizon, and the direction of the given object. Both shown in Fig. 7.

The radar reach is one of the important tactical parameters of the radar. It depends on the number of technical parameters of the radar, of which the acquaintance lets for calculating the reach. It enables this so-called levelling the radar range in the free space.

When deriving the levelling reach, it is assumed that the radar and the target are located in unrestricted homogeneous space of no electromagnetic wave suppression, where phenomenon of the refraction does not appear and there is no influence of the earth on the propagation of waves. It is of course idealized situation, all the same it allows enough exactly to estimate the range of radar in real conditions. In the active radiolocation with passive reply, the range has a two-way character, since signals reflected from the destination are coming back to the radar. It can be assumed, that the power’s density $p_n$ of the wave emitted by the radar, in the distance $R$ of the radar equals:

$$p_n = \frac{P_s}{4\pi R^2}, \quad (1)$$

where $P_s$ - power emitted by the radar.

Directional antennae of the big directional profit $G$, even row 103, are applied in the radiolocation. Power’s density $p_n$ directed towards its maximum radiation equals:

$$p_n = \frac{PG}{4\pi R^2}. \quad (2)$$
The target come across on the way is reflecting radiated electromagnetic energy, and so it is possible in this case to treat him as the transmitter about the power of:

\[ P_a = p_a \sigma = p_a \sigma = \frac{P G \sigma}{4\pi R^2}, \]  

where \( \sigma \) – effective area of the target.

In this case, the power's density reflected by the target equals:

\[ p_r = \frac{P}{4\pi R^2} = \frac{P G \sigma}{4\pi^2 R^4} . \]  

From the equation above, after transformation, it is possible to calculate the maximum radar reach for the active radiolocation with passive reply:

\[ R_{\text{max}} = \sqrt{\frac{P G \sigma A}{(4\pi^2)^2 P_{\text{min}}}}. \]  

In the case in question, unlike the passive method, proportionality is to the square, so the doubling of the meter of the equation causes the increase in the maximum reach scarcely by the 19%. In order to increase the range twice, one should e.g. increase the power emitted by the radar sixteen times. It is a basic equation for the radar reach concerning any radar devices which work in an active method with passive response.

4.2. Warning Device L-006LM

Warning system of radar L-006 LM (SPO-15LM) "Berioza" is designed to warn the crew that their aircraft is being lighted by radars of anti-aircraft rockets or artillery systems or fighters, so that it is possible to take right protection measures. That enables taking adequate actions to avoid the attack. The system warns about radars of the anti-aircraft defence rocket systems, artillery or radars of fighter planes. Depending on the type the warning, the warned machine can perform dodge or start to attack the threatening object. SPO-15LM provides detection of radiation and shows the direction from which the radar waves are coming. System also shows the type of the radar and its work mode. Furthermore, it is able to estimate the radar’s system power, its distance and speed of approaching. Additionally, the time needed to enter the range of the ground system or to foresee if the fire of the opponent will be effective. In the case of being radiated by a few radars systems, the devise finds and prioritizes the one of the greatest threat. It is the omni-directional radar alarm receiver which controls the active interferential machine and the launcher of decoys, or disrupting flares. The multidirectional radar warning receiver can detect the majority of the aircraft radiating frequency (Fig. 8)

System provides:

- detection of hostile ground, surface, and air radars’ direction which radiate the aircraft;
- specification of the radiation types and their work modes;
- the measurement of the power of the signal of the radars with estimation of their reach, along with determining the approach time to zones of including an anti-aircraft shells and anti-aircraft artillery or the intercepting
plane;
- identification of the biggest threat for the aircraft, providing it is lighted by a few radars simultaneously.
- traffic lights and sound.

Warning radar system L-006 ŁM (SPO-15) "Berioza", shown in Fig. 8, is installed on different aircrafts and helicopters, and also on sea ships (rocket boats etc.). It consists of:
- front azimuthal aerials;
- control centre;
- position of the cockpit indicator;
- HF econverters;
- receiver;
- computer;
- angle aerials;
- power plack;
- wide range aerials.

Technical information about SPO-15LM:
- surveillance zone:
  - in the azimuth \( \pm 180^\circ \);
  - in the elevation \( \pm 30^\circ \);
- operating frequency range \( 4.45 \sim 10.3 \) GHz;
- power supply \( 27 \) V;
- electricity conscription \( 5 \) A;
- time needed to be ready for operation \( 20 \) s;
- weight of the set \( 20.5 \) kg.

5. Conclusion

Nowadays, protecting planes from missiles with infrared guided heads (IR) is one of priorities. The reason for that is IR’s efficiency. Latest war experience shows that about 90% of every shoot down of an aircraft in armed conflicts is done by infrared guided missiles.

The protection of aircrafts against MANPADS is usually guaranteed by false thermal targets created by electronic or optical active deafening systems. Electronic-optical active deafening systems are based on modular deafening of the infrared radiation. Even though the devices presented in the article are produced and assembled on military aircraft, conducted analysis has proven that a possibility of applying them on civilian aircrafts or helicopters exists.

The Ukrainian technology, unlike her foreign equivalents, does not require the electronic signal of the counteraction of great power in order to differ from the one which transmits the real target. Adros systems are especially effective in combating missiles such as FIM-92 Stinger, Stinger-POST, Magic, Sidewinder, Mistral, and other.

It is important, that the construction of Adros systems makes it possible to adapt the system to all types of aircrafts and helicopters. Research and production capacity of Ukraine, as well as experience in supporting the system, allows to adapt the system to future new electronic and optical studies of technology of counteraction.

Implementing the system into the aircraft aims at warning the crew about radiation of air-defense rocket systems or artillery systems, so that the crew would be able to take up appropriate measures, e.g. avoiding such stations.

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Computer Simulation in Management of Transport Processes

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Abstract

The article discusses the methods of computer simulation of intellectual human activity, where the knowledge of experts - specialists in a given field is coded in the form of symbolic expressions that constitute appropriate sets of facts and rules of conduct, resulting in programs called expert systems. Specialized computer programs created in this way are extremely useful in the management of organizations, including various types of transport enterprises. In the paper the description of expert systems that facilitate making organizational, economic, social decisions to support transportation processes.

KEY WORDS: management, transport, decision support, expert systems

1. Introduction

Technology is a transformation of knowledge and tools in a social benefit. This description can be further elaborated by showing relationships and feedback existing between the subjects of technological development [1], this is shown in Fig. 1. Without applying three key elements of civilization progress: development of science, technology and innovation, it will not be possible to build a knowledge-based economy. From the point of view of the transport company, the basic problem is not knowledge in itself, but its practical application [4, 11, 12].

New technologies are first and foremost a factor of economic development. But science, knowledge and technology are also necessary for the proper functioning of society, for its well-being [8]. According to the United Nations Development Program, new technologies are becoming a strong and key tool for social development [10]. Social development and technological development can be mutually reinforcing. This is largely through education and the development of skills that are necessary for the effective use of technology, especially in economic systems, including logistics and transport [3, 4, 6].

2. Symbolic Expert Systems

Research on artificial intelligence led to the formalization of general methods and strategies for solving problems. When describing specialists' knowledge and expertise, attention should be paid to their importance in expert systems. If problem solving methods and strategies developed in the field of artificial intelligence are to be applied to computerized problem solving, there must be an emphasis on knowledge in this field.

Feigenbaum said that the paradigm of expert systems comes from the knowledge they have, not from the formalisms and inference schemes used in them. Expert knowledge is the key to the system, while knowledge representation and inference schemes provide mechanisms for its use [9].

An expert system can be defined as a computer program that can emulate expert troubleshooting. The expert system is an "intelligent computer program that applies knowledge and procedures of reasoning (inference) to solve problems of a level of professional difficulty in a specific field that requires the knowledge of an expert during a study and practice" [7]. Its structuring in expert systems is shown in Fig. 2.

The term expert systems refers to the way knowledge is represented, because in this case it is most often presented in the form of words, i.e. symbols and complex structures, in the form of facts and conditional sentences, i.e. rules, structure and meaning very similar to natural language, used in interpersonal
Building expert systems is based on mapping knowledge from a given field. This mapping, or knowledge representation, is to ensure drawing conclusions based on the collected knowledge. Knowledge representation must provide ways to describe objects and concepts and the relationships between them. It is therefore a set of syntactic and semantic convention that allows the description of a given field.

Knowledge can be presented in a procedural or declarative form [1]. The procedural form indicates how to achieve the intended goals, that is, a set of procedures and functions, or activities that allow to achieve the set results. On the other hand, the declarative form of knowledge concerns the description of certain situations, objects and concepts and relationships between them and indicates what the given problem concerns and what is to be the goal of the solution, and not what steps to take to achieve this solution. Within the scope of artificial intelligence, knowledge in a declarative form is most often used. The procedural form is used in the modeling of inference processes.

The purpose of creating an expert system is to systematize transport problems at the level of the high special type of knowledge. Thanks to this, specialist knowledge in the field of developed transport issues, which is not widely available, can be more easily acquired and used by transport company personnel who do not employ experienced specialists. The expert system carries out two main functions: it develops a conclusion and explains its reasoning. The conclusion may be a recommendation for a specific transport problem. It should be noted that the set of conclusions must be fully specialized. The expert system works in the consultation mode, i.e. the user consults with the system.

The basic structures of contemporary expert systems are modular and consist of basic program blocks closely cooperating with each other such as: knowledge base, mechanism of inference, mechanism for explaining queries, user interface (block facilitating dialogue). The auxiliary blocks are: the explanation block and the acquisition (knowledge) block [5], as shown in Fig. 3.

The mechanism of explanation facilitates the user's conversation with the system, but above all confirms the rightness of reaching the results of reasoning by demonstrating the next steps of the inference or command chain. The user can use the expert system to solve complicated transport problems or to get recommendations when choosing one of the alternative decisions.

The explanation block allows you to answer any questions you may have about how the expert system will reach the conclusions or to explain why the expert system requests additional data from the user.

Knowledge base is a specific element for a specific field and contains systematized knowledge and experience of an expert in this field: description of objects and dependencies, description of problem solving, heuristics, facts. The application machine is an algorithmic part of the system and is used for viewing knowledge and inference based on it, as well as initial facts introduced by the user. The separated knowledge allows for easy modification of knowledge that can be supplemented, exchanged and deleted without affecting other system blocks. The explanation mechanism, which is usually an integral part of the expert system, serves several purposes, facilitates the user's conversation with the system, but first of all confirms the rightness of reaching the results of reasoning by demonstrating the next steps of the inference or command chain with intermediate stages of reasoning.

Skillful combination of knowledge and experience in the field of information systems engineering and management allows the development of an effective IT tool supporting decision making, including risk analysis, planning, organization and implementation of logistics tasks [2, 6, 8]. This is especially important in transport enterprises, where precise professional information is required in a very short time. These requirements are met by expert systems because, which due to their high speed of action and the accumulation of a large amount of specialized knowledge, they are a tool enabling effective adaptation to the constantly increasing requirements of the customer using transport services. Moreover, they are effective in adapting to the rapidly changing surroundings.

Such systems are also built to create, for example, task recommendations for employees, especially carriers. Fig. 4 presents the expert planning system in a transport organization, especially in terms of its financial needs [4]. Such a system asks questions about the current state of property and its possible dispositions, and then applying the rules of the financial knowledge base, creates a list of recommendations seeking to maximize profit in given conditions.

Fig. 4 Expert system of transport planning

In developing and supplementing the planning rules presented in the drawing, there are several stages that must be created in the system's knowledge base. The first step is the collaboration of knowledge engineers with finance experts to determine the thematic areas. At this stage, accurate analyzes of macroeconomic factors are taken into account, such as: interest rate, expected inflation rate, current tax regulations, future trends in legislative changes in tax regulations and typical investment strategies. Knowledge gathered in the first stage of financial planning is used at the next stage. The second stage focuses on creating the right rules. In addition, there is the possibility of making continuous changes and additions. In the third stage, based on the knowledge base, a prototype of the system is created, which is thoroughly tested by knowledge engineers and in cooperation with experts. This prototype is the basis for further development and verification of the operating expert system. In the next stage, the developers are employed to implement the expert system. The last stage, already during operation, is to maintain the knowledge base of the system along with the possibilities of changes in realities or the way of using it.

4. Conclusion

The study presents the possibilities and the example of using an expert system in the management of an organization, which can be any enterprise, with special attention focused on entities performing transport tasks. An important factor when using expert systems is the ability to gather in-depth expert knowledge. In addition to the advantages of expert systems to solve the complex transport problems, there are other tangible benefits, such as the easy possibility of transferring knowledge and availability of knowledge, easy duplication of coded knowledge, speed of obtaining professional, effective information and delivery of answers in a very short time. Expert systems finding application in transport enterprises, allow users for faster decision making or presenting recommendations.

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Research of Statistical Dependence of Perceived Personnel, Legal and Security Risks on the Size of SMEs in the Transport Sector

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Abstract

The basis of this article is to assess statistically the dependence of the perceived personnel, legal and security risks on the size of SMEs in the transport sector in Slovakia, based on our empirical research realized in 2017. Based on the results we can say that the personnel risks belong to the serious risks that negatively affect the entrepreneurial environment of the SMEs in the transport sector. The dependence the SME entrepreneurs perceive was detected between the personnel risks and size of SMEs. It was also found out there was no dependence between the legal and security risks and size of SMEs. The overall results of the empirical research show the importance and significance of dealing with the risk assessment of the risks and their sources in the SMEs in the transport sector in Slovakia.

KEY WORDS: risk; risk management; risk assessment, small and medium-sized enterprises (SMEs), transport

1. Introduction

Managers are increasingly faced with the responsibility to take important decisions to ensure prosperity, financial stability, and competitiveness under uncertainty and risk conditions [1]. Therefore, more and more enterprises are beginning to realize the need and importance of risk management. According to various global surveys and studies [4, 6, 17], it can be said that risk management means a significant contribution to increasing the performance, and competitiveness of enterprises in dynamic changes of both the external and the internal environment.

Small and medium-sized enterprises in the transport sector represent an important part of their economies in developed countries and the same situation is in Slovakia [10]. The SMEs has especially favorable conditions for the risk management because enterprises are very close to all aspects of individual operations and knows much strength but also the vulnerable areas of their enterprise. Although small and medium-sized transport businesses owners are intuitively aware of the current sources of risks that affect their everyday lives, they are unlikely to be aware of such sources of risk they do not have direct experience with [2].

Therefore, it is necessary to raise awareness and foreknowledge among SME managers about risk management in enterprises around the world, but especially in businesses in Eastern Europe and the Slovak Republic [13]. The application of risk management in many companies in Slovakia compared to advanced countries has considerable deficiencies [7, 19]. It is important for business managers to be able to identify the most serious risks, create scope for discussion, and propose preventive measures with a focus on preventing business crises. This fact implies the need for systematic risk management also from the side of the SME managers in the transport sector [15].

2. Goal and Methods

The aim of this article (based on the empirical research) is to analyse the dependence between the intensity of the perceived personnel, legal and security risks and the size of SMEs in the transport sector by utilising selected statistical methods and tools of statistics, to assess the risks of the SMEs compared with the results of the research during previous years in Slovakia. It is necessary to show (with the help of the results) the need of the managers to identify the risks and to implement the risk management process in the SMEs in the transport sector with an emphasis on preventing the company crises.

In order to meet the objective stated the empirical research methods (questionnaires, interviews with competent persons of SMEs), statistical methods, i.e., the analysis of variance using quantitative tools of statistics (percentages, averages, homoscedasticity, Bartlett's Test, Kolmogorov-Smirnov Test, F-test, Kruskal-Wallis Test, Box-and-Whisker Plot) and software MS Excel were used. The usage of the statistical methods and tools was to show whether the average (mean) values of the personnel, legal and security risks are dependent on the size of the enterprises in Slovakia or not.

To fulfill the goal the quantitative method “analysis of variance” was used [16]. The analysis of variance was determined by the parametric or non-parametric tests. For using the calculation of the parametric tests two basic conditions had to be met: the resulting p-value of the intensity of the risks of the homoscedasticity test (identity of variances) and the normality test; they were to verify the intensities of the risks that must be higher than the level of significance of 0.05.
3. Results

In 2017 the investigators of the project VEGA No. 1/0560/16 “Risk Management of Small and Medium Sized Enterprises in Slovakia as Prevention of Company Crises” supported by the Scientific Grant Agency realized an empirical research aimed at detecting the key entrepreneurial risks of the SMEs in Slovakia and the state of implementing the risk management process. 487 SMEs participated in this research. Out of 487 participants, there were 64% of the micro-companies, 24% of the small-sized companies and 12% of the medium-sized companies. A number of selected enterprises obtain more than 28% of all participating enterprises.

The addressed owners and managers of the SMEs in the transport sector in Slovakia were to determine maximally three risks out of seven ones they consider as the key risks in their business. The most expected risks are personal, legal and security risks in the transport sector by authors and their experiences. It is possible to expect dependence of perceived personnel, legal and security risks on the size of SMEs in the transport sector.

Personnel risks were selected mainly in view of the high fluctuation of employees in the transport sector. The second reason is lack of labor force in the area of passenger and freight transport, which is absent in Slovakia nowadays. According to available data from Leitner, 2015 there are missing about 3000 drivers in passenger and freight transport [11, 12].

Legal norms are becoming more and more dynamic and constantly changing in the area of legislation in Slovakia. Many times, legal standards act as positive and negative on the state of transport in the country [3].

Safety is itself an important element in the field of transport. We are currently following a steady trend in transport, which talks about the need to ensure and place ever greater emphasis on the quality and safety of transported goods [14].

<table>
<thead>
<tr>
<th>Risks</th>
<th>BSCs</th>
<th>Micro sized enterprise</th>
<th>Small sized enterprises</th>
<th>Medium sized enterprises</th>
</tr>
</thead>
<tbody>
<tr>
<td>Security risks</td>
<td>$\mu$</td>
<td>30,640</td>
<td>25,650</td>
<td>28,462</td>
</tr>
<tr>
<td></td>
<td>$\sigma$</td>
<td>0,166</td>
<td>0,134</td>
<td>0,121</td>
</tr>
<tr>
<td></td>
<td>$\kappa$</td>
<td>2,110</td>
<td>0,965</td>
<td>3,001</td>
</tr>
<tr>
<td></td>
<td>$\sigma_f$</td>
<td>0,024</td>
<td>0,028</td>
<td>0,034</td>
</tr>
<tr>
<td></td>
<td>$\sigma_{2f}$</td>
<td>0,012</td>
<td>0,018</td>
<td>0,032</td>
</tr>
<tr>
<td>Personnel risks</td>
<td>$\mu$</td>
<td>32,950</td>
<td>32,220</td>
<td>30,741</td>
</tr>
<tr>
<td></td>
<td>$\sigma$</td>
<td>0,169</td>
<td>0,027</td>
<td>0,182</td>
</tr>
<tr>
<td></td>
<td>$\kappa$</td>
<td>3,771</td>
<td>-0,397</td>
<td>3,001</td>
</tr>
<tr>
<td></td>
<td>$\sigma_f$</td>
<td>0,018</td>
<td>0,027</td>
<td>0,035</td>
</tr>
<tr>
<td>Legal risks</td>
<td>$\mu$</td>
<td>30,290</td>
<td>28,46</td>
<td>22,500</td>
</tr>
<tr>
<td></td>
<td>$\sigma$</td>
<td>0,177</td>
<td>0,259</td>
<td>0,128</td>
</tr>
<tr>
<td></td>
<td>$\kappa$</td>
<td>5,210</td>
<td>1,163</td>
<td>-1,546</td>
</tr>
<tr>
<td></td>
<td>$\sigma_f$</td>
<td>0,021</td>
<td>0,177</td>
<td>0,045</td>
</tr>
</tbody>
</table>

The next step in fulfilling the objective was to assess the dependence between the identified risks and the size of the enterprise, i.e., to what extent depends or does not depend on the type of perceived risks on the size of the enterprise in Slovakia (micro-enterprise, small and medium-sized enterprise). Risks were selected for the assessment, i.e. personnel, legal and security risks, using the quantitative method "analysis of variance". The necessary information for the analysis of variance is given in Table 1. The table of characteristics of level and variability details the individual characteristics of the statistical set of individual risks in three groups of SMEs according to the size of the enterprise. The basic statistical characteristics (BSCs) are as follows: $\mu$ – the average intensity of risk to the enterprise, $\sigma$ – standard deviation intensity of risk to the enterprise, $\sigma_2$ – variance intensity of risk to the enterprise [5].

4. Analysis of Intensity Dispersion of the SMEs’ Perceived Personal Risks in the Transport Sector in Dependence on the Enterprise Size

Based on the SME's survey results in the transport sector personnel risks were identified as the most important risks. Using the Barlet test (p-value = 0.127), the main assumption of homoscedasticity can be considered as fulfilled. Also, based on the Kolmogor-Smirnov Test, the normality of the examined file was met. The values (p-value) of the test were: 0.072 for micro-enterprises (total number of employees up to 10), 0.109 for small enterprises (10-50 employees) and 0.142 for medium-sized enterprises (20-250 employees).
Table 2
Analysis of the intensity variance of SME's personnel risks in the transport sector using the F-test

<table>
<thead>
<tr>
<th>Variance of SME’s according to the size of enterprise</th>
<th>Sum of Squares</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>0.0029</td>
<td>2</td>
<td>0.0014</td>
<td>0.0359</td>
<td>0.0096</td>
</tr>
<tr>
<td>Within Groups</td>
<td>1.4931</td>
<td>37</td>
<td>0.0404</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1.4960</td>
<td>39</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

After analyzing the variance of personnel risks SME'S in the transport sector intensity in conditions of the Slovak Republic using a parametric F-test, the value of which is 0.0096 (Table 2), the data can be considered statistically significant since the value is less than the chosen significance level (0.05). On the basis of the above, it can be concluded that there is dependence between the intensity of the personnel risks that SME's in the transport sector are experiencing and the size of the enterprise at the confidence level 95% (Fig. 1).

Fig. 1 Results of the graphical representation of perceived personnel risks in dependence on enterprise size in the transport sector using Box and Whisker plot

Dependence is confirmed by several authors [10, 11, 14, 18] that medium-sized enterprises or small businesses have fewer transport services than micro-enterprises. Medium-sized enterprises are able to more financially rewarded their employees than small or micro-enterprises.

5. Analysis of Intensity Dispersion of the SMEs´ in the Transport Sector Perceived legal and Security Risks in Dependence on the Enterprise Size

As was mentioned, the security and legal risks have been identified as important factors affecting the operation of SMEs in the transport sector in Slovakia. Using the Bartlet test (p-value = 0.219), the main assumption of homoscedasticity can be considered as fulfilled. Also, based on the Kolmogor-Smirnov Test, the normality of the examined file was met. The values (p-value) of the test were: 0.103 for micro-enterprises (total number of employees up to 10), 0.116 for small enterprises (10-50 employees) and 0.197 for medium-sized enterprises (20-250 employees).

Table 3
Analysis of the intensity variance of SME's in the transport sector legal and security risks using the F-test

<table>
<thead>
<tr>
<th>Variance of SME’s according to the size of the enterprise</th>
<th>Sum of Squares</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>0.1451</td>
<td>2</td>
<td>0.0726</td>
<td>1.4909</td>
<td>0.2358</td>
</tr>
<tr>
<td>Within Groups</td>
<td>2.2871</td>
<td>47</td>
<td>0.0487</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2.4322</td>
<td>49</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

After analyzing the variance of legal and security risks intensity in conditions of the Slovak Republic using a parametric F-test, the value of which is 0.2358 (Table 3), the data can be considered statistically nonsignificant since the
value is higher than the chosen significance level (0.05). On the basis of the above, it can be concluded that there is no dependence between the intensity of the legal and security risks that SMEs are experiencing and the size of the enterprise at the confidence level 95% (Fig. 2). From the point of view of the dependency hypothesis, this result can be considered correct since the legal and security risks are very specific. The size of the enterprise only partially impacts them (as evidenced by the p-value close to significance level).

The results of our own empirical research show that personnel, legal and security risks are among the four most important risks that negatively affect the current business environment of SMEs in the transport sector in Slovakia. Using statistical methods, the dependence between the intensity of personnel, legal and security risks perceived by entrepreneurs and the size of the enterprise was analyzed.

It is possible to say, that one of the most important risks in SME’S are personnel risks in the transport sector. Based on the personnel risks analysis, it can be concluded that the perceived personnel risks are dependent on the size of the enterprise. The number of employees affects the size of personnel risks. This is evidenced by further processed survey results that point to the highest intensity of personnel risks sources for SMEs:

- inadequate staff qualifications;
- high fluctuation of employees;
- drop in working ethics and discipline;
- staff mistakes.

Compared to the results of the 2013 statistical survey, personnel risks are still among the key risks of SMEs. In 2013 they were identified as the third most important with 14% share of overall risks and the dependence between perceived risks and the size of the enterprise was identified, too [9].

The structure of the muscle with no moving parts allows achieving quite short response time – the favorable parameter for the application in active suspension. That is why as an initial stage of the presented research the investigation of the operational parameters of the muscle itself is very important.

6. Conclusions

Every enterprise should concentrate on increasing the security of its activities and processes. The reasons are not only elementary effort to achieve positive economic results but especially the responsibility the management bears in connection with all interested parties [8]. The employees, customers, regions, state and a lot of other subjects make the profit from the results of the entrepreneurial activity of the small-sized, medium-sized or large enterprise in the transport sector.

The application of risk management leads to an improvement in business performance and also a cost saving. It is important that managers are convinced that effective risk management provides less negative surprises, greater financial stability and enterprise performance. It also provides opportunities for earning profits and maintaining a good enterprise in the transport sector. The improvement of awareness about the possibilities and approaches to the risk management in the entrepreneurial activity support the successfulness of the business performance, the development of the regions and last but not least, also the country. The risk management is an assumption for a successful accomplishment of the business activities of the organization from the point of view of security and sustainable development.

The results obtained will be compared with similar research at international level, with universities in the Czech Republic, Poland, Hungary, Serbia and other foreign organizations. The achieved results are the basis for the professional public as well as for other organizations that are trying to help companies with effective application of the risk management process in enterprises in Slovakia.

Acknowledgment

Publication of this paper was supported by the Scientific Grant Agency: The project VEGA No. 1/0560/16 - Risk

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**Inland Waterways (IWW) for the Oversize Cargo Transportation and Water Tourism**

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**Abstract**

Inland waterways have been used for cargo transportation and tourism in many Countries. Inland waterways could serve for both passive and active water based tourism and cargo transportation. Many Countries around the Baltic Sea are plains and abound in rivers and channels with natural environment which makes them very attractive for visitors and freight navigation as well. Meantime the Baltic Sea Region (BSR) states railway network has been developed very well and railways account for the largest portion of the freight movement, except for the oversize cargo segment which is very complicated to transport by railways and roads. Natural environment, interesting historical and sightseeing spots, fairly low density of population and availability of quality services close to the inland waterways play a very important role in water tourism development.

This Article analyzes oversize cargo transportation by IWW and water tourism objects close to the IWW in BSR, possibilities for development of new freight- and tourism related products on the inland waterways, advantages and disadvantages of the IWW freight and tourism in BSR.

**KEY WORDS:** oversize cargo transportation; water tourism; forecast methods

1. **Introduction**

Inland waterways have been widely used for cargo transportation, especially oversized and heavy cargo shipping [1, 2, 9] as well as for water based tourism in many Countries, where there are rivers, lakes and channels that are navigable for barges, boats and yachts. Inland water tourism and freight navigation on inland waterways are important sector of economy but today inland waterways being mainly used for the recreation and have potential for the oversize cargo transportation. Inland water tourism could provide for passive and active water based tourism.

Passive tourism (recreation) means fishing and sailing from one touristic attraction object to another without involving big physical activity in the boat’s moving. Active tourism means sailing in Mountain Rivers, covering big distances between the visited venues and objects and so on. Many Countries around the Baltic Sea are plains and abound in rivers and channels navigable for boats and yachts as well as inland passenger cruise ships, which is found very attractive for passengers.

Inland water tourism development based on natural environment, interesting historical places, not very high density of population and availability of quality services close to the inland waterways. Such interest for the inland waterway tourism it is possible to meet in any Baltic Sea region Country, especially in the South and North parts of the Baltic Sea.

Some IWW are used for the barges or freight inland navigation but today major part of the freight in the Baltic Sea region are transported by railways and roads. Oversize cargo transportation through IWW can reduce transport costs and also reduce restrictions and limitations on railways and roads [6, 8, 10].

2. **IWW E70 and Other IWW in East Baltic Sea Region (Lithuania) Analysis**

Lithuania’s IWW were used in middle ages by local population for conveyance of goods and people and by Vikings as well who sailed down the River Nemunas and other rivers to reach the Eastern part of Lithuania, Belarus, Ukraine and other East Countries. IWW, which is known nowadays as route E70, was widely exploited back in medieval times and the E41, called Wilhelm Channel which links the Minija River and Kursiu bay, was built in 19th century. IWW E70 was established by Germans, for connection of Klaipeda via Prussia with Western European Countries and used to convey wood and other commodities like coal, grain and alike.

The historical idea of the construction eastern part IWW E70, which would link attitudinally watersheds, was an innovative achievement of the 18th century thought. An example of this technical thought was the Bydgoszcz Canal in Poland and Finow Canal in Germany [4].

After WWII, the North section of the IWW E70 was used for coal shipping from Poland to Lithuania, as well construction materials (destroyed buildings materials) were transported from Konigsberg to other places of the former Soviet Union via Klaipeda Port.
The mentioned North section of the IWW E70 was used as cargo transport artery until the entire railway network in Poland, Konigsberg (Kaliningrad) Region and Lithuania was fully rebuilt after the Second World War, namely until the end of the 5th decade of the 20th Century. Soon after that (circa 1957 - 1960) biggest part of the mass cargo between Poland and former Soviet Union start transporting by railways, and North section of the E70 IWW operated just episodically. Since 1960 in E70 IWW North section no investments were made for maintenance and development thus causing a general decline in transport of goods and passengers.

Technical and technological conditions of the E70 IWW today do not induce the cargo movement. Meantime, the North section of the E70 IWW is very promising for water tourism and could also be used for the oversized and heavy cargo transfer.

Revitalization and adjusting for tourist and recreational purposes eastern section IWW E70 could be a factor responsible for the development of water tourism. This waterway may fulfill a transit function for water tourists sailing from the West to the East of Europe, or become the destination of their water travels due to its numerous historic, hydro technical and natural potential. These activities have a significant impact on regional and local development [5].

Oversize cargo transportation is attractive specially to the areas that are in the vicinity or neighboring to the IWW and offer possibility for freight navigation via IWW from Klaipeda to Kaunas, in some places by the Rivers Nevezis, Neris and certainly on the E70 IWW (Fig. 1).

Lithuania’s Road transport inspection data shows that up to 14000 oversize cargo units, every year are being transported by roads from Klaipeda, or to Klaipeda Port [11]. Oversize shipping data on mentioned directions are presented in the table 1 below.

<table>
<thead>
<tr>
<th>Year</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of permits for oversize or heavy cargo transport</td>
<td>10655</td>
<td>10845</td>
<td>11793</td>
<td>13155</td>
<td>13615</td>
<td>14250</td>
</tr>
</tbody>
</table>

Investigations of the Oversize cargo transportation in Lithuania reveal that between 5 and 7 percents of the Oversize cargo in Lithuania carried between Klaipeda port and other places in Lithuania can be transported in full or part shipment through IWW [9, 12] (Fig. 2).

Water tourism boosted over last decades, when marinas and other IWW infrastructure and tourist service facilities were built which offer good potential to attract more and more water tourists.

### 3. Forecast Basis for the IWW Using for Freight Navigation and Water Tourism

IWW as more environment-friendly conveyance could be used on larger scale in freight transportation and water tourism. Network system of different transport modes for cargo and passenger transportation in general is the same. At the same time oversize cargo transportation by road network cause multiple hindrances for the passenger segment, because of oversize cargo transport by roads which causes restricted traffic for other transport units, especially passenger transport [9].

Oversize cargo or water tourist flows are random values, so it is relatively difficult to assess how these cargoes will fluctuate significantly. The precision of the results of the traffic analysis directly relates to investments in the development of roads, railways, ports, waterways, terminals, and therefore large errors or inaccuracies in the forecast of oversize cargo flows or water tourists can negatively effect on investment planning and can make mistakes.

In calculating forecast flow parameters based on the results of a particular past period, it is first appropriate to calculate the mathematical expectations of random variables according to the formulas [8, 9]:

\[
Q_t = (Q_0 + b \cdot t) \cdot M,
\]
where \( Q_i \) - cargo, passengers or water tourist flows during the forecast period; \( Q_0 \) - cargo, passenger or water tourist flows in last statistical point (year); \( b \) - forecast coefficient; \( t \) - period in years from first year (statistical point) until forecast period (number of years); \( M \) - multi criteria forecast coefficient.

Forecast coefficient could be calculated based on statistical data as follows:

\[
b_i = \frac{Q_i - Q_0}{\Delta t},
\]

(2)

where \( Q_i \) - cargo, passengers or water tourist quantities per year \( i \), taken from statistical data; \( \Delta t \) - period in years between year \( i \) and first statistical year (point).

Forecast coefficient finally could be found as:

\[
b = \frac{\sum b_i}{n_b},
\]

(3)

where \( n_b \) - number of \( b \) coefficients.

Multi criteria forecast coefficient \( t \) could be calculated on the basis of influence factors, such as global and regional economic situation, development programs and so on [8].

Forecast accuracy could be calculated by dispersion (\( \sigma_y \)), which is equal to square error (\( e \)) taken as equal to dispersion and can be calculated as follows:

\[
e = \sigma_y.
\]

(4)

Dispersion can be calculated as follows:

\[
\sigma_y^2 = \frac{1}{n_i - 1} \sum (Q_i - m_{ni})^2,
\]

(5)

where \( n_i \) - number of the statistical points (years); \( m_{ni} \) - mathematical hope can be calculated as follows:

\[
m_{ni} = \frac{1}{n_i} \sum Q_i.
\]

(6)

On the basis of forecast accuracy it is possible to calculate forecast pass that means pass between optimistic forecast flow (\( Q_{opt} \)) and pessimistic forecast flow (\( Q_{pess} \)) by formulas:

\[
Q_{opt} = Q_i + e;
\]

(7)

\[
Q_{pess} = Q_i - e.
\]

(8)

Assessing current and possible oversize cargo, passenger or water tourist flows, it will be possible to determine these flows in future, growth trends and possible oversize cargo, passenger or water tourist flows, which can use inland waterways for the planning development of IWW and investments.

4. Case Studies of the IWW Used for Oversize Navigation and Water Tourism

Oversized cargo transportation by inland waterways proves as very beneficial, due to less restrictions involved in respect of weight and size in comparison with railway or road transportation conditions. Based on the method described in the methodical part, the oversize cargo flow forecast via Lithuania’s IWW in 2026 was estimated (about 7 percent from total oversize cargo transportation to and from Klaipeda Port).

<table>
<thead>
<tr>
<th>Year</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
<th>2025</th>
<th>2026</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>707</td>
<td>736</td>
<td>766</td>
<td>820</td>
<td>825</td>
<td>810</td>
<td>860</td>
<td>913</td>
<td>942</td>
</tr>
<tr>
<td>Optimistic</td>
<td>774</td>
<td>803</td>
<td>833</td>
<td>887</td>
<td>891</td>
<td>877</td>
<td>927</td>
<td>980</td>
<td>1010</td>
</tr>
</tbody>
</table>

As can be seen from the Table 2 above, the forecast oversize cargo flow on Lithuania’s IWW in 2026 could be
about 942 units. The maximum value of the optimistic forecast is about 1010 units.

For water tourism, many rivers, lakes and channels are potentially explorable, because of the possibility to operate small draft boats. For example, Lithuania used for the freight navigation about 350 km of the IWW, whilst for the water tourism used more than 900 km IWW, which are subject to services of the Lithuania’s IWW Administration [12].

Based on the Lithuania’s IWW parameters it is possible to design the inland waterway barge for oversize cargo transportation with the following main technical data [7, 15, 16]: length – about 60 m; width – about 10 m; draft – under 1,2 m; DWT – about 500 t. In case of using pusher with length about 16 m (Fig. 3), barge length could be increased up to 84 m (total length of the barge and pusher in Lithuania IWW cannot exceed 100 m) and using lightweight construction materials capacity of the barge could be increased at about 35%, or up to 700 tons [2, 16]. Additionally, in case using lightweight materials for barge construction it is possible to achieve barge capacity up to 900 tons [16].

Calculations of the main pushers parameters are received as follows (Fig. 4): length – about 16 m; width – about 6 m; total resistance in case of 8 kn (15,6 km/h) speed could be about 185 kN and request towing force of the pusher about 750 kW [14-16].

Fig. 3 Barge with the pusher on IWW

Fig. 4 Typical inland waterway pusher: length 16,2 m; width – 4 m

Water tourism on Lithuania’s IWW increase annually up to 6 – 8 percent and should be considered for further upgrade of IWW. As small boats used in water based tourism do not require large and expensive facilities, just small jetties or quay walls could be constructed.

Oversize cargo could be loaded and unloaded by using other equipment in some prepared places. Some examples are presented below (Figs. 5-6).

Fig. 5 Ramps for oversize cargo loading operations on non-prepared shore

Fig. 6 Heavy lifting crane used for oversize cargo loading operations on non-prepared shore

Assumedly we can conclude that oversize cargo could be transported through Lithuania’s or other Baltic Sea countries’ inland waterways and use the local ports and other places, on different type of barges or pontoons suitable for the oversize cargo transportation.

At the same time, IWW could be applied for water tourism as well, since it is easier to find passenger (tourist) embarkation or disembarkation areas.

5. Conclusions

IWW could be exploited to larger extent in water tourism and oversize and heavy cargo transport in Lithuania and other BSR Countries as an environment-friendly and attractive conveyance.

Forecast of oversize cargo flows through Lithuania’s IWW shows that up to 1000 units annually per navigational period could be transported as such, thus ensuring fewer limitations/restrictions for passenger transfer on roads.
Lithuania’s inland routes, such as E70 and E41 are the most promising and most convenient inland waterways in Lithuania for oversize transport, as well as water tourism.

Possibility to utilize different type of barges and pushers on Lithuania’s IWW and usage of lightweight materials in barge or pontoons construction can increase freight/conveyance capacity up to 800 tons.

Water tourism could be developing parallel or separately from oversize cargo segment.

An opportunity for the development of water tourism on IWW E70 is the creation of integrated tourism products in national and international scale.

References

Comparative Measurement of Instruments Used for Evaluation of Terrain Trafficability

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Abstract

The author has been dealing with the evaluation of trafficability of terrain for a long time. The most used instruments in the Army of the Czech Republic are the Telescopic Penetrometer PT-45 and the Cone Penetrometer from the Trafficability Test Set. Based on long-term measurements, they were determined the advantages and disadvantages of both devices. It would be useful to merge this knowledge to improve the evaluation of terrain trafficability in the Czech Army. Therefore, it was used the measurement ran by ERDC (Engineer Research and Development Center in USA) and it was measured with both instruments concurrently. The result was the discovery of dependencies between these two instruments. This can help to find out the relationships between them although it is measured in different depths and with different endings. All this enables to improve the ability of evaluation of low endurable terrain and thus better mobility of the troops.

KEY WORDS: trafficability, telescopic penetrometer, cone penetrometer

1. Introduction

The author has been dealing with the overcoming of low endurable terrain in the Czech Army for a long time. The determination of trafficability of terrain is very important for mobility of the troops. And the more accurate and quick the evaluation is the more successful the troops can fulfill their tasks. Instruments used for evaluation of the terrain are the penetrometers. In the Czech Army the most used are the Telescopic Penetrometer PT-45 and the Trafficability Test Set with the Cone Penetrometer. Each of them has its own advantages and disadvantages. It would be profitable to put together the advantages of both and to find the best solution meeting the requirements of the Czech Army. It means to have reliable instruments and accurate evaluation at the same time. To be able to compare them and use the working procedures of both of them it has to be found the dependencies between them, if they exist. Because they have different working methods, shapes, etc. So it was decided to measure with both concurrently and to try to find the relations between them. Perfect mastering of the topic of trafficability – the reliable instrument, the accurate evaluation and the means for overcoming is the main and basic assumption of mastering the mobility. And this is the key for successful troop tasking [1-3].

2. Measurement Conditions

The measurement was carried out in autumn 2017 on Mississippi river bank (Fig. 1) in the USA by ERCRD Engineer Research and Development Center. During this measurement it was measured the VCI (vehicle cone index) of HMMWV- High Mobility Multipurpose Wheeled Vehicle. It was measured the VCI of given vehicle and within this measurement it was measured with both instruments.

Fig. 1 Measurement Conditions
3. The Instruments

They were used two instruments. The first one was the Telescopic Penetrometer PT-45. It is used in the Czech Army – Field Manual Žen 2-16 Vojenské silnice a cesty – Military roads and Ways [4]. The second one is the Trafficability Test Set. This set is used in the Army of the USA and some other NATO countries. The procedure of this is described in the Field Manual 5-430-00-1 Planning and Design of Roads, Airfields and Heliports in the Theater of Operations – Road Design [5]. The basic advantages and disadvantages are that the telescopic penetrometer has little weight and it is very user-friendly and easy going. The disadvantage is not so accurate evaluation, which is problem. On the other hand, the cone penetrometer has very accurate evaluation, but the procedure of measuring is difficult and time consuming, even the set is very heavy and big, which is not suitable for engineer soldiers in the Czech Army [6]. That are simply the reasons, why it was started with the comparative measurements of these two measurements. Although the instruments have different endings and measure in different depth the author hope to find the solution having the advantages of both. More about them is written below.

3.1. The Telescopic Penetrometer PT-45

The most used instrument for evaluation of low endurable terrain in the Czech Army is the telescopic penetrometer PT-45 (Fig. 2). This instrument is supplemented with penetrate thorn. This thorn is pressed to the soil. On the dial we can read the value which is needed to press the thorn to the different depths. This press is found out in MPa. The depths in which is the press read are 5, 10, 15, 20, 25 and 30 centimeters on the same place. Each measurement is made three times in one-meter distance.

The number of vehicles which could go through the given area is determined from the evaluation table of the trafficability of a terrain due to their weight. As a low supporting terrain we consider the terrain where the telescopic penetrometer measures the value low than 3 MPa [4].

3.2. The Trafficability Test Set

This set contains the penetrometer, soil sampler, remoulding equipment and a bag of hand tools (Fig. 2). The terrain trafficability is judge according to the relation of two indexes - rating cone index [RCI] and vehicle cone index [VCI]. If $RCI > VCI$, than the terrain is trafficable for required passes of given types of vehicles [5].

4. Rating Cone Index

The rating cone index is a product of two other indexes – the remoulding index RI and the cone index CI. The cone index is measured by cone penetrometer and it shows the value of resistance of the soil against the penetration of the thorn, measuring the soil in its whole condition. The values are measured in different depths depending on the critical layer. The measuring principle is analogous to the telescopic penetrometer PT 45. The cone penetrometer measures terrain in these depths 0, 6, 12 and 18 inches. The remoulding index RI completes the measurement of the soil resistance with penetrometer, because it looks at the consolidation of the soil after the passes of vehicles. Practically the value is determinated by the remoulding tests in the soil sampler. Firstly, the soil is taken to the cylinder and the resistance of the unbroken soil is measured with the cone penetrometer. Then there are simulated the passes of the vehicles and the soil is deformed by the hammer. The soil resistance is measured for the second time. The ratio between
the values of resistance after and before is the remoulding index RI. The product of cone index CI and remoulding index RI is the rating cone index RCI. This value is much more punctual that the value of soil resistance.

4.1. Vehicle Cone Index

The vehicle cone index VCI is value specific for every type of vehicle and for given numbers of passes. It is usually counted for one or fifty passes, but this value can be counted for any required value. The vehicle cone index can be estimates for any vehicle through a formula, which takes into account contact pressure factor, weight factor, track factor, grouser factor, bogie factor, clearance factor, engine factor and transmission factor.

5. Measurement Procedure

As it was mentioned above, it was used the measurement for determination of VCI of HMMWV. The measurement procedure was following. The vehicle tries to overcome the given area. After it mired, it was pull out. And the measurement along the tracks started. Firstly, it was measured with the cone penetrometer and the remolding test were taken. Then it was measured with the telescopic penetrometer at the same places. At the end the soil samples were taken to their determination. After that the evaluation of the measured values follows (Fig. 3).

6. The Result of the Measurement

Despite the above mentioned differences in shape of penetration part of depths of measurement the authors tried to find some comparable quantities. So they relate values to the same depths, convert to the same units and do some other necessities. But finally they were able to find the dependencies between the measured values (Figure 4). This allowed the development and improvement of evaluation using both systems.
7. Conclusions

In the Army of the Czech Republic they are used two instruments – telescopic penetrometer PT-4 and the cone penetrometer from the Trafficability Test Set. Because each of them has its advantages and disadvantages, it was decided that it would be useful to merge these procedures of measuring to find the most effective solution, which would best suit the requirements of the Czech Army. The first assumption was to find out, whether they are some dependencies between the measurement values to be able to work with both evaluation systems and instruments. It was used the measurement run by ERDC to fulfill this first aim. During this it was measured with both instruments concurrently – at the same time, place and with same conditions. Then the measured values were convert and compared and the dependences between them were find. This result enables to use both systems of evaluation of low endurable terrain to find the best solution of evaluation. This solution should match the best from botch system to be able to best follows the given conditions of the Engineer troops of the Army of the Czech Republic [7, 8].

Acknowledgment

Presented work 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.

References

Operational Economic Aspects of Warning Collision Systems for Helicopters

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Abstract

In the presented article we discuss the operational economic aspects of detection and anti-collision systems used in helicopters. We are describing helicopter protection anti collision systems with high voltage wires the Wire Strike Protection System (WSPS). There is the basic information about the Powerline detector provided. We compare current generations of OASys radar systems (Amphitech Systems) and LOAS (Goodrich Sensor Systems) using a laser. We are evaluating these systems in terms of their detection performance and financial demands to implement them into different types of helicopters. We are also analysing an accidental balance that is directly related to the use of these specific devices on civil helicopters.

KEY WORDS: detection of high voltage lines, anti-pollution systems, pilot training, accident prevention

1. Introduction

Helicopter collisions with obstacles are the concern of both civilian and military helicopter operators. High-voltage power helicopter protection devices have been available for several years. The magnitude of incidents caused by helicopter collisions with high-voltage lines in civilian helicopters in the US is about 5% of all accidents that have occurred since 1963 up to the present. Despite the excellent experience with the effectiveness of existing anti-collision systems on US Army helicopters, there is no detailed study of these incidents and the potential of the currently available accident reduction devices [3]. The Federal Aviation Administration (FAA) reports on 208 civilian helicopter crashes for a 10-year period (1970-1979). [7] In these accidents, 37 people died and 52 people suffered serious injuries, 88 aircraft (42%) were destroyed and 120 aircraft (58%) were damaged. On the basis of the analysis of these aviation accidents, it was concluded that the use of an effective helicopter warning device, which would substantially reduce the number of air accidents, is necessary [6]. By analyzing the helicopter accidents it was found out that the use of wire cutters would be effective in up to 49% of the investigated accidents. Further training of pilots for these specific situations would, moreover, increase the effectiveness of the measures in 56% of the accidents. The FAA recommends pilot training, installation of wire cutters and equipment capable of alerting the pilot in front of the high-voltage line on all types of helicopters. Measures to protect the rotor blades and tail blades are essential to prevent accidents in such situations [7].

2. Helicopter Protection Systems in Collision with Wires

One of the systems that can provide helicopter protection against frontal collisions, is the system WSPS. This system is manufactured by Bristol Aerospace Limited. A typical installation of this system consists of a roof knife and one or more knives mounted on a helicopter. The deflector is guided vertically along the center of the windscreen and guides the cables to the cutters. Fig. 1 shows the system installed on Bell 206. The effectiveness of the WSPS was verified by the US Army through pendulum tests conducted at the National Impact Dynamic Test Facility in Langley, Virginia. In the fourth chapter, Table 1, models and WSPS costs for helicopters that have FAA approval for WSPS assembly are presented. Installation of WSPS can be done by a qualified helicopter mechanic in about 40 hours [7]. For the blades to be effective, the helicopter must fly at a speed of more than 30 knots. The manufacturer states that if a WSPS helicopter hits the wire at an angle of less than 60 °, WSPS does not need to cut the cable (Fig. 2).

![Fig. 1](image1.png)  
Fig. 1 The cutter placed on the Bell 206 Jet Ranger [7]  

![Fig. 2](image2.png)  
Fig. 2 Shows the maximum efficiency angle for an obstacle barrier [7]
In addition, the maximum climb angle at which the WSPS should come in contact and is still effective is ± 5°. The system is designed to cut a 3/8 "diameter steel cable with a 12,000 lb strength. If a wire contact occurs during a flight, the manufacturer suggests that the blades be replaced immediately.

2.1. Powerline Detector System

If an electric line is detected in a helicopter flight path, the Powerline detector gives the pilot warning by beeper 1800-feet far from danger. The warning sound increases the frequency when the electric line is approaching. If the pilot is still approaching the power line, the red indicator lights up in the cockpit. During a flight in a multiple-wiring area, the system may be temporarily interrupted [4]. The detector Powerline is compatible with all civilian and military helicopters and can only be installed by a certified manufacturer. Installation takes approximately two days. The unit needs a 28 V DC (Vdc) power supply provided by the helicopter deck. It detects electrical signals at 60 Hz. The company Safe Flight tested the life of the detector. The average failure-free time of the detector is more than 10,000 flight hours. The retail price of the Powerline detector product is listed in the fourth chapter. Aerodynamic resistance of the antenna is not known, but is probably negligible, especially when mounted on the helicopter tail. This detector only detects active electrical lines and the detection range depends on the power in the lines. The system does not recognize other types of wires, such as cable wires, weak telephone lines, and inactive power lines.

3. OASys Radar (Amphitech Systems)

The system uses a radar mounted to transmit 35-GHz radio frequencies to detect obstacles in the flight path (Fig. 3). The radar is constantly looking for obstacles in its view area. At the given time, the system uses data from the aircraft GPS receiver to calculate the flight path of the aircraft every 19 seconds. Three zones with increasing potential risk the system labels audiovisual.

If the obstacle is located in any of these three zones, the pilot is notified optically. The intensity of the light depends on the proximity and the obstacle zone and is reported by the small display in the cabin, which illuminates in accordance with the distance and towards the obstacle. OASys also adjusts flight requirements. For example, during startup, the system does not scan a wide angle around the helicopter but only a short distance ahead of it. However, when the aircraft increases its speed, the scan narrows and monitors the space far ahead in the flight path (Fig. 4). The OASys radar has a maximum range of 1600 meters. This system is also effective in rain and fog conditions. The OASys consists of a box located inside the helicopter and a sensor mounted in the helicopter's nose. Sensor dimensions are 15.48 " × 16.78 " × 22.44 " and total weight is about 54 pounds. The system uses a 35 GHz radar and allows obstacle detection in the flight path direction.

OASys can now be installed on the Bell 212, Bell 412 and Eurocopter AS-350 models (Fig. 5). These systems are installed by the Amphitech company. The Amphitech Company sells the radar system as a kit that the helicopter
mechanic can install in less than 24 hours. The Amphitech company is currently working to obtain OASys installation permission for all helicopter models in the US and Europe.

![Image](image_url)

**Fig. 5 The scanning head of OASys [7]**

The expected life of the OASys radar is 20,000 flight hours or 20 years with proper maintenance. Some parts of the system need to be replaced every 2500 hours of flight, but this process can be completed by the mechanic in less than 1 hour. The OASys price is listed in the fourth chapter. OASys does not recognize objects behind or directly above the aircraft. Therefore, the system will not alert the pilot when the presence of wires is near the tail rotor when hovering or taking off [7].

4. **Loas System**

Goodrich Sensor Systems are systems that provide helicopter pilots with information on obstacles. They use the laser to do this. They can detect small obstacles such as Solid State Relay SSR wires and transfer these data to the aircraft's navigation systems. When scanning the area, the laser radar uses a narrow beam that is not dangerous to human eyesight. The system consists of a sensor head mounted on a helicopter fuselage and an electronic control unit that is inside the cabin. The system weighs about 35 pounds and the cylindrical scan head measures 8.66" and 15" in diameter. The LOAS requires 300 watts of electricity to operate. Goodrich states that the average time between failures for electronics and optical components of the system is over 1000 hours. The LOAS system is an adaptable system that can be implemented in sea ships, aircraft, and rotorcraft. The system is compatible with all commercial rotorcraft and was successfully tested on the Eurocopter EC155, Bell 412 and Bell UH-1H. The system has the ability to be directed in the direction the pilot requires. The scanning sector in the vertical plane is from 2 m to 2 km. The horizontal plane is 180°. The scanner head and system electronics are shown in Fig. 6.

![Image](image_url)

**Fig. 6 LOAS scanning head [7]**

LOAS can be installed by the Goodrich Company or the helicopter manufacturer. The Goodrich Company works with the third party companies to design installation kits, which can be purchased separately so that the consumer can install LOAS on different helicopter models. Mounting and sensor can be located anywhere on the troop, but the system will work best if it is located in the helicopter's nose. Goodrich does not provide the exact price of the system. Due to its weight (35 lb), the LOAS system can be mounted on larger helicopters [7].

5. **Costs for the Operation of Detection and Anti-Calculation Systems Used in Handles**

Funds used for the operation of detection and anti-collision systems are used to cover the costs incurred in procuring and operating them. We can divide the cost items into the following groups:

- **Procurement** of detection and anti-collision systems that have to meet the requirements for safety, quality, capacity and economy of operation. The main criteria for choosing a new system are its security (safety certificate), price, quality, lifetime, return on investment. Aeronautical technology can be purchased either through direct purchase or by leasing. The cost of the detection and anti-collision systems consists of the cost of technology and the cost of
Depreciation arising from the use of detection and anti-collision systems reflects the extent of their wear. It can either be moral, which arises from the gradual obsolescence of the technique, or physical as a result of its use. Depreciation is carried out over several accounting periods when the procurement cost is reduced and reflected in costs. The depreciation principle has to be performed according to Act No. 595/2003 Coll. on Income Tax as amended and Act No. 431/2002 Coll. on Accounting as amended. The asset may be amortized evenly or expeditiously.

Maintenance and repair of detection and anti-collision systems is one of the largest cost items. Costs are broken down by type of technique. Every maintenance is carried out by qualified personnel using certified spare parts from specialized companies. Costs incurred for repairs and maintenance must be adequate for the use of the equipment.

Wage and payroll costs have a large share of airline costs. They consist of wage costs, statutory social insurance, health insurance, other social security and other costs. Wage costs include gross wages and salaries, including non-cash employee benefits.

Here are some of the data related to the procurement and operation of detection and anti-collision systems. Airline companies understand the importance of new technologies and their impact on air traffic safety [1, 2, 5]. Detection and anti-collision systems are designed to both reducing operating costs and increasing air traffic safety. As a rule, future detection and anti-collision systems will be available through software updates, which reduce future maintenance costs and total flight downtimes. In Table No. 1 there are models and costs on WSPS procurement for helicopters that FAA approved for assembly. WSPS installation can be done by a qualified helicopter mechanic in about 40 hours.

### Table 1

<table>
<thead>
<tr>
<th>Helicopter</th>
<th>Price (U.S. $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bell 204, 205, 212, 412</td>
<td>8,515</td>
</tr>
<tr>
<td>Bell 206A, B, L, L-1, L-3, L-4</td>
<td>6,870</td>
</tr>
<tr>
<td>Bell 222, 230, 430</td>
<td>34,000</td>
</tr>
<tr>
<td>Bell 407</td>
<td>7,370</td>
</tr>
<tr>
<td>Bell 427</td>
<td>13,995</td>
</tr>
<tr>
<td>MD Helicopters 500, 500C, 500D</td>
<td>7,450</td>
</tr>
<tr>
<td>MD Helicopters 500E, 500N, 530FF</td>
<td>7,450</td>
</tr>
<tr>
<td>MD Helicopters 600N</td>
<td>12,995</td>
</tr>
<tr>
<td>Eurocopter AS-350</td>
<td>13,995</td>
</tr>
<tr>
<td>Eurocopter AS-355</td>
<td>13,995</td>
</tr>
<tr>
<td>Sikorsky S-76</td>
<td>20,000</td>
</tr>
</tbody>
</table>

The Powerline detector gives the pilot an audible warning of danger. The retail price for the Powerline Detector is $11,800, without installation. The company Safe Flight tested the life of the detector. The average failure-free time of the detector is more than 10,000 flight hours. The OASys radar costs $170,000 without installation. The installation may cost somewhere between 5,000 and 10,000 USD. The expected life of the OASys radar is 20,000 flight hours or 20 years with proper maintenance. Some parts of the system must be replaced every 2500 hours of flight. This process can be done by a mechanic in less than 1 hour. Goodrich Sensor Systems provide the helicopter with information on obstacles. The Goodrich Company does not provide the exact price of the system, but the estimated price would be about $100,000 without installation. Goodrich reports that the average failure-free time for electronics and optical system components is over 1000 hours.

### 6. Conclusion

Most of the helicopter collisions occurred during the day, with good visibility when the machines were piloted by experienced pilots. It is clear that timely helicopter pilots’ responses can prevent accidents caused by helicopter collisions with high voltage lines. From the analysis of the cost of procurement and operation of HVS protection systems and helicopter warning systems, it is clear that these costs are relatively large. Nevertheless, these costs are necessary because they make a significant contribution to increasing flight crew safety. They also reduce the risk of airline losses that may arise from a helicopter collision with VVM. If we want to conduct low altitude flight operations on the basis of recommendations from FAA Specialists and Air Force Specialists, it is first necessary to explore the aerial maps and conduct a reconnaissance flight at a higher altitude in the intended area of activity. HCV is hard to see, partly due to imperfections in the human eye and partly due to masking effects. Wire movement during a sunny day may cause fuse and disguise of contour lines. Older cables can be hard to see because their age often changes the colour. For example, copper wires oxidize with age and change colour to greenish, making it difficult to distinguish from grass and trees in the background. The exact localization of particular wires may change over the day due to varying ambient temperatures, which may cause the wires to stretch or pull out. The exterior view of the pilot can also
be influenced by the cockpit and vibration cabin environment. The cockpit cover may not always be clean, which reduces visibility. It is known that the performance of a person deteriorates after longer exposure to certain vibrations. For example, human eyes and intraocular structures have natural frequencies ranging from 20 to 90 Hz. Most helicopters have structural frequencies in the range of 20 Hz. Therefore, research needs to be expanded in this area, which is needed to understand how the human eye perceives obstacles such as the different types of wires in the air traffic environment.

References

The Experimental Testing of the Operational Capabilities of the Compression Superstructure Prototype

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Abstract

This paper deals with the experimental testing and the rechecking of the compression superstructure for the forest forwarders. The design of the compression superstructure is based on the requirements of the specification, where there is a 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: experimental test, dendromass, modular superstructure, fixed frame, strength rechecking, hydraulic pressure

1. Introduction

Experimental testing on a real machine is the last phase in the development of the machine. Developing a modular superstructure of the compressing side panels [3] creates a new technology for processing dendromass and timber transport. The machine utilization is increased (Fig. 1). In order to perform the kinematic (limit parameters of the hydraulic motors), dynamic and stress analysis of the superstructure fixed frame the multi-body simulation and finite element method was used [1, 4]. Experimental testing of real force loads should demonstrate the consistency of the theoretical assumptions and practical possibilities. The values of the stress states will determine the operating life of the superstructure.

2. Experimental Testing of the Compression Superstructure

The purpose of the experimental testing is to find the real values of the load cases. Due to the unpredictable material conditions of the load (moisture, wood remnants [4]), the strength analysis of the virtual model was carried out for the weights of 3 tones (Fig. 1) [1]. The load weight of 3 tons is the maximum weight of the transported dendromass and is limited by the tilting of the haul bed by two hydraulic motors. The force load cases of the hydraulic motors was measured by the pressure in the hydraulic system and empirically derived for the piston dimension. The enormously high force load case of the hydraulic motors is assumed to be the beginning of the tilting (position angle 0°) [1, 5]. This is due to the concept of the tilting. The fixed frame has been designed for 3 tons loads with safety coefficient $k = 1.5$.

Fig. 1 Forest forwarder. The virtual prototype (left), the real prototype with the tracked chassis (right) [1, 5].

3. Real Conditions for the Experimental Testing

The experimental test was carried out in the winter. Dendromass is very moist and the weight for the same volume is the highest. Before the compression, the dendromass is placed non-uniformly in the haul bed. After the
compression, the branches protrude rearwards and upwards above the side panels, thus increase the transport capacity of a forwarder (Fig. 2) [1, 4].

The determination of the compression can not be defined by the exact calculation. One can only estimate compression of the dendromass min. 30%. On the basis of the experimental tests, the weighing rate was found to be approximately 1.6 to 2 tons of the fresh dendromass (Fig. 2) [1, 2]. The technical parameters of the forwarder with the superstructure of the side panels are shown in Table 1.

The parameters of the haul bed are calculated theoretically. In practice, the dendromass was loaded to more than the theoretical volume of the haul bed (Fig. 2). The dendromass increase was achieved at approximately a 25% more than the volume of the haul bed in Table 1.

![Fig. 2 Forwarder loaded with dendromass, weighing (left), rear view of the dendromass surface area (right) [1]](image)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight of the empty tracked forwarder with the superstructure</td>
<td>11 260 kg</td>
</tr>
<tr>
<td>Front section</td>
<td>4 900 kg</td>
</tr>
<tr>
<td>Rear section</td>
<td>6 360 kg</td>
</tr>
<tr>
<td>Superstructure</td>
<td>1 950 kg</td>
</tr>
<tr>
<td>Weight of the fully loaded tracked forwarder with the superstructure</td>
<td>12 800 - 13 310 kg</td>
</tr>
<tr>
<td>Weight of the dendromass</td>
<td>1 500 - 2 050 kg</td>
</tr>
<tr>
<td>Surface area and volume of the haul bed in the different side panels slopes</td>
<td></td>
</tr>
<tr>
<td>Side panels in the vertical position (transport)</td>
<td>SA = 2.15 m², V = 9.6 m³</td>
</tr>
<tr>
<td>Side panels max. open (loading)</td>
<td>SA = 2.82 m², V’ = 12.7 m³</td>
</tr>
<tr>
<td>Side panels min. open (compression)</td>
<td>SA’’ = 0.95 m², V’’ = 4.3 m³</td>
</tr>
</tbody>
</table>

4. Experimental Test Procedure and the Resulting Values

The grab and the loading crane are used to load the dendromas into the haul bed. The compression side panels are in the fully opened position when loading the dendromass. When loading the wood, the compression side panels are in the vertical position. You can not compress a wood timber.

The compression of the dendromass occurs in three phases. The first phase is the haul bed being filled with dendromass. In the second phase, both side panels are gripped - the dendromass is compressed. The side panels open and the dendromass is added, which is compressed again. In the third phase, the empty space is again filled with dendromass. The side panels open only to the vertical transport position. The load was created and ready for the
transport to the landfill.

At the landfill, the dendromass load is dealt with in two possible ways. The dendromass unloading with a crane grab. This is in case of the space lack in the landfill. Or, the tilting of the load is used [3]. The tilted dendromass forms a compressed heap.

The pressures in the tilting hydraulic motors (Fig. 3) and in the compression hydraulic motors were measured in the experimental tests. Table 2 shows the measured pressures in the hydraulic system for the compressing and the tilting of the dendromass and the equivalent force of the hydraulic motors.

Table 2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pressure (bar)</th>
<th>Equivalent axial force for a hydraulic motor (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compression side panel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compression – max. pressure</td>
<td>208</td>
<td>40 840</td>
</tr>
<tr>
<td>Tilting of the haul bed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Begin of the tilting - slope angle 0°</td>
<td>125</td>
<td>79 500</td>
</tr>
<tr>
<td>Process of the tilting</td>
<td>80</td>
<td>50 900</td>
</tr>
<tr>
<td>End of the tilting – max. slope angle 57°</td>
<td>70</td>
<td>44 500</td>
</tr>
<tr>
<td>Peaks in the hydraulic system when finish tilting of the compression dendromass</td>
<td>208</td>
<td>40 840</td>
</tr>
<tr>
<td>Partially tilting down</td>
<td>110</td>
<td>70 000</td>
</tr>
<tr>
<td>Final tilting down into the transport position</td>
<td>125</td>
<td>79 500</td>
</tr>
</tbody>
</table>

Fig. 3 Experimental test of the tilting haul bed with the dendromass, course of the pressure in the hydraulic motor tilting, \( p_1 \) – return (tank) pressure; \( p_2 \) - working pressure [1]

5. Rechecking of the Superstructure Strength Analysis

After the experimental testing, a supplemental strength analysis was performed for the fixed frame. The fixed frame is most stressed when tilting the dendromass from the haul bed to the landfill. The strength analysis was performed for a load weight of 2 tons for the three haul bed positions - 0°, 30° and 57°. The load weight 2 tons is the maximum working weight. This weight is verified by measuring the real test of the superstructure [1, 4, 5].
6. FEM Analysis of the Superstructure Fixed Frame

The computational model of the fixed frame was created from a 3D model. The computational model contained the shell elements and the solid elements. This analysis was performed on a similar principle and a similar approach as used in the papers [2, 5, 6].

Equivalent axial forces for the load cases were loaded at defined locations according to the results of the experimental testing (Table 3).

The axial forces of the load cases for the maximum weight of 2 tons.

<table>
<thead>
<tr>
<th>Description of the axial forces</th>
<th>0° slope</th>
<th>30° slope</th>
<th>57° slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force in the hydraulic motor</td>
<td>F_{1x} [N]</td>
<td>-27 250</td>
<td>-11 024</td>
</tr>
<tr>
<td></td>
<td>F_{1y} [N]</td>
<td>-6 320</td>
<td>-4 424</td>
</tr>
<tr>
<td>Force in the first kinematic lifting member</td>
<td>F_{2x} [N]</td>
<td>7 100</td>
<td>5 880</td>
</tr>
<tr>
<td></td>
<td>F_{2y} [N]</td>
<td>-1 628</td>
<td>-1 904</td>
</tr>
<tr>
<td>Force in the joint of a haul bed</td>
<td>F_{3x} [N]</td>
<td>42 600</td>
<td>10 471</td>
</tr>
<tr>
<td></td>
<td>F_{3y} [N]</td>
<td>-8 200</td>
<td>-12 371</td>
</tr>
</tbody>
</table>

7. Results of the Fixed Frame FEM Analysis for the Tilt Begin

The strength analysis was performed on a fixed frame for the load case of the forces according to Table 3 during tilting compressed dendromass. The resulting stress state of the strength analysis is shown in Fig. 4 for the position of the haul bed 0° (tilt begin) and for the load of 2 tons. The legend color spectrum used, shows the reduced stress distribution of 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 for the material of metallurgical products.

Fig. 4 shows the reduced stress distribution at the beginning of the haul bed tilting. In the superstructure are the great forces. The inclination of the hydraulic motors is very small. The forces of the hydraulic pressures begin to fall sharply (Fig. 3). Other tilting load cases are subject to reduced stress in the range of up to 90 MPa. These situations occur when the compression dendromass of 2 tons is blocked in the haul bed.

8. Conclusion

The paper dealt with the experimental testing and the strength verification of the superstructure of the forest forwarder. The purpose of the superstructure is to allow the transport of the forest dendromass from the harvesting site to the landfill site at the maximum possible quantity achieved by compressing.

The experiment demonstrates that the superstructure is suitable for the set conditions of the practical environment. After the experimental verification, a strength analysis was performed on the real load case from the tilting of the haul bed. The resulting strength analysis values meet the strength requirements of the superstructure design. The capacity of the load weight is not limited, although the compressed load exceeds the volumetric space of the haul bed of the superstructure.
Acknowledgement

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).

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.

References


Innovation, Informatization and Digitization of the Infrastructure Facilities  
Design and Construction of High-speed Railways in Russia & Eurasian Union

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Abstract

Nowadays in Russia there is a great interest towards informatization in the field of infrastructure construction and the huge desire to learn from the leading countries experience and implement BIM Infrastructure in the construction of high-speed railway line Moscow – Kazan: industry leaders began to apply information modeling in the beginning of the century and now BIM is used by all employees and contractors of these companies. In Russia, such a level of adoption of this technology is rare, but the trend of development of the industry towards the development of investment projects and their management on the basis of BIM was set by the Russian government several years ago. New project of high-speed railway line brings the wave of innovation and digitalization into Russian and Eurasian Union Railways. Automatic design system of high-speed railway projects creation provides new approaches to the design and construction of the infrastructure facilities, that could help to save time and money.

KEY WORDS: new high – speed line Moscow-Kazan, Barren path, CAD, BIM infrastructure, construction, common data environment, infrastructure objects in EAU, high-speed rail

1. Introduction

The defining criterion in the world railway construction is the creation of high-speed rail networks and technological devices of the new generation. In favor of high-speed rail transport means that the world community is concerned about the pace of growth of motorization and related environmental problems, especially for large megacities. In particular, the world is changing priorities in favor of more environmentally friendly modes of transport, including rail, which is confirmed by a number of studies.

It is proved that at 400-800 km distances the high-speed highway train is more preferable for travel speed and other factors - safety, comfort, economy, reliability (regularity) of transportations than aircraft or car.

In the context of structural and infrastructural changes in the world economy and politics, we can see the opportunities and chances for Russian and Eurasian countries innovative development through the creation of a qualitatively different transport infrastructure.

Demand of the railway industry is able to act as a catalyst for growth for a whole range of high-tech industries (high technologies in metallurgy, electrical engineering, fuel and energy, information and telecommunications sectors). The compatibility of high-speed railways with other railways generates a multiplier effect of using advanced devices and technologies throughout the country's railway network. The innovative railway complex is one of the few real opportunities of Russia and the Eurasian Union (along with energy sources, military and aerospace technologies) in terms of reaching new geostrategic boundaries. The plans of the Russian Federation are to create high-speed rail lines to transport passengers at speeds up to 350 km / h according to the "Strategy for the development of rail transport until 2030" look less ambitious than in European countries [1]. The "Strategy" assumes the construction of only 1,500 km of such lines, but this is a huge step for Russia in the high-speed railway lines development.

Implementation of high-speed innovative technologies could possible solve two major tasks facing Russia, such as modernization of the economy, and preserving the territorial integrity of the country.

BIM (building information modeling) software purpose is creating and managing information at all stages of the construction life cycle and the ability to create projects of civil structures and infrastructure facilities in a short time. The advantage of the application is the speed and flexibility of design, the opportunity of technical and economic analysis with less resources.

At concept stage of an infrastructure structure design, be it a railway or a bridge, the BIM design tools make it possible to test the digital model of the facility and get leveled performance indicators. Identification of errors, collusions and shortcomings of the object digital model takes a small amount of time and reduces the risk of additional costs at the stages of construction and operation. To identify collisions at each stage of the design, the position of the BIM-manager is introduced, which monitors the correctness of joint design between the departments of the project organization.

2. High-Speed Railway Line Moscow – Kazan

Russian experience of international interaction of railway organizations, integration of technologies, participation in foreign projects is the section of "Eurasia" transport corridor.

High-speed railway line Moscow – Kazan project involves the simulations work of Russian and Chinese expert
High-Speed Rail Moscow Kazan is the first Russian high-speed passenger highway project in Moscow with the prospect of extending to Yekaterinburg. The distance is 770 km (in the long run to Yekaterinburg 1,595 km). The route will pass from Moscow to Kazan through the major cities of Vladimir, Nizhny Novgorod, Cheboksary, the territory of 11 regions of the Russian Federation will fall into the zone of attraction of the SCM [2]. The cost of the project is more than 1 trillion. rub. (30 mln dollars) About 300 man-made structures, 117 km of overpasses, three large bridges across the Volga, Oka and Suru will be built at the Moscow – Kazan high-speed railway line (Fig. 1). Optimum rolling stock on the HSM - 8-car electric double-train (length of 200 m), with a speed of up to 400 km/h.

3. Innovative BIM Technological Solutions.

New technological solutions in the sphere of BIM are reflected in almost all types of construction and installation works. The application of advanced technologies for information modeling of infrastructure facilities began. In order to ensure constructive uniformity, technical solutions of unified artificial infrastructure structures have been developed. These innovative solutions include designs for the Moscow – Kazan high-speed railway line section with speeds from 200 km/h and up to 400 km/h, for which the contact electricity network KS-400 was developed on the basis of mathematical modeling of dynamic interaction with current collectors of electric rolling stock [3].

Designing with the development of unified constructions of artificial infrastructure structures for the gauge of 1520 mm made it possible to provide [4]:
- the necessary tools for all design participants to develop a plan and profile of the railway track and design bridges;
- development of the main provisions of the construction organization;
- technological and price unity, saving of project resources and design time.

The large, medium, small bridge structures design (85–95)% of the total number of bridges, overpasses, overpasses and viaducts) is based on unified solutions for span structures, piers, bearing parts, expansion joints, and other structures (Figs. 2 and 3).

4. Bridges and Overpasses Construction. Unification

In the basis of designing extra-class bridges across large water barriers Klyazma, Oka, Suru and Volga (only 5
out-of-class bridges, including two bridges across Klyazma), the following design solutions are laid: - in the part of main bridge spans individual solutions were offered, multi-span reinforced concrete beams of variable cross-section and reinforced concrete arch were implemented; - on the approach sections, unified solutions of spans and piers, with the taking into account the relief and geological factors [5].

The design of small Infrastructure objects is based on unified design solutions of pipes with cross sections from 1.5 to 3 m and individual projects of frame-truss bridges with spans of lowered construction height up to 20 m.

5. Main Design Solutions for Structural Structures of the Upper Structure of the Way

The structures of the Moscow-Kazan high speed railway are designed to meet the requirements for strength, stability and deformation, taking into account the vibration-dynamic effect of trains while minimizing costs throughout the life cycle. It is envisaged to install two protective layers of the roadbed along the entire length of the high-speed highway at least 2.5 m in total height [6].

The earthen canvas is designed from the condition of ensuring the safe movement of high-speed railway rolling stock with speeds up to 400 km/h.

During the design, the following tasks were solved:
- the design of a road bed is grounded depending on engineering-geological and natural conditions;
- the necessary complex of measures for protecting the road bed from the harmful effects of natural factors is justified.

The adopted design solutions for the roadbed correspond and are technically linked to the structures of the upper track structure, man-made structures and engineering communications. The maximum accumulated residual deformation of the main site of the roadbed with a ballastless structure of the track top structure should not exceed 15 mm for the entire service life (Figs. 4 and 5).

6. The Structure of the Upper Structure of the High Speed Railway Line Moscow-Kazan

In the world practice, the advantages of ballastless structures of the railway upper structure over traditional, ballast, are the stability of geometric parameters and high resistance to movement of the track in the longitudinal and lateral directions. Due to this, increased speed characteristics of movement and less wear of the rolling stock are achieved. It should also be noted convenience and speed of installation with the necessary equipment and low costs for the ballastless structures of the railway upper structure service.

The disadvantages include a relatively high construction cost, increased noise and vibration during the passage of rolling stock. A significant drawback of the ragged path is also that its laying on the earthen canvas can only be considered if the subsequent sediments or soil heaving are completely excluded, hence, higher requirements for stabilizing the subgrade must be met [7]. Based on the world experience, it is not recommended to use the ballastless structures of the railway upper structure in zones of potential subsidence of the surface, seasonal freezing of soils with a high level of groundwater, in the presence of a thickness of soils with low bearing capacity and other specific geological conditions that complicate the control over deformation processes.

Advantages of the classic top track structure on ballast are the simplicity of straightening the path in the profile and plan during operational deformations, low construction costs, greater versatility for different operating conditions and better parameters for damping noise and vibration.

The shortcomings of the way on ballast are high operating costs and the worst geometry of the track. At speeds of more than 250 km / h, there is an aerodynamic lift of the crushed stone when the train passes, to prevent which measures are taken to secure the ballast prism, for example, by impregnating its surface with a polymeric binder.

With regard to the application of different types of track structure under Russian conditions, different experts hold different opinions. Designers of the pilot section of the SCM Moscow-Kazan on the basis of a complex of technical and economic factors came to the conclusion about the advisability of constructing an airborne engine at sections with speeds in excess of 200 km / h. Plots where the estimated speed of the train is lower is proposed to be built on ballast [9].

The High speed railway line Moscow-Kazan skeleton, with the exception of separate points, is designed under two tracks (Fig. 6);

The thickness of the first protective layer should be at least 0.70 m (7.55 mn m³), the second protective layer should be at least 1.80 m (more than 22 million m³).
Precipitation of the foundations of the roadbed for the entire period of operation should not exceed:
- for road sections on ballast (not more than 100 mm);
- for road sections on ballastless structures (no more than 15 mm).

During the design stage special technical requirements (STU-2016) were taking into account, as well local climatic, geological and other conditions, the Chinese CRTS III design, which was abbreviated RUS, was adapted by the designers (Fig. 7).

At the experimental ring of JSC "VNIIZhT" the resource tests of the ballastless structures of the railway upper structure were completed:
- from the company TINES - design EBS;
- from ALSTOM - design NBT;
- Max Bogl - FF-Bogl construction;
- from RZD-construction - LVT design.

The results of the tests confirmed the viability of the of the ballastless structures of the railway upper structures (over 630 million tons of operating time).

In accordance with the requirements of the special technical terms: the design of the ballastless upper structure of the track is generally composed of rail lashings, elastic intermediate rail fasteners, sub-rail supports, a base of plates or monolithic concrete, a hydraulically bonded carrier layer [8]. Operating range is from -47C to +68C.

The required materials for ballastless upper structure: prefabricated slabs. (for construction with slabs); monolithic base of the path; laying self-compacting concrete.

7. BIM Infrastructure

Infrastructure Building Information Modeling (BIM) technology will be applied to the design and construction of the Moscow-Kazan high-speed railway project, the usage of the BIM tools on the high speed line project will take place in three stages: the development of the BIM- standard, approval, then the implementation phase [9].

For the Right-of-way three-dimensional model development the following digital data is used: topographic plans, point cloud files, laser scanning data and aerial photography (Fig. 8).

**Fig. 6 Ballastless structures of the railway upper structure**

**Fig. 7 CRTS III RUS design**

**Fig. 8 Creation of a right-of-way three-dimensional model**

**Geological BIM model**

The model (Fig. 9) is created on the basis of geological exploration data and includes such data as: drilling data, engineering geological survey lines, geotechnical boundaries, boundary line between rocks on the plan of horizontal section and exploratory section, delineating lines of layers of geological periods, delimiting fault line [10].
Roadbed BIM Model Development
The roadbed modeling is carried out using the necessary parameters, the choice of materials, and the conditions for the execution of engineering work (Figs. 10 and 11). It is possible to select typical patterns of the roadbed to provide highly effective, flexible and qualitative elaboration of the design solution variant.
8. Conclusion

The introduction of information technology in the field of industrial, civil, infrastructure construction should contribute to the development of the industry as a whole and the emergence of competition in the CAD market. In addition, a significant economic effect from the application will be achieved with: expansion of R&D financing, training and teaching of technical specialists at the universities of the Eurasian Economic Union [11].

High-speed railway lines is a modern indicator of the quality of life and communication capabilities of society, as well as an indicator of the development not only of the transport sector, but also of the socio-economic and political potential of the state as a whole. Precautions in the Russian political and administrative practice to create predictive models of the country's territorial development on long-term prospects [12].

The usage of project management tools in conjunction with innovations, informatization and digitalization allow to automate and modernize the infrastructure, including the construction of high speed railways, can be carried out at a qualitatively new level, which makes it possible to combine the transport accessibility and economic development of not only a single region or country, but the whole Eurasian Union.

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Assessment of the Impact of Klaipeda State Seaport Cruise Shipping on Air Pollution

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Abstract

Cruise shipping is one of the fastest growing shipping types, especially in the Baltic Sea region. Most research usually are focused enough on cruise tourism and its economic added value in the region and sufficient empirical studies have been carried out to substantiate this. However, the impact of cruise shipping on the air quality of urban areas near to seaports is studied less, so the purpose of the study is to evaluate the impact on the Klaipeda air quality made by pollutants (sulfur, nitrogen, carbon oxides, non-methane volatile organic compounds and particulates) that are carried out by cruise ships that come to Klaipeda Seaport. The research objectives were to analyze cruise shipping technologies, to draw up a methodology for calculating the amount of pollutants in the exhaust gases of cruise ships, to establish the tendencies of cruise shipping development in Klaipeda Seaport, to calculate and forecast the dynamics of emissions of cruise ships and to assess the impact of pollutants from cruise ships on the air quality in Klaipeda. The dynamics of pollutant concentration from cruise vessels has growing tendencies in Klaipeda Seaport during 2013-2017: on average annually pollution increases by more than 11 t, where are 78% of nitrogen oxides, 12% of carbon monoxide, 6% of non-methane volatile organic compounds, 4% of particulates, 0,03% of sulfur oxides.

KEY WORDS: cruise shipping, cruise ship pollution, air pollution

1. Introduction

Cruise shipping is not only a profitable seaport activity but an activity that adds value to economy of entire region, promoting cooperation between seaport, city and tourism business sectors and strengthening the link between these sectors. Development of cruise shipping in Klaipeda Seaport has a growing tendency due to the regional development of Baltic Sea cruise tourism. [2, 13] According to scientific studies, the economic issues of cruise shipping have been analysed in a sufficiently detailed way by assessing the seafaring incomes of cruise shipping mandatory fees for maritime services, as well as assessing the positive economic effect generated by cruise shipping tourists. [5] Based on the identified benefits, development of cruise shipping is being promoted, new vessels are being attracted, and Klaipeda is being added to new routes. In order to increase the economic benefits, the development field of Klaipeda Seaport as a technological service for cruise shipping was developed. It suggests that surveys of cruise shipping problems are broad enough to justify the economic benefits of cruise shipping to the regional and national economy, however, there is another aspect of cruise shipping development – the impact of cruise ships on the environment, and in particular on air pollution. [11] Following the tendencies of development in the concept of green logistics [3, 9, 10], the requirements and their importance for the sustainable development of the logistic global supply chain, attention must be paid to the potential negative impact of cruise shipping on the environment [12]. Therefore, the rates of sulphur emissions (SO₃) of shipping have been reduced in certain intensive shipping regions. According to Annex VI of MARPOL [14], the Baltic Sea region is classified as an intensive shipping region, therefore, sulphur emission rates are reduced for all vessels. The aim is to control the concentration of nitrogen oxides (NOₓ) in the exhaust gases as they contribute to global warming. Typical marine engines use fuels that release harmful substances into the atmosphere during combustion, and thus, pollutants fall not only into industrial regions but also to urbanized areas. Without taking appropriate measures, emission of harmful particles can increase by 1.5 times or twice by 2050. Therefore, discussions on how to reduce pollution from ships are being actively debated in the international global space. The main criteria for reducing air pollution are reducing the concentration of nitrogen oxides (NOₓ), carbon monoxide and dioxide (CO or CO₂), in common statistical databases marked as CO₂, sulphur oxides (SOₓ), hydrocarbons (CH), soot and other particulate matter (PM) in exhaust gases. This problem is relevant not only in shipping activities, but also in the land transport sector, as transport is both a key instrument for ensuring global supply chain and mobility of passengers. [6]

Taking into account the fact that shipping is carried out in a seaport, and in the Baltic Sea region, seaports usually interconnect and have direct interaction with the urbanized territories of the port city, the problem of particulate matter (PM) concentration in the air is also relevant, it has a direct impact on the deterioration of the health of the population. For the calculation of exhaust emissions of cruise ships, the general methodology for calculating the emissions of harmful substances is used [20], and it is also used in the main assessment methodologies for European Environment and Sustainable Development [9].
2. Methodology

For calculating the exhaust emissions of cruise ships, the general methodology for calculating the emissions of harmful substances is used [19], the same methodology is used in the main assessment methodologies for European Environment and Sustainable Development. This algorithm was also used in studies by other scientists to evaluate the amount of harmful substances released by vessels in various ports of the world: C. Denizir A. Kilic [7, 8] assessed the changes of air pollution caused by cruise shipping in seaports of Turkey; S. Vidale et al. [21] analysed the case of Italian seaports; M. Pandolfi et al. [16] investigated the situation of air pollution in the Strait of Gibraltar. According to [20] proposed methodology for assessing air pollution from ships, the emissions per one cruise ship were calculated according to the following formula:

\[
E_{\text{travels},i,j,m} = \sum_p \left( Q_{i,j,m,p} \cdot EF_{i,j,m,p} \right),
\]

(1)

here \( E_{\text{travels}} \) – emission over a complete trip (t); \( Q \) – fuel consumption (t); \( EF \)– emission factor (kg/t); \( i \) – pollutant; \( j \) – engine type (slow, medium and high-speed diesel engine, gas turbine and steam turbine); \( m \) – fuel type; \( p \) – different phase of trip (cruise, hotelling, manoeuvring).

Firstly, fuel consumption for each vessel was calculated according to engine type, fuel type, and vessel phase, and then emission of harmful substances. When searching for technical parameters for cruise ships, some ship data was not available. The following formula was used to assess emissions of harmful substances for such cases:

\[
E_{\text{travels},i,j,m} = \sum_p \left[ t \sum_e \left( P_e \cdot LF_e \cdot EF_{e,i,j,m,p} \right) \right],
\]

(2)

here \( E_{\text{travels}} \) – emission over a complete trip (t); \( EF \)– emission factor (kg/t); \( LF \) – engine load factor (%); \( P \) – engine nominal power (kW); \( t \) – time (h); \( e \) – engine category (main, auxiliary); \( i \) – pollutant; \( j \) – engine type (slow, medium, and high-speed diesel, gas turbine and steam turbine); \( m \) – fuel type; \( p \) – different phase of trip (cruise, hotelling, manoeuvring).

The concentrations of NOx, SOx, CO and PM were calculated. Such algorithm of calculation defines a sufficiently large amount of intermediate calculations that are needed to harmonize the collected data and the indicator units used in the methodology. Cruise ship construction year and gross tonnage of ships have been found in the vessel search database [17] by ship name or IMO number, however, in order to calculate their emissions, the power of each cruise ship was searched additionally, which for cruise ships, the name of which begins with letter A, was found in the cruise ship database [18], while the data for other vessels was found in the database [15].

Using the regression analysis method [1, 4], it was found that the operating power of the engines of the cruise ships that arrived at KSS in 2013-2017, is related to the gross tonnage (Fig. 1).

![Fig. 1 Cruise ship main engine (a) and auxiliary engines (b) dependence on cruise vessel gross tonnage](image-url)
The overall emissions of harmful substances from cruise ships have been calculated by assessing the duration of the vessel’s cruising in different activities of navigation (Fig. 2).

Restricting to the calculation of emissions of harmful substances in the city of Klaipeda, the cruise ship cruising duration was calculated from the moment, when the ship enters the exclusive economic zone, which is 12 km, and cruising duration when navigating through channel, depending on the mooring berth, manoeuvring to berth and duration of hotelling at terminal (Fig. 2). Since the cruise ship’s main and auxiliary engines operate at different loads and time period, for the sake of accuracy, the cruise ship’s average standard values set out in the methodology were used [21], which are presented in Table 1.

<table>
<thead>
<tr>
<th>Navigation phase</th>
<th>Main engine load, %</th>
<th>Main engine operation time, %</th>
<th>Load of auxiliary engines, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cruise (in-port and up-to-port)</td>
<td>80</td>
<td>100</td>
<td>30</td>
</tr>
<tr>
<td>Manoeuvring</td>
<td>20</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>Hotelling</td>
<td>20</td>
<td>5</td>
<td>40</td>
</tr>
</tbody>
</table>

By calculating engine power, fuel consumption can be estimated of each cruise ship, during each cruising and hostelling phase, separately for the main and auxiliary engines. By calculating fuel consumption, using known standards of emission factors, the emission concentrations of different substances of NOx, SOx, CO and PM have been calculated.

3. Importance of Cruise Shipping to the Seaport and Port City Interaction

Analysing dynamics of cruise ships entering Klaipeda Seaport in 2004-2016, it can be seen that in the long period, the annual absolute change for cruise ships is less than 1 ship, which means that the number of cruise ships calling at Klaipeda Seaport is stable, it corresponds with the forecasts of KSSA that in 2018 64 vessels will be serviced, and in the absolute annual growth it is 1 ship (Fig. 3).
According to the global cruise shipping market, cruise shipping tonnage in the global cruise ship market is increasing, however, small and medium-sized cruise ships dominated in the sample of Klaipeda Seaport of oncoming ships in 2013-2017. Indicators of descriptive statistics in 2013-2017 suggest that KSSA is dominated by the cruise shipping of smaller parameters, however, analysing the dynamics of the changes in ship sizes, one can observe that the situation is changing (Fig. 4).

Since it is already known which cruise ships will come in 2018, this data is also included in the analysed period. If at the beginning of the period, in the sample of KSSA oncoming ships 10% of the ships were very small vessels, 15% were very large vessels, while 85% were small and medium-sized cruise ships, of which more than half (57%) were small cruise ships (Fig. 4), at the end of the period, very small cruise ships accounted for 16%, large cruise ships – 41%, and small and medium-sized vessels accounted for 44%, of which more than half (57%) consisted of medium-sized cruise ships. Such data suggests that cruise shipping tendencies in KSSA are changing parameters of oncoming ships are increasing and the proportion of large ships has increased by 35%. In the period of 2013-2017, a rather moderate but positive change in very small cruise ships is recorded, because the average annual absolute growth rate constitutes 0,21 (y=0,2143t+3,5714), while the most intense growth is recorded in the sample of large cruise ships, where the average annual absolute change amounts to 4,31 (y = 4,3143x + 4,0667). This suggests that cruise ships calling at KSSA are increasing, which increases their engine power, and which results in both increased fuel consumption and positive changes in emissions of combustion pollutants into the air.

4. Assessment of Air Pollution by Cruise Ships in Klaipeda State Seaport

Analysing the technical data of most commonly calling ships at KSSA, it can be seen that large vessels are dominated such as “Costa Pacifica”, with the highest frequency of calls, mega-type cruise ship, as well as the multifunctional large ships “Marina”, “Mein Schiff4” and luxury cruise ship “Seven Seas Explorer” (Table 2).

Table 2

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Vessel data</th>
<th>Main engine</th>
<th>Power, kW</th>
<th>Manufacturer</th>
<th>Name</th>
<th>Quantity</th>
<th>Power of auxiliary engines, kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIDA cara</td>
<td>194</td>
<td>38557</td>
<td>1339</td>
<td>1996</td>
<td>2005</td>
<td>VD</td>
<td>Multi-functional</td>
</tr>
<tr>
<td>Costa Pacifica</td>
<td>290</td>
<td>114500</td>
<td>3780</td>
<td>2009</td>
<td></td>
<td>D</td>
<td>Extremely large</td>
</tr>
<tr>
<td>Hamburg</td>
<td>144</td>
<td>15067</td>
<td>420</td>
<td>1997</td>
<td>2012</td>
<td>M</td>
<td>Small cruise</td>
</tr>
<tr>
<td>Marina</td>
<td>240</td>
<td>66084</td>
<td>1250</td>
<td>2011</td>
<td></td>
<td>D</td>
<td>Multi-functional</td>
</tr>
<tr>
<td>Vessel</td>
<td>Length, m</td>
<td>Gross tonnage</td>
<td>Number of passengers</td>
<td>Year of construction</td>
<td>Reconstruction</td>
<td>Vessel size</td>
<td>Power, kW</td>
</tr>
<tr>
<td>------------------------</td>
<td>-----------</td>
<td>---------------</td>
<td>----------------------</td>
<td>---------------------</td>
<td>---------------</td>
<td>-------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Mein Schiff 4</td>
<td>293</td>
<td>99526</td>
<td>2506</td>
<td>2015</td>
<td>D</td>
<td>Multifunctional</td>
<td>44000</td>
</tr>
<tr>
<td>Nautica</td>
<td>181</td>
<td>30277</td>
<td>824</td>
<td>2000</td>
<td>2004</td>
<td>VD</td>
<td>Small cruise</td>
</tr>
<tr>
<td>Ocean Majesty</td>
<td>135</td>
<td>10417</td>
<td>535</td>
<td>1966</td>
<td>2013</td>
<td>M</td>
<td>Luxury</td>
</tr>
<tr>
<td>Seven Seas Explorer</td>
<td>224</td>
<td>55254</td>
<td>809</td>
<td>2016</td>
<td>D</td>
<td>Luxury</td>
<td>32000</td>
</tr>
<tr>
<td>Silver Whisper</td>
<td>186</td>
<td>28258</td>
<td>423</td>
<td>2001</td>
<td>2016</td>
<td>VD</td>
<td>Luxury</td>
</tr>
</tbody>
</table>

Most of the ships are equipped with engines of different power produced by the specialized manufacturer Wärtsilä, while the number of installed main engines varies from 2 to 6 engines (Table 2), classified as group of medium-speed diesel engines, driven by marine diesel. Analysing the structure of all the cruise ships calling at KSSA throughout the whole period according to the year of construction, it should be noted that a quarter, i.e. 25% of all vessels, calling at KSSA, are not older than 11 years old, but even 26% of vessels are older than 29 years old. Applying the methodology and using the presented ship technical parameters as well as calculations of emissions from pollutants based on them, the current and predicted emissions of air pollution from cruise ships were assessed (Table 3).

**Table 3**

<table>
<thead>
<tr>
<th>Number of vessels</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOx, kg</td>
<td>15.76</td>
<td>26.81</td>
<td>23.23870482</td>
<td>24,45043228</td>
<td>37,198546</td>
<td>89,095711</td>
<td>21,83816</td>
</tr>
<tr>
<td>NOx, kg</td>
<td>43,664</td>
<td>74,065,27</td>
<td>643,18,1739</td>
<td>676,577,7029</td>
<td>102,656,1</td>
<td>869,56,971</td>
<td>610,81,728</td>
</tr>
<tr>
<td>NMVOC, kg</td>
<td>3336.79</td>
<td>57,02,97</td>
<td>4959,101,157</td>
<td>5260,595694</td>
<td>8098,8016</td>
<td>6855,6301</td>
<td>4753,29</td>
</tr>
<tr>
<td>TSP PM, kg</td>
<td>2076,57</td>
<td>3539,74</td>
<td>3076,188,081</td>
<td>3260,004,116</td>
<td>5010,292</td>
<td>4242,2832</td>
<td>2937,9715</td>
</tr>
<tr>
<td>COx, kg</td>
<td>5829,62</td>
<td>9921,04</td>
<td>8598,320,785</td>
<td>9046,659,943</td>
<td>13763,462</td>
<td>11681,808</td>
<td>8080,1192</td>
</tr>
<tr>
<td>Total emission, kg</td>
<td>54825,38</td>
<td>93255,83</td>
<td>80975,023</td>
<td>85249,48</td>
<td>129565,9</td>
<td>109825,8</td>
<td>76874,95</td>
</tr>
</tbody>
</table>

The research shows that in 2017, most of the air pollution was nitrogen oxides (NOx), whose total emissions during the cruise season amounted to 85.96 t, which accounted for 78% of all harmful substances (Fig. 5).

![Fig. 5 Dynamics of emissions from air pollutants per one cruise ship in 2013-2017](image-url)
Analysing the dynamics of total pollutants emitted from cruise ships to the atmosphere, it can be noted that the number of ships in the seaport increases, overall emissions are also increasing, and on average every year with the arrival of almost 4 ships more at the seaport, the average amount of emissions increases by more than 11 t, which means that on average one additional vessel releases about 3 tons of pollutants into the atmosphere. However, in 2018, predicting that the number of cruise ships in KSSA would be larger by one vessel, it is predicted that their total emission generated will be 15% lower. Analysing the release of atmospheric pollutants in different phases of cruising to port, it can be seen that both cruising at medium speed, both in manoeuvring and standing when both the main and auxiliary engines are operating, the largest proportion of the emissions of nitrogen oxides is recorded. However, when manoeuvring and hostelling with relatively low nitrogen oxide emissions, the release of non-methane volatile compounds and particulates, under the operation of main engine, significantly increases. In order to determine how the problems of air pollution caused by cruise shipping relate to the creation of an economic added value for the city, and to determine the possibility of increasing the potential economic value in regard to the potential negative impact on air quality, it is possible to analyse what part of the pollution emissions is incurred by one passenger of a cruise ship who has visited the city of Klaipeda (Fig. 6).

Fig. 6 Pollution emissions according to number of passengers and economic benefits-generated by passengers (Eurostat, 2017)

According to the indicators of passenger dynamics in 2013-2017, it can be stated that the number of passengers visiting the city is increasing every year. Since not all cruise passengers visit the city, it is therefore relevant to compare the tendencies in the growth of pollution emissions with the economic benefit-generated by one passenger. Analysing the part of emissions per one passenger from a cruise ship, who has visited the city, it can be seen that as the number of passengers in the city increases, the part of pollution per passenger decreases (Fig. 6), the average annual increase in the amount of cruise tourists in Klaipeda decreases polluting emissions accordingly by 0.14 kg, which allows to assume that there is a reduction in the economic benefits and ecological damage imbalance, what can be confirmed by the quantitative expressions given in Fig. 7. Fig. 7 shows that in order to increase the economic benefits and ecological damage balance, it is necessary to attract cruise ship passengers to the port city, because the sum of each passenger expenditures and the ratio per them of cruise shipping emissions on average annually changes to EUR 3.49/kg, which means that attracting more city visitors from cruise ships and offering them attractive tourist market products can increase this indicator.

Fig. 7 Dynamics of cruise ship passenger-generated income and overall emission ratio (Eurostat, 2017) [2]
approximately by about 12.12 million Eur/t, which means that the emission of cruise ships increases faster than the potential income from cruise shipping tourists.

5. Conclusions

The analysis of cruise shipping changes in Klaipeda Seaport allows to make assumptions that the largest part of ships calling at Klaipeda Seaport in 2013-2017 was up to 58 thsd. t. gross tonnage and their engines did not exceed 33 thsd. kW, but rapidly grew the number of large ships of over 50 thsd. t. gross tonnage, while the largest part of calls during the whole period was formed of large multifunction vessels, of which 45% were operated no more than 5 years after the reconstruction. Calculating the dynamics of concentrations of sulphur and nitrogen oxides, non-methane volatile organic compounds and particulates released by cruise ships in Klaipeda Seaport, it can be stated that the rates of pollution of these substances are increasing and annual average annual increase is just over 11 t, which means that one additional cruise ship calling at KSSA emits about 3 t of pollutants, of which 78% – nitrogen oxides, 12% – carbon monoxide, 6% – non-methane volatile organic compounds, 4% – solids, and 0.03% – sulphur oxides. After analysing the link between pollution emissions from cruise ships and the economic value added by the cruise shipping tourists to the city, it can be noted that even with the increase in the number of passengers who visit the city, their added economic value-generated, per tonne of pollutants, has a decreasing dynamics, i. e. cruise ship emissions are increasing faster than attracting potential income from cruise shipping tourists.

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Analysis and Implementation of Airworthiness Directives

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Abstract

Many studies by aviation experts describe the latest trends, innovation and technologies unfortunately we forgot to highlight the needs, importance and impact of some very basic tasks to be refreshed by the readers and aviation industry. One of them is topic related to the airworthiness directives and their importance along the whole aircraft operations, airline operations and of course safety. Even precisely described problematic of airworthiness directives along the FAA or EASA regulations, and well-established procedures within the continuous airworthiness management organizations, there are still cases where this subject is not well understood or somehow not on the list of critical tasks. Definition of airworthiness directive (AD) can be described as a document issued or adopted by EASA/FAA which require actions to be performed on aircraft to restore an acceptable level of safety. In most cases those directives are issued due to the unsafe condition as a result of a deficiency in the aircraft, or an engine, propeller, part or appliance installed on this aircraft, and that condition is likely to exist or develop in other aircraft. There is several ways how to be informed about issued directive with applicability to operators aircraft or its part is available and usually operators are well informed about planned or immediately issued directive. Further analysis, assessment and evaluation is done in order keep the highest level of safety.

KEY WORDS: aircraft, airworthiness, aviation authority, EASA, safety

1. Introduction

Airworthiness has a number of aspects which relate to the state of an aircraft and we can defined it as a legal and mechanical status of an aircraft in terms of its readiness and suitability for a flight. The aim of airworthiness directives is to improve acceptable level of safety along the aircraft and in parts [4]. This is in direct relationship with airline operations, thus affecting commercial aspect of airline itself by various factors. The most important factor is focused on safety. Airworthiness directives are considered as the best “tool” how to prevent dangerous or catastrophic events due to the aircraft performance in its operations. In order to react by correct and fast way for issued directive, departments of continuous airworthiness need to be well trained and organized, what is very complex task for those departments, and significant experience in airworthiness directives analysis is required. Even some of those directives are considered as “easy to perform”, unfortunately several cases exist where not proper understanding of required actions (by directive) caused difficulties and not clear picture of directive status during airworthiness review by inspectors done once per year or during the delivery or re-delivery from/to lessor of the aircraft. To help to prevent this situation, proper management of issued directive should be in place. If it is not implemented, this can directly affect the safety but also the value of the asset (aircraft) and finally, airline reputation.

2. Objectives

2.1. Airworthiness Requirements

Airworthiness is universally underpinned by regulation and standards. Effective regulation, across all spectrum’s, dictates the behaviors required of a regulated entity (organization, agency or person). A regulated entity subscribes to following the regulations in their business processes (compliance) and the regulator verifies that the processes and displayed behaviors conform (conformance) to the regulations [3]. The airworthiness requirements are addressed in the regulations. Airworthiness Directives (AD) have various characters in its way of performance. The ADs contain mandatory instructions to carry out actions on aircraft, engine, propeller or component in order to address an unsafe condition which exists, or is likely to exist, or could develop. It may be issued by any National Aviation Authority (NAA) which has responsibility for the regulation of design of those aircraft or components. It is usual for an NAA to require compliance with an AD issued by another NAA with such responsibility where such aircraft are operated by or maintained by regulated organizations within its jurisdiction. Most of them require maintenance actions such a one-time inspections, repetitive inspections, parts replacements, but some of them have operational character such a revision of Aircraft Flight Manual pages in order to correct not clear procedure to be done by crew. Those types of directives are not so common, so our intention is more focused on those related to the maintenance actions.
2.2. Improving Airworthiness Directives Management

In accordance with Regulation [7], in the Annex Part 21, an airworthiness directive is defined (par.21A.3B) - a document issued or adopted by EASA (European Aviation Safety Agency) which mandates actions to be performed on an aircraft to restore an acceptable level of safety, when evidence shows that the safety level of this aircraft may be otherwise compromised! For such purpose each AD identifies the unsafe conditions, types of affected aircraft, systems or equipment, which actions are rendered mandatory, compliance time, and the effective date. When an AD is not introduced on an aircraft, part or equipment within the specified terms of compliance the Certificate of Airworthiness is no longer valid. There are many distinct internal processes, controls, and actions necessary for AD compliance planning, implementation, and auditing. The following most important design criteria shall be considered [5]:

- The AD management process may consider an integrated approach among all departments who have a role in evaluating, defining, planning, executing and reporting compliance with an AD;
- Every AD shall follow the same standard process steps;
- Avoid checks that do not add value to the process and optimize the process;
- One IT system should be used to demonstrate compliance, avoiding dependence on human factors;
- Employees involved in any AD process step shall be aware of their task and responsibility and shall be trained;
- Careful review of the AD with particular focus on any unique aspects of the AD;

This means that implementation an ADs requires to define exact steps and we often need the maintenance system analysis to apply all requirements of optimization of sub processes.

3. Methodology

3.1. Implementation an Airworthiness Directive

The main point of an airworthiness directive is for it to be implemented by an airline. There are thousands of issued ADs and new ones become available every day. Sometimes, especially for small operators and start-ups, it can be a challenge to get their head around monitoring and complying with all of them.

There are 3 simple points of implementation:

1. Monitoring of all relevant airworthiness directives. This can easily be done via the websites of the EASA. They also have a feature in which we can sign up to receive all or selected ADs directly to your inbox, as soon as they are published.
2. Determining which ADs are applicable to your aircraft or engine. If an AD is component related, determining whether this component is (or could be) installed on your fleet.
3. For all applicable ADs – a thorough analysis of the AD. As a result of the analysis we need to know exactly:
   a. Does this AD affect my specific aircraft, engine, components?
   b. If yes, what action do I need to do?
   c. When is the threshold for doing that action?
   d. Are there more requirements than just one? Perhaps an inspection first, and a component replacement later?
   e. Ordering the required maintenance from your MRO.

3.2. Compliance Requirement

From the above mentioned it is clear that implementation an airworthiness directives and supportability requirements focused on aircraft airworthiness and using the effective implementation an airworthiness directives program that prevents dangerous failures consequences. Compliance of airworthiness directives implementation has a direct impact on the safety of aircraft operations and because airworthiness is a subset of safety and therefore many of the concepts involved should be maintained for other safety domains. Maintenance personnel (the air carrier’s internal staff or the MRO provider) are responsible for precisely accomplishing AD work instructions and attending to detail with execution. Fig. 1 below depicts the view of a generic AD compliance process for air carriers.

4. Analysis of Directives Implementation

Best way for describing of the ADs and the assessment is to present the practical implementation in below. On 20th of July 2009 there was on Emergency Airworthiness Directive issued by EASA concerning Cockpit Forward Side Window inspection on all manufactured ATR 42 and 72 aircrafts equipped with PPG Aerospace cockpit forward side glass windows with specific Part Numbers NP158862-1 and/or NP158862-2. This directive had Emergency character which defines its urgent or very high importance for operators. Usually this type of directives need to be performed in very short time after its official issuance by EASA. This Directive was issued due to the reported event occurred during which the left hand forward side glass window on an ATR72-212 aircraft blew out while performing a ground pressure test. The investigation revealed some anomalies on this window at the level of “Z-BAR” on the windows external side and at the level of the inner retainer on the windows internal side. These anomalies are considered as precursors of this specific failure. Air or water leakages between “Z-BAR” and the outer glass ply, or between the inner retainer and inner
glass ply indicates the presence of deteriorating structural components in the window. An in-flight loss of a forward side window could have catastrophic consequences for the aircraft and/or cause the injuries to people on ground. The loss of the forward side window while aircraft is on ground with positive differential cabin pressure could also cause injuries to people inside or around the aircraft. Accordingly, this directive mandates initial and subsequent repetitive inspections of left and right cockpit forward side glass windows and in case of discrepancies, the replacement of the window(s). Required actions to be performed are within 10 days after accumulation of 2000 total flight cycles on a given cockpit forward side window. Inspections of the windows need to be done in accordance glass manufacturer (PPG Aerospace) service bulletin [2] where exact procedure, locations, measurements, drawings and details are listed. If one of the several conditions are not in compliance with service bulletin requirements, subsequent maintenance actions or reinspection in shortened interval are in place or the window must be replaced without any delay prior to next flight of the aircraft. If inspection shows no deterioration of specific areas and all measurements are within the limits of service bulletin, there is still requirement of reinspection of the windows with 550 flight hours interval. As per explanations above, we can see that even on fully serviceable windows without any damage, there is a requirement of continuous inspections after 550 flight hours, what is not ideal situation for the operators of the aircraft ATR42/72 and the only way, how to avoid those inspections is to replace the window by other type or part number which is defined and allowable by aircraft manufacturer, unfortunately this is expensive solution, especially when inspected windows are without any defects. Normally all those windows are replaced only when deterioration of window starts and maintenance action, shortened inspection intervals or need of window replacement is in place. To continue the story and
to show the importance and in-service experience with this directive, in August 2012 despite ongoing inspections cockpit forward side window blew out during the flight on ATR72-212 aircraft (Figs. 2 and 3). Degradation of the window was considered to have been the cause for this failure. Even the initial airworthiness directive was issued with requirement of scheduled inspections of the specific area of the window after 550 flight hours, it was decided by revised airworthiness directive that the requirements of the inspections are to be more modified in relation to the cycling / pressurizing of the airframe. Added condition was to reinspect the window each 750 flight cycles additionally and this modified directive is also mandating all the operators to replace those windows until 1st January 2020 and after this date, it is prohibited to install on any aircraft the PPG Aerospace cockpit side windows with part numbers NP158862-1 or NP158862-2 (Figs. 4-6).

Fig. 2 General view of Left Cockpit Forward Side Window of an ATR72

Fig. 3 Incident on Right Cockpit Forward Side Window of an ATR72 from 2012

Fig. 4 Inspection technique as per PPG Aerospace service bulletin NP-158862-001

Fig. 5 Cross sectional view of forward side window with Z-BAR without damage, with damage and repair and Z-BAR inspection gauge
5. Conclusion

Above example was analyzed in order to present new approach of implementing ADs and consequences of unfollowing up potential degradation of level of safety within the aviation industry. Despite the initially issued airworthiness directive, the occurrence happens with some 3 years later and immediate action was done by EASA and operators in order to improve safety precaution for the whole fleet of ATR aircrafts world-wide. Aviation industry standards are mandatory to follow up with all applicable and valid regulations in place, unfortunately some operators, countries or civil aviation authorities are not recognized as reliable ones and professionally proved. This is mostly applicable in 3rd countries or generally countries not strictly following regulations and their local authorities. In some cases, we are unable to get the strong evidence of some airworthiness directives that had been applied by correct way. If we are in doubt if directive or the works generally were not done as per the aviation standards, we can’t consider the aircraft or its parts suitable and safe to fly. Mainly because of this, there is a need of directives assessment and evaluation procedures to be done by experienced team of continuous airworthiness management. This team is then responsible to follow up all valid and applicable options on directives to be correctly assessed, performed, recorded and archived. Sometimes it is just small detail missing where directive can’t be accepted with sufficient evidence and need to be re-done, what creates not only the financial impact, but more often operational impact as well.

References

2. EASA AD no. NP-158862-001, 2009
Flight Optimization for Remotely Piloted Aircraft

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Abstract

The research is focused on the development of Remotely Piloted Aircraft Systems (RPAS). The design process involves the application of Systems Engineering Approach. The objective is to design a small long endurance unmanned aircraft system. Long endurance also depends considerably on air vehicle gliding quality. This paper describes the calculation of parameters providing the best gliding qualities for the air vehicle being designed. The obtained results will be further used in experimental flight simulations and practical experiments for comparison with the aim that the development reaches design objectives. As shown by the results previously obtained from calculations, they are very close to similar systems currently in use and operation.

KEY WORDS: aircraft design, engine, matching plot, remotely piloted aircraft system, wing, gliding performance

1. Introduction

An aircraft without an engine is not able to take off independently, but it is capable of gliding and landing, as performed by sailplanes and gliders.

A typical glide angle for most General Aviation and transport aircraft is about 5–7 deg. The gliding flight performance during the launch phase, landing and free flight phase depends on many factors: design, weather, wind and other atmospheric phenomena.

Gliding flight parameters will be calculated to analyze flight performance and to get the best possible gliding flight attitude for the air vehicle for maximum endurance. The Drag Polar shown in Fig.1 below demonstrates the difference between parameters in the case of flights for maximum endurance and maximum range. The drag polar is a plot of aircraft drag versus velocity. The velocity is expressed in calibrated airspeed [1, 2, 6].

The aforementioned parameters are very important for a gliding flight. To analyze flight performance, we will use the Drag Polar plots, two of which are shown in Fig. 1 below as an example [3, 5].

2. Glide Flight

When the engine is turned off, \((T = 0)\), it is necessary to maintain the airspeed for gliding flight and, the air vehicle should be put at an attitude in which the glide angle is smallest that insures minimum rate of descent [2, 4]. The equations of motion are the following:

\[
0 - D - W \times \sin \gamma = m \times V = 0;
\] (1)
\[ L - W \times \cos \gamma = m \times V \times \gamma = 0, \tag{2} \]

where \( \gamma \) is the flight path angle (the angle between the velocity vector and the air vehicle x axe vector on the horizontal). Dividing one equation by the other, we will get:

\[ \tan \gamma = -\frac{D}{L} = -\frac{1}{L/D}. \tag{3} \]

We can define the glide angle as the negative of the flight path and obtain the following equation:

\[ \tan \gamma_1 = \frac{1}{\left(\frac{L}{D}\right)}. \tag{4} \]

where \( \gamma_1 \) is the positive glide angle.

From the above data, we can make the following conclusions:

a) the glide angle depends only on \( L/D \) and is independent of the weight of the vehicle;

b) the flattest glide angle occurs at the maximum \( L/D \).

3. Glide Range

The glide range is expressed in distance that an aircraft travels along the ground during the glide descend. It is easy to see from Fig. 2 that:

\[ \tan \gamma_1 = \frac{h_1 - h_2}{R} = \frac{-\Delta h}{R}. \tag{5} \]

or

\[ R = \frac{h_1 - h_2}{\tan \gamma_1} = \frac{L}{D} \times (h_1 - h_2). \tag{6} \]

As we can see from the equations above, the gliding flight range depends on \( L/D \) and \( \Delta h \). Also, the maximum range occurs when \( L/D \) is maximum, that is the maximum range glide is flown at the minimum drag airspeed \( V_{md} \) [3, 6].


The glide angle is almost always small for an equilibrium glide. Under such circumstances it is possible to make the following approximations (\( \gamma_1 << \pi \)):

\[ \cos \gamma_1 \approx 1 \quad \sin \gamma_1 \approx \tan \gamma_1 \approx \frac{1}{\left(\frac{L}{D}\right)}. \tag{7} \]

The important result of this assumption is that it is possible to make an approximation that:

\[ L = W \times \cos \gamma \approx W \rightarrow V = \sqrt{\frac{2 \times W}{\rho \times S \times C_i}}. \tag{8} \]

and we can use weight to calculate the airspeed [1, 9].

2. Rate of Climb (Sink)

The rate of climb is given by the following equation:
From Eq. (9), we can exclude \( \sin \gamma \) and get:

\[
h = -V \times \frac{D}{W} \approx -V \times \frac{D}{L} = -V \frac{C_{D}}{C_{L}} = \sqrt{\frac{2 \times W}{\rho \times S \times C_{L}}} \times \frac{C_{D}}{C_{L}}\tag{10}
\]

or

\[
h = -\frac{2 \times W}{\rho \times S} \times \frac{C_{D}}{C_{L}^{3/2}}.\tag{11}
\]

The rate of climb is negative (then this is a sink rate) and it is related to the quantity \( C_{D}/C_{L}^{3/2} \). If we need to minimize the sink rate, we must minimize the ratio \( C_{D}/C_{L}^{3/2} \). So, we get the following assumptions [5, 6]:

a) to get the maximum range, we must operate at the maximum \( L/D \) condition (minimum drag);

b) to get the maximum endurance (minimum sink rate), we must operate at the minimum power required condition.

3. Time to Descend

The rate of descend depends on the altitude (through the density \( \rho \)). To get a precise solution for the time to descend, we need to include density variations in calculations. If we assume that the change in altitude is relatively small (in this case it is less than 50 m), and we assume that the density is constant and the angle of attack (AoA) is constant, we will get the following equation:

\[
\text{Time of Flight} = \text{TOF} = \frac{-\Delta h}{h} .
\]

where \( h \) is the assumed constant. The value \( h \) is that calculated for the altitude half way between the initial and final altitudes. Large altitudes are incremented by several small ones. It is very easy to set theorems, lemmas, definitions, examples and proofs [1, 6].

4. The Best Glide Performance for the UAS Air Vehicle

To get the best glide performance of the UAS air vehicle being designed, at this design stage it is necessary to define a drag polar equation, which is expressed in the following form:

\[
C_{D} = C_{D0} + \frac{C_{L}^{2}}{\pi \times AR \times E} \tag{13}
\]

or

\[
C_{D} = C_{D0} + K \times C_{L} . \tag{14}
\]

where \( K \) is the induced drag correction factor.

As drag and lift are dependent on the Mach number, Reynolds number and geometric configuration of the wing, which were calculated and determined already in previous design steps, the parameters are taken from those stages and given further [4-6].

4. Gliding Flight Performance

The Table 1 below shows the parameters of the unmanned aircraft system air vehicle used for the calculation.

<table>
<thead>
<tr>
<th>Air vehicle parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air vehicle weight</td>
<td>( m = 7.066 \text{ kg} )</td>
</tr>
<tr>
<td>Wing reference area</td>
<td>( S = 0.98 \text{ m}^2 )</td>
</tr>
<tr>
<td>Design glide flight altitudes</td>
<td>( h_1 = 350 \text{ m} )</td>
</tr>
<tr>
<td>Air density at glide altitude</td>
<td>( \rho = 0.842 \text{ kg/m}^3 )</td>
</tr>
<tr>
<td>Gravity acceleration</td>
<td>( g = 9.80665 \text{ m/s}^2 )</td>
</tr>
<tr>
<td>Wing leading edge sweep angle</td>
<td>( \Lambda_{LE} = 32.57^\circ )</td>
</tr>
<tr>
<td>Wing aspect ratio</td>
<td>( AR = 8 )</td>
</tr>
</tbody>
</table>

The gliding flight performance was determined with the help of two methods. One calculation method was based on the maximum \( L/D \) value, while the other one on the best glide velocity.
1. Using the above equations, the gliding flight performance calculation based on the maximum $L/D$ was completed in two ways – for the maximum endurance and for the maximum range.

The difference between the two above mentioned ways lies in the fact that the maximum endurance flight occurs in the minimum sink rate condition that occurs at minimum power required flight condition, and the maximum range condition occurs at the minimum drag condition (max $L/D$).

The calculation results are summarized in Table 1 below.

2. For the calculation of the gliding flight performance based on the best glide velocity, the MATLAB Aerospace Toolbox™ software was used. In MATLAB, programming is based on C++ programming language.

The advantages of programming in MATLAB are imbedded standard parameter calculation scripts such as ISA atmospheric parameters ($\text{atmosisa}$) or value conversion scripts ($\text{correctairspeed}$) [4, 6]. The example script is shown in the Fig. 3 below:

\[
[T, a, P, \rho] = \text{atmosisa}(400);
\]

\[
\text{TAS}_{bg} = \sqrt{\frac{2 \times W}{\rho \times S}} \times \left[ \frac{1}{4 \times C_{D_{0}}^2 + C_{D_{0}} \times \pi \times e \times AR \times \cos^2 \Phi} \right]^{1/4}.
\]

The best glide velocity is calculated using the following equation where TAS (true airspeed in meters per second) is the velocity of the aircraft relative to the surrounding air mass:

\[
\text{TAS}_{bg} = \sqrt{\frac{2 \times W}{\rho \times S}} \times \left[ \frac{1}{4 \times C_{D_{0}}^2 + C_{D_{0}} \times \pi \times e \times AR \times \cos^2 \Phi} \right]^{1/4}.
\]

The best glide angle is calculated using the equation:

\[
\sin \gamma_{bg} = -\sqrt{\frac{4 \times C_{D_{0}}^2}{\pi \times e \times AR \times \cos^2 \Phi + 4 \times C_{D_{0}}^2}}.
\]

The minimum drag during gliding flight or the best glide drag is calculated using the equation:

\[
D_{\text{min}} = D_{bg} = 1/2 \times \rho \times \text{TAS}_{bg}^2 \times S \times 2 \times C_{D_{0}} = -W \times \sin \gamma_{bg}.
\]

The best glide lift is calculated using:

\[
L_{bg} = L_{\text{max}} = W \times \cos \gamma_{bg} = \sqrt{W^2 - D_{bg}^2}.
\]

Using the previously obtained results, the drag and lift coefficients are calculated by using the equations:
\[ C_{Dbg} = \frac{Dbg}{q \times S} \quad (19) \]

and

\[ C_{Lbg} = \frac{Lbg}{q \times S} \quad (20) \]

The correctness of the calculations is checked by constructing plots of drag and lift-drag ratio for the air vehicle as a function of CAS.

Parasite drag is calculated by the following equation:

\[ D_p = \frac{1}{2} \cdot \rho \cdot S \cdot C_{D0} \cdot TAS^2. \quad (21) \]

Induced drag is calculated using the equation:

\[ D_i = \frac{2 \cdot W^2}{\rho \cdot S \cdot \pi \cdot e \cdot AR} \cdot \frac{1}{TAS^2}. \quad (22) \]

Total drag is calculated by the equation:

\[ D = D_p \times D_i. \quad (23) \]

As was expected, the maximum \( L/D \) occurs at approximately the best glide velocity calculated and visualized in the plot. In the Fig. 4 below the plotting \( L/D \) versus CAS and parasite, induced, and total drag curves are shown:

![Fig. 4 L/D versus CAS and parasite, induced, and total drag curve plots](image)

The minimum total drag (i.e. \( D_{bg} \)) occurs at approximately the same best glide velocity calculated above.

<table>
<thead>
<tr>
<th>Flight Condition</th>
<th>Max Range (m)</th>
<th>Max Endurance (s)</th>
<th>Glide Velocity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>957.82</td>
<td>829.56</td>
<td>-</td>
</tr>
<tr>
<td>Endurance (TOF)</td>
<td>53.87</td>
<td>61.50</td>
<td>-</td>
</tr>
<tr>
<td>( C_{Lmd} )</td>
<td>0.5314</td>
<td>0.92048</td>
<td>0.53157</td>
</tr>
<tr>
<td>( C_{Dmp} )</td>
<td>0.02774</td>
<td>0.05548</td>
<td>0.02774</td>
</tr>
<tr>
<td>( \gamma_1 )</td>
<td>2.9882°</td>
<td>3.45°</td>
<td>2.9873</td>
</tr>
<tr>
<td>( V_g )</td>
<td>17.78 m/s</td>
<td>13.51 m/s</td>
<td>14.7268 m/s</td>
</tr>
<tr>
<td>( \left( \frac{L}{D} \right)_{md} )</td>
<td>19.1564</td>
<td>16.5912</td>
<td>19.1625</td>
</tr>
<tr>
<td>( D_{bg} )</td>
<td>-</td>
<td>-</td>
<td>3.6111 N</td>
</tr>
<tr>
<td>( L_{bg} )</td>
<td>-</td>
<td>-</td>
<td>69.1989 N</td>
</tr>
</tbody>
</table>
The results calculated in MATLAB Aerospace Toolbox™ software differ a little from those calculated in the first part, which is possible because of a different mathematical algorithm. In part (7), the calculation was based on the max. L/D value, but in part (8) the mathematical algorithm began with the best glide flight speed calculation and afterwards obtained other values. The result comparison is shown in the Table 2 below.

5. Conclusions

The gliding performance results represent a preliminary evaluation of the performance of the UAS air vehicle being designed. As the main objective of the system is long endurance available airfoils for wing design was very carefully evaluated and two airfoil types selected for construction to obtain the best results, but this is also the reason why the wing structure becomes more complicated (two airfoil types, geometric and aerodynamic twist). The performance of the wing (with the complete design parameters mentioned above) should be tested in CFD program and compared with those obtained in calculations during this stage of design. This will be completed in further design stages.

To completely evaluate air vehicle performance, the gliding flight should be evaluated together with climbing that are exchangeable flight modes in the mode of loitering. During flight performance evaluation the best value of climb (sink) \( \Delta h \) that gives most endurance should be determined.

An experimental examination of the results is also foreseen for further design phases with a live model of the UAS air vehicle that should show difference because of winglets in the design structure, which theoretically will enhance gliding performance reducing drag and augmenting lift. The parameters will be obtained and calculated during the flight of air vehicle live experimental model.

References

Factors Determining the Success and Failure of Military Transport Operations - Human Factor in Transport

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Abstract

The article discusses the problems of conducting transport operations in the army. The original contribution of the authors in this field of research lies in the fact, that special attention has been paid to the Human Factor to estimate the risk of transport. Analysis of the impact that Human Factor, has on the risk of the transport is based on cultural aspects. The most important anthropological factors were identified in carrying out a successful military campaign in a culturally different countries (Somalia, Iraq, Afghanistan). The authors present the results of pilot studies on the impact of the human factor on risk assessment in the implementation of transport operations in the army and for the civilian drivers group.

KEY WORDS: military transport operations, Human Factor, risk assessment

1. Introduction

The changes taking place in the modern world force enterprises that allow people, regions and states to function and develop mutual relations. Transport and its infrastructure are indispensable for the implementation of these activities, which in logistic terms can be considered as an element and component of logistics processes and as an important factor of economic policy. The development of transport and its infrastructure is indispensable for the correct implementation of the above-mentioned challenges. Unfortunately, both transport and the use of its infrastructure entails the possibility of extraordinary events and crisis situations, i.e. creates the possibility of collisions, accidents, breakdowns or disasters. These events carry human losses (wounds and deaths) and material losses. It can therefore be concluded that transport safety is an extremely important issue and affects the overall state and level of state security. To begin a detailed discussion of the safety and risk of transport processes, a brief discussion of strategic transport is necessary. Strategic transport is a characteristic element of the armed forces and combines the problems of state security and transport processes.

The possibilities of moving armed forces in a timely manner in order to fully take up actions and to carry out the tasks of the North Atlantic Alliance (NATO) is the most important element of the so-called „military credibility”. The implementation of tasks requires the ability to move forces within and between theaters of actions, including transatlantic transfer. Crisis response operations force the possession of the ability to transfer and support forces outside NATO. The need for strategic mobility applies to all forces capable of displacement (DF - Deployable Forces). These forces include: High Readiness Forces (HRF) intended for participation in limited-scale crisis response operations, Lower Readiness Forces (LRF) for rotation and supply, and all categories of forces within larger displacements. The need for strategic mobility also applies to the traffic and transport necessary to ensure the ability to conduct operations.

1. In order to emphasize the essence of problems and needs in the field of strategic transport for the needs of the army, below are presented some key conclusions that result from the authors' own research in this field [14, 17-21]:

2. Ongoing executive capabilities of the armed forces, including the Polish Armed Forces in the field of strategic transport are limited. No NATO countries armed forces do not have a sufficient number of own transport resources, therefore they are forced to acquire them on the commercial market or through international cooperation or programs;

3. Transport management Polish Armed Forces in the context of the above-mentioned tasks, caused a number of problems and difficulties, including among others:
   • no possibility to launch tender procedures before the decision on the use of armed forces by the relevant state authorities was made, which reduced the time necessary to obtain commercial transport means (tender procedures under the Public Procurement Act);
   • late determination and frequent change of transport dates due to the dynamics of changes in the international situation, negatively affects the compliance with applicable procedures;
   • a large variety of regulations and procedures regarding, inter alia, the transport of dangerous goods by air transport and the diversity of standards in the field of material codification and standardization;
   • financial constraints, and thus the lack of the possibility to conclude e.g. dormant contracts or limited availability of transport resources under the SALIS program.

4. According to the research, the most desirable direction for the development of strategic transport capabilities...
of the Polish Armed Forces is the purchase of new strategic transport means, further participation in international programs and initiatives as well as charter or leasing of transport vehicles in a national configuration.

5. The most important criteria that should be taken into account in the strategic planning process of troops are the operational priorities, i.e. the ability to quickly obtain the appropriate means of transport according to the imposed deadline and the requirements of commanders.

6. The limited executive capacity of the armed forces and the growing needs in this respect imply the need to outsource transport services.

2. Hazards Identification in Transport Processes

Risk identification is one of the most important and basic elements of risk management. Appropriate implementation of this process is necessary not only for risk management. The stage of risk identification consists in collecting the most important information on the occurring threats that may affect directly or indirectly the implementation of designated transport tasks. Risk identification consists in: identifying threats, defining, categorizing and describing various types of risks that may jeopardize the correct implementation of objectives both during the organization and implementation of transport processes. Identified threats may prevent the achievement of the set goals and cause damage. Risk identification should include all events, both internal and external, causing it, because they are important in guiding and making decisions. These include both known and new risk categories.

The risk occurring in transport processes may involve [22, 23]:
- incorrect decisions caused by untruthful, unreliable, insufficient and incorrect information;
- ignorance or non-compliance with regulations and designated procedures;
- human factor;
- technical factor;
- a random factor.

Transport, and in particular strategic transport, is connected in particular with the possibility of the risk of damage to goods and sometimes even their loss [17-19]. This threat is very often the result of incompetence of the carrier, which leads to the situation of a threat during transport of goods. The threat to safety during the transport of entrusted goods arises through external factors, mainly concerning the technical condition of the vehicle, securing the goods during transport and the influence of the external environment on the transported goods. In particular, we should be take to account elements such as:

1. Technical condition of the vehicle [18]. Carrier with a new fleet, which is monitored on a current basis in terms of technical condition and repaired only at authorized points will be a bigger competitor on the market than companies whose cars leave much to be desired in terms of technical condition, age of vehicles, the number of kilometres travelled and carrying a greater probability of defects in the means of transport.

2. Adequate protection of the goods. The most important thing is to transport the entrusted goods with a suitably chosen means of transport and properly fix the parcel, arrange it properly so that it does not pose a risk of displacement while driving.

3. Technical condition of roads. It is a factor related to the environment affecting the transport process. This is the only factor on which the company has no influence. This involves adjusting the driving technique by the driver to the conditions with which he must face. If the technical condition of the road does not allow for a smooth passage, the driver must adapt the driving technique to the prevailing conditions.

4. Driver skills [19]. Minimizing the risks resulting from road transport is related to the driver's skills, his psychophysical state, relevant qualifications and his experience. There are situations in which even the best-trained driver can make a mistake. Very often it is related to the driver's fatigue, distraction and stress that he has to face. The increase in the level of safety in transport is influenced by legal regulations. They concern the maximum driving period without interruption, frequency and length of breaks in driving, obeying traffic rules, high driving culture, and caring for well-being (e.g. rest during breaks).

A very important role in the identification of risk is consistency [1, 3]. Thanks to it, it is possible to select all significant threats and define the types of risks arising from them. The essence of risk identification is to capture all risk categories that may occur in the company's operations. Therefore, it is recommended to use different methods that are complementary and verifying. It should be emphasized that attempts to develop a priori list of possible risk categories will never be universal and comprehensive, applicable to the risk management of each enterprise. They should be treated as an example requiring adaptation to specific conditions. The identified risk factors should be analysed in order to determine the probabilities of occurrence of a given risk and determine the possible effects. All risk factors should be analysed, which simultaneously threaten the achievement of the set goal. The omission or down-scaling of some risk factors reduces the sense of further action, and thus exposes the venture-related venture to failure. Having at their disposal the collected reasons for the occurrence of risk, they should be examined in detail on what angle they affect the objectives pursued. You can also examine what impact they have on the overall enterprise. When describing the effects of risk, factors such as: safety or lack thereof and certainty or uncertainty of the task should be taken into account.

3. Risk Assessment in Military Operations

Risk assessment is possible in various ways. However, it is always a difficult and time-consuming element in the
entire risk management process [5, 6]. The process of risk assessment allows to influence the extent to which a given event will affect the achievement of the designated goal related to a properly performed transport task. The uncertainty of potential events that may arise during transport preparation and the trip itself is assessed from two perspectives: probability and effects [1-4, 7]. The stage of risk identification (Fig. 1) in risk management is aimed at reducing the impact of risk on the task by measuring the probability of the occurrence of a given type of risk as well as the possible effects in which it may occur. The procedure used in this way allows you to assess the level of risk, which allows you to take appropriate decisions and preventive actions aimed at minimizing the risk. The risk assessment system should have a definition for different types of probabilities and effects of events [14, 16]. The effect, also referred to as consequences, means all possible consequences, such as: financial losses, time losses, losses related to car downtime or the occurrence of other adverse events.

![Fig. 1 The methodology of risk assessment in military transport [20]](image)

The assessment of the effects of identified events is based on the estimation of the assumed outcomes that will affect the performance of the task [15]. This includes the impact and consequences that the risk entails. Assessing the effects of risk on, for example, a five-point scale (the proposal is presented in Table 1).

<table>
<thead>
<tr>
<th>The effects or consequences of risk</th>
<th>Detailed description of the effects</th>
<th>The point value of the effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>slight</td>
<td>minimal, small impact on the implementation of tasks and goals; minimal financial consequences; no legal consequences; no impact on employee safety</td>
<td>1</td>
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<tr>
<td>little</td>
<td>little impact on the implementation of tasks and goals; small financial effect; no legal consequences; no impact on employee safety</td>
<td>2</td>
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<tr>
<td>medium</td>
<td>medium impact on the implementation of tasks and objectives; average financial impact; moderate legal effects; no impact on employee safety</td>
<td>3</td>
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<tr>
<td>major</td>
<td>serious impact on the implementation of tasks, serious threat to the deadline for completing the task, the possibility of not achieving the set objective; serious financial losses; serious legal consequences; the possibility of danger to the health and life of employees</td>
<td>4</td>
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<tr>
<td>disastrous</td>
<td>failure to complete the assigned tasks and objectives, failure to perform the task within the prescribed period; very high financial losses; very serious and extensive legal consequences; violation of employee safety, loss of health and life</td>
<td>5</td>
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</table>

When assessing the consequences of threats to transport processes, the worst case that may occur for the analysed situation should be taken into account. The assessment of the probability of occurrence of a given risk should be made in terms of the frequency of occurrence of a given event. You can use a five-point probability scale, which determines how often a given event occurs. An example of the probability rating scale is given in Table 2.
After estimating the most important parameters, a list of all hazards that may occur in the transport process should be made, taking into account the significance of the danger (Fig. 2). The significance of risk is the result of negative events and can be expressed as the product of the probability of risk and the effects of risk occurrence according to the following formula:

\[ CR = P \cdot C, \]  

where \( CR \) – risk significance coefficient; \( P \) – the probability of risk occurrence; \( C \) – the effect/consequences of the risk.

The formula provided assumes that the level of risk is dependent on both the likelihood of a risk and their consequences. The grouped risk types present real threats to the tasks and objectives being pursued and indicate the directions of corrective actions.

Fig. 2 Risk assessment in transport: factors × consequences

4. Human Factor in Risk Assessment

As shown in Fig. 2, one of the most important elements, is the Human Factor which affects the magnitude of risk in military transport. Based on expert research, the authors have determined that the Human Factor is more important during the realization of transport plans than, for example, the technical parameters of the roads during transportation.

What exactly is the Human Factor and how is it defined? We can define Human Factor as understanding human performance within a given system: trust, fear, decision-making, stress are crucial in so-called “golden hour” [10, 12].

In industry, the Human Factor (also known as ergonomics) mean the study of how humans behave physically and psychologically in relation to particular environments, products, or services. Many large manufacturing companies have a Human Factors department or hire a consulting firm to study how any major new product would be accepted by the users in its design. A Human Factors specialist typically has an advanced academic degree in psychology or anthropology or has special training. The term usability is now sometimes used as an alternative to Human Factors like human error or human resource.

Today there are 2 different views on Human Factor as a cause of failure [10]. The so-called “old approaching” means:

- human error is the cause of most accidents;
- the engineered systems in which people work are made to be basically safe;
progress on safety can be made by protecting these systems from the unreliable human through selection, procedures, automation, training and discipline.

The other “new approaching” sees human error not as a case but as a symptom of failure:
- human error is a symptom of a trouble deeper inside the system;
- safety is not inherent in the systems - people have to create safety;
- human error is systematically connected to features of people tools, tasks and operating environment.

Progress on safety comes from understanding and influencing these connections [10].

The Human Factor is very difficult to measure. Other component factors will be dominant in the determination of the Human Factor in the army and others in the case of testing according to the same methods in the civilian industry. Based on their own experience and using the knowledge of experts who deal with the problem of transport organization on a daily basis, the authors of the article have listed the 12 most important factors affecting the so-called Human Factor:

1. lack of communication - errors and disruptions in the information flow;
2. routine - certainty resulting from long-term practice combined with the loss of awareness of existing threats, caused by often repetitive activities and tedious work;
3. lack of knowledge - lack of clarity or certainty of understanding something, lack of language skills;
4. distraction - caused by distraction, confusion, mental chaos;
5. lack of cooperation in the team - inconsistent effort of a group of people caused by lack of a sense of community of purpose, fear of pointing management to mistakes made by others, inappropriate style of leadership or inappropriate communication;
6. fatigue - it is ignored, because until it is excessive, people do not realize it;
7. lack of resources - lack of tools, materials, outdated documentation, improper working conditions;
8. pressure - caused by the pressure of superiors or colleagues, lack of time, improper setting of tasks;
9. lack of assertiveness - lack of ability to refuse to perform a task resulting from lack of self-confidence, anxiety or complexes;
10. stress - nervousness caused by e.g.: time pressure, new methodology, change in the scope of tasks, competition or private factors;
11. carelessness - incorrect assessment of possible consequences of action caused by e.g.: pressure, lack of experience or lack of knowledge;
12. comfort (deviation) - acceptance by most people of deviations from the instructions as standards facilitating work.

The aim of the research was to indicate those factors that are dominant in the case of success or failure to complete the task. The described 12 factors were presented to two group: first - 35 military drivers (participants of foreign missions) and were asked to choose the most important factors, and the second - 35 civilian drivers (bus drivers). The comparison took place in such a way that participants compared all 12 factors with each other. The more important factor was rating 1 - a factor less important in a given pair - 0. The maximum value that a single indicator could have obtained was 11 points. Obtained results of tests are presented in Fig. 3.

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The studies carried out in group of military drivers, have shown that fatigue (10 points), stress (10 points), routine (8 points) and pressure (7 points) are of the greatest importance for success or failure in the implementation of the task (Figs. 3 and 4, a). The least important was the lack of resources and the lack of assertiveness. It has been assumed that the lack of assertiveness will be the least important factor, because the army is a hierarchy institution and
the soldiers carry out orders.

Completely different factors indicate civilian drivers. In their opinion, the most adverse impact on the success of the task pressure (11) and lack of assertiveness (10) (Figs. 3 and 4. b). A bit smaller, but also very important is lack of knowledge (8). This is due to the fact that civilian drivers are not used to working under pressure and are not as assertive as soldiers who are specially trained for this.

It should be noted that the presented results were made on a small research sample – the results of pilot studies. Currently, research is conducted on groups of 300 people, both civilian and military drivers. The completion of the research will allow for a more complete identification of the most important elements of the Human Factor in the process of estimating transport risk.

Fig. 4 Pareto-Lorenz Chart - result of research: a - group of military drivers; b - group of civilian drivers

5. Summary

When carrying out military transports, in addition to the behaviour tests of drivers, it is necessary to create procedures according to which the organization of the entire transport system is to be organized. This system should be adapted to a specific cultural region. It must refer to all aspects of transport in which a human play role: communication, updated technical documentation or organization of team-work. Components that need to be tested are:

1. defined main participants involved in transport, including the main coordinator responsible for the organization;
2. systematic characterization of the transport system of a given region and the socio-economic situation of the state from the residents' perspective;
3. indication of activities undertaken by residents and entities involved in the procedure;
4. examining the limitations, challenges and human potential in the region's transport system.

The conducted research shows communication problems at the local level, as well as problems with the lack of appropriate tools, lack of knowledge of customs, including stressful and motivating factors. Cultural research is proving necessary to understand the cultural environment of the planned transport operation. They also indicate the necessity of synergic cooperation between the army and the inhabitants, the government administration, and, in the case of missions, also non-governmental organizations. The aim of such action is to minimize and eliminate negative effects.

References


The Risk of Stopping the Air Traffic Over the Europe as the Result of Volcanic Eruptions in Iceland

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Abstract

The aim of this paper is presentation of increasing risk of stopping of the air traffic over the Europe as the result of eruptions of the Iceland’s volcanoes.

KEY WORDS: air traffic, Europe, risk, explosion of the volcano

1. Introduction

Since many years is increasing of air traffics from Europe to the far regions of the globe. From 60ites the dominant position has have the air transport. This is based on the wide and narrow fuselage of airplanes with jet engines. The problem is linked on the vulnerability of air traffic to the external conditions. Many often is take into consideration the wind and the precipitation. But is exist of the source much more stronger and dangerous. This the volcanoes ash in the air.

2. Case Study

The initial point to analysis is review of the information about event in 1982. In this time the airplane Boeing 747-236B of British Airways, number BA 009, was flying from Great Britain to the Auckland in New Zealand with the midpoints landings in Bombay, Madras, Kuala Lumpur, Perth and Melbourne, flew into the volcanic ash cloud. This cloud was created by emission from the volcano Galunggung (placed about 240 km on south-east direction from the Jakarta in Indonesia), which caused the choking and stopping work all four engines [1, 2]. In the time of the flight BA 009 in the 2 minutes were been stopped all four engines. The crew has decided to slide to the closest airport. In the moment of event the airplane Boeing 747-236B was at height11000 m. The air control was directed the airplane to the airport Jakarta- Halim Perdanakusuma.

Falling down in the slide flight the crew has trying to restart of the engines. At the high 4100m they in sequence restarted all engines. Thus this regained the control over the engines the crew regain control on the airplane. They had have problem with the visibility through the windscreen. Thus using the monitoring of DME the airport and observation by the narrow free area from the volcanic ash on the windscreen had landed in the airport.

After landing the inspection confirmed that the windscreen has been covered by the matt material of the volcanic ash. Analysis of the engines shown that the volcanic ash had penetrated interior melted in the combustion chambers and gluttled these interiors and turbine blades. It created the problems with combustion process of the fuel and later stopped the turbines. In the time of the slide flight the engines were been cooled. This reduced the temperature inside and the volcanic ash clotted and crumbled and left the engines. This helped to restart them [1, 2].

3. Definition of the Problem

On 14 April 2010 when the activity of volcano Eyjafjallajökull had increased its activity many air control companies decided to close the air space. Until 20 April 2010 was been restarted the air traffic [1, 2]. Many air transport companies had noticed a big economic loses, but many rail and bus transport companies noticed big incomes and numbers of passengers. Many passengers were disappointment that this reliable transport has been stopped by some stupid volcano. It was seemed that it was the single event. but the problem from 2010 doesn’t vanished. The present data are not linked with the air traffic but with the seismic activity around the Europe continent. It has suggest o repeat this event but in the wider than in 2010 range.

4. Discussion

The problems with the increase of earthquake occurrences in the European region were probably initiated after a huge earthquake in the south Asia region in December 2004. The event that could begin the process of change of stability of the Earth’s plates was the earthquake on December 26, 2004 [4] with a magnitude of 9.1 (Fig. 1) [7].

This earthquake evoked a change of stability in the Indo-Australian Plate and later the Arabian, African and European Plates.
On April 11, 2012 two earthquakes with magnitudes of 8.2 and 8.7 occurred near the island of Sumatra. The location of these earthquakes adds more data to the theory [8] that the Indo-Australian Plate may be breaking up (Fig. 2) [6].

Since the several months is increased numbers of earthquakes on the Mid-Atlantic Ridge. It is connection of several tectonic plates under Atlantic Ocean. These earthquakes are concentrating the direction of the Island. Only in one day 1 March 2017 there were three earthquakes (Fig. 3). The Islands volcanologists had observed since several weeks the increased seismic activity in the region of four volcanoes Katla, Hekla, Bárðarbunga i Grimsvötn. These people suggests that all volcanoes are ready to erupt in each moment [5].

![Fig. 1 Map showing earthquakes with magnitudes of > 5.0 from 1965 to December 25, 2004 [4]](image1)

![Fig. 2 Plate breakup region near the island of Sumatra [6]](image2)

![Fig. 3 View from the webpage European-Mediterranean Seismological Centre on 1 March 2017, state of earthquakes at 10:05 CE time [3]](image3)

It means that may be to repeat the paralyze of the air traffic similarly as has been in 2010. However it could be in much more scale. Maybe is some possibility to reduce the blocking the air traffic.

Here is to show the possibility to use the support connections by use an another modes of passenger transport in relation Europe-America. It may be the combined connections rail-sea to the ports on Mediterranean Sea and later by use fast sea-ship to the Marocco. There from the airports in Casablanca and Rabat will be possibly flights to the America.

Another case is to use a well-known old solutions in the airplanes technology. It may be modern the airship or airplane with the piston engines. In the first case the carrier force is thus use the carrier gas, in the second case the piston engines have an integral equipment in the air filters which haven't the jet engines.
5. Conclusion

The subject of this article is vulnerability of air traffic to the external conditions.

On the time of explosion of the volcano are emitted a big volume of the ash. If will be erupt some of these four volcanoes as the first will be decision to reduce possibility of accident similar as has been in the flight BA 009 by the prophylactic ban of the air traffic, no by analysis of probability or the reliability function. It is better to calculate of the economic loses than the number of dead victims.

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Perspectives of Special Equipment in the Defense and Crisis Management

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Abstract

In crisis situation there is a need of devices and equipment characterized as special equipment. The paper provides a notion of SPECIAL EQUIPMENT, an implied categorization of special equipment, its possible development from a view of scientific and professional activities. The bases stem from orientation and heading of needs of allied groups assigned for needs of defense, for needs to solve non-standard situations, when it is supposed that special equipment is to be operated and deployed. Special attention is paid to mobility of special equipment. The container program being solved is examined from a transportation point of view, as well as its loading and stability. Such equipment requires a ballistic protection and ballistic hardening. This issue is solved with specific materials and engineering technologies to be developed for purposes of ballistic hardening. The paper deals also with issued of providing the electric energy and water for container working places with special equipment.

The paper provides particular examples of new equipment, constructed in cooperation of the Faculty of Special Technology of the Trencin University called by Alexander Dubcek in Trencin with particular facilities and organizations in the Slovakia.

KEY WORDS: Crisis situations, renewable sources of energy, photovoltaic collectors, logistic container, power systems, mobile assets of crisis management

1. Introduction

Practice has shown the needs in provision of defence operations and in crisis situations. Special equipment is necessary for their provision. The author’s working place is puts its brains to development of special equipment from a view of provision with basic human needs in rising a crisis situation [1]. Provision is needed for:

- Reconnaissance of theatre of operation.
- Operation control taking a neighbouring population into consideration.
- Working places of participants from a view of ballistic, chemical and biological protection.
- Awareness of participants and population.
- Transportation and approach from access roads.
- Delivery of foods and supplies.
- Delivery of potable and utility water.
- Medical care and treatment
- Provision of electric energy.
- Decontamination of theatre of operation.
- Preparation for damage disposal caused by emergency.

There is a need to provide an affected area with energies and water aiming to ensure basic human needs in defence operations and crisis situations. Within a research program the authors have dealt with such provision assuming that equipment would be deployed in different environs using traditional input energy sources and power supply as well as energy from solar radiation and wind energy. A mobile version has been proposed as well, namely, embedding instruments and equipment in containers, transportable to destination by a helicopter, automobile or a ship.

Trencin University called by Alexander Dubcek in Trencin, Faculty of special technology, Department of automobiles and special equipment has recently paid attention within its scientific work and contacts with practice to the following areas:

- Hardening of mobile and transportation systems through an improving of their ballistic protection.
- Container program of mobile special equipment.
- Development of high-energetic materials within the responsibility of Slovakia in range of EOD (Explosive Ordnance Disposal) NATO program.
- Ecological and autonomous sources of electric energy as a part of mobile equipment.

This heading has stemmed from current needs of logistic and armament provision in crisis situations [2].

2. The Needs of Crisis Management From a View of Provision of Special Equipment

We have solved the following needs from a view of special equipment needed for crisis management [3]:

Approach and availability, cross-ability in water, in muddy, mountain and forest terrain, roads, air.
Mobility and transportation of equipment and systems.
Hardening of mobile working places through a ballistic protection.
Provision with electric energy.
Provision with potable and utility water.
Medical care.
This paper shows possible provision with electric energy, potable and utility water and a container system for transportation of equipment and systems.

3. Approaches to Solving a Mobility of Working Places for Special Equipment and Their Hardening

The activities related with containers are up-dated in accordance with customer requirements, so their dimensions, quality and equipment have been changing as well.

Expansion of containerization in a global distribution of goods got in military area and crisis management and was requested by many armies [4]. Application of a transport unit with standardized dimension is useful from several views, namely in cooperation of allied forces in foreign missions. Military logistics of NATO container systems, relating transport means, is based on air or shipments and on a follow-up transportation on wheeled vehicles. Therefore the requirements for driving range, loading capacity, speed in movement on hardened roads, cross ability through a rugged terrain, etc are laid on these vehicles. Up-to-date special wheeled vehicle for transportation of container systems must be equipped with a hydraulic system for a loading and unloading of a container itself and a ballistic protection depending on a requested protection level.

An advantage of a road transport is a transportation of a container to destination or to a maximum approach. All land communications are available within driving range. Vehicles with special superstructure are applied. Disadvantage of such transportation is a smaller amount of containers.

Advantages of a railway transport are in a possible transportation of large amount of containers with a transport means that is impossible in road transportation. It results in lower transportation costs and a better price. Benefit is a possible transportation of very heavy shipments. Cons is a need of available railway, transport in a hard terrain is impossible, shipment to a destination takes longer time, low flexibility, possible breaking of a timetable and a slow handling.

Air transport of containers can be arranged as a container in a freight carrier, e.g. of type – C 130, AN 124, IL 76, A 400M and a lifted container under slung from a rotor wing. The both options are used in a work with special equipment, e.g. transport of spare parts and dismantled equipment to a destination, which is equipped with airport, airfield, e.g. Kandahar or a transportation of a repair container, power systems, and water treatment plants lifted on a rotor wing directly to a destination in terrain.

Faculty of Special Technology (FST) has solved two areas within its scientific and research work – hardening of containers with a ballistic protection and transportation, loading of containers for transportation on wheeled vehicles. FST brought a solution when a container was arranged and loaded on TATRA 815-7 10x10 truck. Chassis of the Tatra 815-7 is designed as a heavy truck applied within army as well as in civilian sector (Fig. 1) [5].

![Fig. 1 An example of a chassis design for a container carrier with a handling arm for loading or unloading of containers in terrain [2]](image)

**Ballistic hardening.** From a view of development of special equipment for needs of a state defence, we can apply the conclusions defined as trends in defence capabilities [6]:
- Development and application of new technologies.
Increase of effectiveness and lethal force of asymmetric threats, mainly active terrorist groups.
Solution of post-conflict situations.
An increasing ration of combat in built-up areas.
Application of highly precise and efficient weapons on targets in environs with civil population.
Saving human sources as a priority in operation planning.
Progressive roboting of combat activities.
Austenitic steels have been recommended for production purposes for special equipment of type as container with a provided ballistic protection based on aforesaid experiments. Technology of dividing with a water stream has no effect on mechanical features of the material.

4. Provision with Electric Energy

Application of renewable sources of electric energy is still a current topic. Such tendency penetrates into mobile equipment as well and their application would be beneficial also in ISO 1C containers being used as mobile logistic assets. It was stated an optional application of mobile non-conventional sources of electric energy based on analyses of consumption of electric energy in logistic assets used in missions of the Armed forces of the Slovak Republic.

By using of unconventional sources a mobile logistic assets would not be dependent only on external mains or on electric source aggregate, but it would have an own optional solution in obtaining electric energy [7].

A problem of finality of oil supplies and fossil fuels is essential and looking for alternative sources is a priority of the day. An energetic need of the technological equipment in mobile container assets varies and therefore it is important to know how to assign an optimum power system. A functional model of island renewable energy supply has been developed to a proposed optimum power set of renewable sources of electric energy.

An application of the developed functional model of island system of renewable sources of energy that had been executed aiming to have available an experimental source of electric energy out of reach to energy mains enables an analysis of operational parameters in particular conditions. A functional model contains a photovoltaic panel and a wind turbine, as representatives of the most frequently used renewable sources of energy (RSE), a microcomputer control and monitoring block and a stand-by power supply and some appliances.

A microcomputer control system enables a continuous measuring of energy supplied from RSE and archiving of data taken. It monitors amounts of accumulated energy and it controls consumption of energy by preset priorities of particular appliances. At the same time it controls critical conditions (surplus and lack of energy) and it performs procedures that had been previously set. Operation of a whole system can be adjusted by PC, whereby the system works autonomously as well with no need to be connected to PC. The PC serves also for a long-term archiving of data and their global assessment.

5. Intention for a Solution of the Potable and Utility Water Provision

Sufficient water supplies require a huge amount of investments, funds into infrastructure, as pipe network, gasoline service stations and water treatment plants [8]. Supplies of potable and utility water are especially important in crisis situations. To solve these tasks an attention is to be paid on:

- Reconnaissance of water sources and diagnostics of its quality.
- Water transport.
- Water treatment.
- Processing, adjustment and transport of bilge as a residual material after water treatment.

The container program was solved for needs of crisis management. Technological processes of water treatment and water itself must meet several requirements:

- Water must be of a suitable quality,
- Water must be delivered in sufficient quantity
- Total production costs must be minimal.

Quality of treated water must meet respective standards or regulations. Regulation of the SR Nr. 354/2006 Reg on requirements for potable water assigned for human consumption and quality of such water is valid for potable water.

6. Conclusions

A current dynamic situation in development of materials brings a possibility to apply them in special equipment. It relates a so called „smart materials“, materials with a memory, composite materials, foam and lite materials etc. The working place of the authors of the paper is included in this activity. Cooperation of the Trencin University called by Alexander Dubcek in Trencin with schools and institutions in Slovakia and abroad is a precondition for development of special equipment in a complex notion. The question of materials and technologies for special equipment has got historical roots abroad and in Slovakia and history of cooperation in past. It forms a base to start solutions of other, new projects being solved on an international level.

Results, achieved by the author in this area, show that a way of development is correct.
References

Transport Machine Design for Adaptive Gripping of Automotive Industry Products

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Abstract

The aim of the paper is to design an adaptive gripper, the main task of which is manipulation. That is influenced by several factors, such as the shape and size characteristics of the object, its behaviour, the roughness of the object surface, the shape and availability of the contact surfaces and the physical properties of the gripped object. The gripper will serve as an industrial robot subsystem that captures a limited number of geometrically, weight and shape-specified objects for a certain amount of time.

KEY WORDS: automation, robotization, manipulation, material

1. Introduction

Material handling is an activity that uses a suitable method to transfer the required amount of material to a designated location in the shortest possible time, in a certain order, in the right position and at the lowest cost. The handling system is responsible for the transfer of materials between workplaces with the least amount of obstacles and connects all workplaces and workshops in the production system by acting as a basic integrator. Handling of the material can be dangerous, especially when it comes to storing and moving larger and heavier goods. In general, hundreds to thousands of tons of material are processed every day, which requires the use of a large amount of labour. Material handling accounts for 30-75% of the total cost of the product. Making material handling more efficient can save 15-30% of costs. Material handling costs contribute significantly to the overall price of the product. Producing an efficient system greatly increases the competitiveness of the product by reducing handling costs.

Transport machines and handling equipment belong to all areas of industry. Each production process consists of a large number of minor operations that interlock. These operations are realized thanks to transport and handling equipment, where we can also include industrial robots \([9]\), which are an integral part of automation. Automation is a process in which the managerial function of a person is replaced by an activity of various devices.

Fig. 1 Assembly of proposed effector design (left) and placing the proposed robot on the automated line (right)

Automation 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, it is the goal of creating an industrial robot effector design
(Fig. 1) to ensure load handling [8] while meeting the requirements of the customer's technical standards.

An important role of engineers is analysing newly designed processes to find an optimal way of executing operation. In the development, design and production process of machines and their subsystems there are nowadays used various methods and approaches. In the processes computer simulations are utilized, which allow to identify structural and dynamic properties of structures by means of virtual reality tools [6, 7], measurements and experimental methods on prototypes or finished products [4, 5] or also by special equipment in laboratories [3].

2. Requirements Imposed on the Manipulator

The basic imposed requirements are a simple control, a necessity of a control by an operator, providing compatibility with operative system. Appliance load capacity is 25 kg and gripping force results from it according to material contact. A number of gripping fingers are 3. Mechanism drive is electrical (AC servomotor) for two mechanisms, because of the fact that one of the fingers has one degree of freedom and the remaining two fingers have two degrees of freedom. Required operative finger range is 0 – 60° (depends on a size of load) and 1.05 rad when rotating two fingers at the change of load shape. Permitted finger length at maximal gripping force is 150 mm. Maximal finger folding pace is 25 mm.s⁻¹ and finger rotation speed 1.57 rad.s⁻¹. Designed robot manipulator will be a part of an automatic line in the Fig. 1. The function of the robot is loading movable containers with ready products.

3. From Load Gripping to the Proposal of Manipulator Working Screw Revolutions

Computation of gripping force (Fig. 2) and the engine output was designed for gripping two basic objects i.e. circle shaped objects and direct planed objects (blocks, cubes). The lowest dynamic friction coefficient between handled material and fingers for which \( f = 0.1 \) (-) was used for the calculation. The condition for the correct functioning of the system (not slipping the load from the fingers) means that the friction force \( F_T \) between the fingers and the load must be greater than the gravitational force of the load \( F_g \). That is according to the relation (1) (when load weight \( m = 25 \) kg, the gravitational acceleration \( g = 9.81 \) ms⁻² and considered safety factor against slip \( k = 1.4 \) (-):

\[
F_g = m \cdot g \cdot k.
\] (1)

By substituting the known values into (1) we find that \( F_g = 343.35 \) N ≤ \( F_T \). The required gripping force \( F \) for handling the load \( m = 25 \) kg at the known friction coefficient \( f \) according to (2) is:

\[
F = \frac{F_g}{f}.
\] (2)

By substituting the known values into (2) we find that \( F = 3440 \) N. When gripping the load of the circular shape, force is decomposed evenly into three components \( F_{n1}, F_{n2} \) and \( F_{n3} \) (Fig. 2) of value according to (3):

\[
F_{n1} = F_{n2} = F_{n3} = \frac{F}{3}.
\] (3)

By substituting the values into relation (3) we find the required gripping force of each of the fingers \( F_n = 1146.66 \) N, which will ensure the safe transport of the loads. When grabbing non-circular cross-section loads, the same condition for the size of the friction force applies to ensure the proper functioning of the system, but the distribution of normal forces is different. This is due to the rotation of the fingers (Fig. 2) and their forces act in the same direction. To achieve balance in free body diagram, the third finger must react with the double force of each of the rotating fingers.

Fig. 2 Effector’s finger spacing when manipulating bodies of different shapes

From the body equilibrium conditions and the friction condition between normal and friction force we find that the normal force acting on the most loaded finger is \( F_{n1} = 1720 \) N. After evaluating the gripping forces of both gripped...
objects it was found that when gripping the object of non-circular shape, the force acting on the non-rotating finger is greater. Therefore, each further calculation was performed at the handling of such loads. Subsequently, a constructional design of the robot manipulator finger with components allowing achievement of the required movement possibilities was created (Fig. 3 on the left).

Fig. 3 Design of one of the fingers (left) and the ball joint motion curve (right)

Gripper motion kinematics is provided by means of ball joint mechanism of a joint sphere with thread. From mechanism motion kinematics point of view, it is necessary to provide two degrees of freedom at two active fingers. This motion was assured by ball joint (Fig. 3 right). When mechanism moves in a vertical direction, the move follows a curve. This motion was ensured by the acceptable slope of connecting ball with thread, which is at ball-joint type: RBL 10D – 40°, RBIDL – 25°. For part of the finger that makes only vertical motion, there is a fixed arm suspension assured by a screw connection. This way, just one degree of freedom of this part was provided.

For a working screw design is necessary to know a loading force size. In the previous calculations, it was found \[ F_r = 16,780 \text{ N} \] that the resultant loading force acting in the working screw axis is \[ F_r = 16,780 \text{ N} \]. For a correct option of the screw is needed to choose a screw with a higher dynamic load rating than the computed force \( F_r \). The next condition is that chosen working screw has high efficiency so we select a ball screw (Fig. 4) for example by company Bosch. Selected screw with dynamic load rating \( C = 27.5 \text{ kN} \), thread effective diameter \( d_0 = 32 \text{ mm} \) and thread pitch \( t = 5 \text{ mm} \) meets requirements, which will be made on it in operation. All other specifications can be seen in the Fig. 6.

Fig. 4 Selected Single Nut with Flange FEM-E-S 32x5x3.5-4 Ball Screw

Revolution of selected working screw have to reach the specific value in order to meet the condition imposed on the manipulator that the pace of the fingers folding is \( v_y = 25 \text{ mm.s}^{-1} \). Since, a lever transmission, according to the Fig. 5, is between the finger folding pace \( v_x \) and the speed of nut moving on the screw \( v_y \), relation (4) can be written as:

\[
 v_y = \frac{a}{c} \cdot v_x .
\] (4)

By solving the speed of the nut motion equation in the vertical direction we get \( v_y = 17.0833 \text{ mm.s}^{-1} \).
With the acquired value of the nut speed $v_y$, it is possible to calculate correct screw revolutions $n$ according to the screw pitch $t$ (5):
By solving the equation (5) we find the number of rotations per second, i.e. $n = 3.4166 \text{ rps}$.

4. Conclusion

The aim of this paper is a partial solution of a robot manipulator design. It consists of the constructional design of gripping fingers for operation with piece loads of maximal weight 25 kg, of selection of the working screw ensuring mechanism drive and determination of its revolutions. It is possible to state that this aim was accomplished. An overall solution of the issue is to reach theoretically functioning equipment, ready for implementation to the real production (Fig. 7). So it is needed the next solution of a ball joint mechanism selection for working motion assurance, calculation of fingers speed, transmission design, drive mechanism design, belt gear of rotating fingers design etc.

Acknowledgements

This work was supported by the Cultural and Educational Grant Agency of the Ministry of Education of the Slovak Republic in the project No. KEGA 007ZU-4/2017: Modernization of the Vehicle and engines study program.

References

Organization Model of Implementation Works in Introducing IT System to Transport Management

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Abstract

Each organization, including a transport enterprise, can acquire and operate the IT System in two possible ways - by designing an individual system or introducing it from a commercial offer that is already available. In both cases, the implementation company has no chance of successful completion task without active participation of users, in particular through a suitably organized, planned and implemented process of implementing the IT System. An important part of this process is the establishment of a project implementation team that would be responsible for the implementation of the information system. The composition of the team and its leadership role in refers to transport systems are described in the article.

KEY WORDS: Information systems, management, transport

1. Informatization System Selection

One of the crucial elements that determine the implementation of Information System (IS) in an organization is the elaboration of IT strategy of the organization [5, 14]. The fundamental element of such a strategy is an IS planning process - creation of so called INFOPLAN, the content of which depends on the following factors [1]: strategy, mission and goals of organization; development of computer science and availability of information technology.

The strategic planning model of hypothetical transport organization has been depicted in Fig. 1. Crucial factor of proper development and incorporation of IS is the analysis of user’s requirements, depicted in Fig. 2. Identification of user’s requirements determines the procedure of IS selection (e.g. developing or purchasing of ready, commercially available system) and it encompasses to transport enterprise [8, 15]:

- analysis of current technology of data processing in an organization of our concern;
- elaboration of guidelines for IS incorporation enterprise;
- elaboration of tenders and invitations for tenders;
- evaluation of tenders’ offers;
- presentations and referents visits of tenders;
- negotiations, Information System selection, contract draw up;
- implementation of Information System in an organization.

2. Information System Implementation

The presented above procedure of IS selection is one of the phases of commonly applied Control Points Methodology, which comprises of [9]:

- problem identification and analysis;
- determination of project tasks;
- elaboration of guidelines for system development (or selection of ready product);
- creation of detailed concept of the IS;
- creation of technical project of the IS;
- programming the IS (or modification of commercially available product);
- organization’s preparation to implement the system;
- testing the system (implementation);
- system exploitation, maintenance and development.
Thus, implementation of IS in accordance with Control Points Methodology may be presented as depicted in Fig. 3, while the overall implementation model may be depicted as in Fig. 4.
3. Project Implementation Team

A success and quality of IS implementation will depend on: manager’s work style; organization of current actions during enterprise conduct; structure and composition of Project Implementation Team [7].

The most important element of implementation process is the Project Implementation Team, that should present the following structure (depicted in Fig. 5) [2]:

- **Steering Committee**;
- **Executive Committee**;
- **Executive Subgroups**.

**Steering Committee** is an assembly of strategic management (command, steering) of the transport enterprise, appointed to prepare and sign the IS implementation contract, and should consists of [3]:

- enterprise sponsor (business owner of system) - usually member of management (the board) of transport company that implements IS - coordinator, authorized to make decisions concerning organizational changes, punctuality control of events and conformity to the budget planned;
- principal project manager, who represents the contractor - a designer (analyst), who knows the system and specific character of transport company concerns;
- project manager, who represents the transport company - usually one of key users or a chief IT expert, responsible for coordination of employees delegated to a project implementation;
• experienced external consultants - independent in respect of system’s implementer;
• representatives of key users.
Main tasks of Steering Committee are [2]:
• making strategic decisions concerning the project as a whole;
• approval of the scope of implementation plan;
• monitoring the IS implementation (analysis of reports of Executive Committee);
• considering applications that reflect the scope, punctuality and budget of the transport enterprise[6];
• periodic evaluation and approval of results of project incorporation works;
• stimulating preventive actions in case of crisis situations [12].

Executive Committee is an assembly of tactical management of the transport enterprise. It consist of:
• principal enterprise manager, who represents the contractor (integrator);
• transport enterprise manager, who represents the company;
• domain managers - experienced implementers of individual functional modules;
• key users (e.g. senior accountant, senior analyst, organization and management expert, IT expert).
Main tasks of Executive Committee are [3]:
• preparation of execution plan of IS implementation;
• settlement of work schedule and responsibilities assignment;
• current management of project implementation works;
• elaboration of documentation plan of IS implementation (project of actions, assessment of time and costs, distribution of assets, use of special techniques and tools, scheduling of activities and control);
• establishment of procedures of efficiency and quality monitoring;
• initiation of correct actions in case of implementation menace;
• appointment and current coordination of Executive Subgroups works;
• elaboration of periodic reports documenting the progression of enterprise (work progress related to the enterprise control points).

Executive Subgroups is an assembly (4-6 people) ascribed to functional modules of IS. It consists of: analysts, designers, consultants, instructors and future users of particular modules. Main tasks of Executive Subgroup are [4]:
• current execution of assigned tasks; documentation of conducted work; elaboration of periodic reports summarizing the conduct of assigned tasks.

There are two types of groups that may be distinguished among Executive Subgroups:
• functional groups - coping with technical issues, users training, logistics, installation and testing, system engineering, maintenance and technical infrastructure;
• supporting groups - coping with financial issues, risk analysis, quality assurance, documentation management, human resources.

Too many functional and supporting groups may lead to enlargement of management structure of transport enterprise. Thus, one may encounter some variations of an organizational structure of Executive Subgroups [11]:
1. Isomorphic structure:
   • exact projection of IS structure by its main functional modules;
   • manager is an integrator;
   • there may be some disturbances, as different parts of enterprise require different time to accomplished system implementation;
   • members of a group do not focus on entire enterprise (this is the role of enterprise management), but on their functional areas only.
2. Experts structure:
   • high responsibility of a manager with limited control over experts (high competency of experts - lower competency of manager);
   • group is self – governing - coordination depends on experts.
3. Partner structure:
   • low individualism of group members – decisions are made by consensus;
   • high pressure to creative cooperation;
   • such a structure, although recommended, is difficult to realize due to people’s habits – everyone wants to be a leader.

4. The Role of Managers and Team Work by IS Implementation

Competences and experience of managers (principal and subgroups) determine implementation process, especially in relation with contractors. Managers’ posture may be described by different style of work [11]. Among others there are autocrat style, absolute freedom style and between them democratic style.

The effectiveness of work of each element of Project Implementation Team is a factor that influences management (steering) of a whole implementation enterprise. The key to increase work effectiveness is a concept of team work supported by an appropriate tool of informatics. The main premises of such concept are [11]:
• reduction of implementation time by multiplication of work efficiency - tasks may accomplished simultaneously by team members;
• intensification of individual creative potential – team members complement one another and actuating their creative potentials;
• rising the quality of team products to the higher level – thanks to common procedures and working methods developed by team, its product quality increases.

5. Conclusion

The elaboration of IT strategy of any organization it is one of the crucial elements that determine the implementation of IS. The fundamental element of such strategy is an IS planning process, the content of which depends on the strategy, mission and goals of organization; development of computer science and availability of information technology.

By implementing an IT system in an transport enterprise, including transport, IT requires appropriate system management in every organization. It should be preceded by a detailed analysis of transport requirements, which can be summarized as follows:
1. Under what circumstances should the transport information system work?, i.e. a description of the system requirements and assumptions or its external description.
2. How the system should work, i.e.: a logical description of the system - a way to implement the basic tasks of the transport system.

The results of such an analysis underline the selection of the transport enterprise IS, and then the organization of its implementation, implemented by the Project Implementation Team responsible for the implementation, launch and modernization of the Transport IS.

References

Security in the Transport of Valuables and Cash

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Abstract

The article is focused on the area of complex security in the transport of valuables and cash. The article provides selected vulnerable parts of the planning and realizing of the transport as well as a description of the incorporation of the Regulation (EU) No 1214/2011 of the European Parliament and of the Council of 16 November 2011 on the professional cross-border transport of euro cash by road between the euro-area member states in the law of the Slovak Republic.

KEY WORDS: private security services, cash in transport, valuables

1. Introduction

The existence of the Eurozone and the common currency - the euro, leads to increased demand for euro cash transfers between the Member States of the European Union. Due to the different law of the EU Members States, not only in the area of private security and transport, it was necessary to create a rule that would differentiate the obligations for the transfer of euro cash. These rules are mentioned in the Regulation (EU) No 1214/2011 of the European Parliament and of the Council of 16 November 2011 on the professional cross-border transport of euro cash by road between the euro-area Member States. This regulation is a generally binding legal act that is directly applicable in its entirety throughout the EU. Its aim is to increase the level of security, respectively reducing security risks when converting euro cash by ensuring the security of the transaction, the security staff and the public.

2. License to Operate a Professional Cross-Border Transport of Euro Cash by Road Pursuant to the Act on Private Security (Slovak Law)

Professional cross-border transport of euro cash by road is private security service by the Slovak Law. The main law is the Private Security Act (The law) [1]. Slovakia has approached the first specific legal regulation of private security services in 1997. In 1997, the first law on private security services came into being. Until 1997, private security services were operated as living and regulation were not sufficient. The current law was in force in 2005 and was 9 times up to now. The professional cross-border transport of euro cash by road was added to the law by an amendment in 2013.

The professional cross-border transport of euro cash by road may be operated under a license issued by the Ministry of the Interior. The license is a public non-transferable document, the validity of which is normally 10 years. For other private security services, the license is issued by the Regional Police Headquarters. License comparison is on the Fig. 1.

Fig. 1 The front of the license for Professional Cross-border Transport (A) and Security Service (B) [1]
There are several types of services in the area of private security in Slovakia. The individual services are shown in Fig. 2.

Fig. 2 Individual services in the area of private security

The Ministry of the Interior will authorize operation and will issue a license if [1]:

- The operator (business operator), the head of the organizational unit of the enterprise, responsible representative or the other responsible person:
  - Is a citizen of the European Economic Area;
  - Is at least 21 years old;
  - Is medically eligible;
  - Has professional competence;
  - Is blameless and reliable.

The condition of blameless and reliability is mandatory for a person who holds at least 15% of the ownership in the enterprise.

The applicant must assume that [1]:

- He has been transporting cash in the last 24 months and has not breached the law.
- He has a Liability Insurance.
- He has a vehicle suitable for carrying banknotes and coins.

If the professional cross-border transport of euro cash by road is operated for our own needs, we are talking about own protection or self-protection service. Self-protection service must be provided by at least one person in an employment relationship with the operator. The conditions for running own protection service are easier than condition for security services for other people. The Ministry of the Interior shall decide on the granting of a license for the operation of own protection service if the number of persons providing own protection and equipment of own protection by means of physical security and other technical means corresponds to the needs [1, 2].

In the field of private security, there are two main categories of professional competence.

1. The professional competence of the operator.
   b. Intelligence Agency and Training and Counseling Service.

2. The professional competence of the person responsible for carrying out the activity, its management and control.

All categories have one thing in common. It is a certificate of professional competence.

1. S – the first level. It is for those who are responsible for carrying out the activity of investigation and physical protection, management and control of these activities.
2. P – the second level. It contains the same as the certificate of type S plus it is necessary for training and counselling and for operators.
3. CIT – the third level. It contains the same as the certificate of type P plus it is necessary for persons responsible for the professional cross-border transport of euro cash by road and for operators of this service (Fig. 3).
Private security services are common in Slovakia. In 2016, over 3500 private security services were registered in Slovakia [3, 4]. More current data is not available yet. The numbers of issued professional certificates in the area of private security from 2013 are in Table 1 and on Fig. 4.

Table 1

<table>
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<tr>
<th>Year</th>
<th>Type of certificate</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CIT</td>
<td>P</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td>60</td>
<td>83</td>
<td>4 132</td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>10</td>
<td>124</td>
<td>4 378</td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>0</td>
<td>193</td>
<td>3 586</td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>1</td>
<td>415</td>
<td>3 810</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 4 The average percentage of individual certificates in the reference period

3. Regulation EU on the Professional Cross-Border Transport of Euro Cash by Road Between the Euro-Area Member States

Regulation (EU) No 1214/2011 of the European Parliament and of the Council of 16 November 2011 on the professional cross-border transport of euro cash by road between euro-area Member States (the Regulation) is the legal act binding on all EU Member States. The regulation gives the basic rules for operation and performance of the euro cash transport. The regulation is mandatory for all members’ states in the area of CIT security. Basic relevant law for the area CIT is listed in Fig. 5.

The professional cross-border transport of euro cash by road between the participating Member States should fully comply with:

1. The Regulation No 1214/2011.
2. The law of the Member State of origin.
3. The Member State of transit (if it is applicable).

Fig. 5 Relevant law for CIT

The validity of the cross-border CIT license is 5 years. This license is issued by the national granting authority (Ministry of Interior of the Slovak Republic, in the terms of Slovakia). Conditions for the issued of the cross-border CIT
license are listed in Table 2.

### Table 2

<table>
<thead>
<tr>
<th>Condition</th>
<th>Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 License to carry out CIT transport in its Member State of origin or, if it has no specific criteria for CIT, the applicant company have to provide evidence that he had regular business in CIT for at least 24 months in its Member State of origin prior to the application with no infringements of that Member State’s national law governing such activities.</td>
<td>Applicant company</td>
</tr>
<tr>
<td>2 No relevant entry in a criminal record. Good repute and integrity.</td>
<td>Managers, the members of board of the company and all security staff</td>
</tr>
<tr>
<td>3 Valid civil liability insurance to cover at least third-party damage to life and property, regardless of whether the cash transported is insured thereunder.</td>
<td>Applicant company</td>
</tr>
<tr>
<td>4 Competences (CIT security staff, vehicles, security procedures, technical competences, education…) for cross-border CIT.</td>
<td>Applicant company</td>
</tr>
<tr>
<td>5 Medical certificate certifying that their physical and mental health is adequate for the task to be performed.</td>
<td>Security staff</td>
</tr>
<tr>
<td>6 They have successfully followed at least 200 hours of ad hoc initial training, not including any training on the use of firearms.</td>
<td>Security staff</td>
</tr>
</tbody>
</table>

All these obligations (business in CIT for at least 24 months, no criminal record, good repute and integrity of the head of company and security staff, the civil liability insurance to cover at least third-party and the required equipment…) are contained in the national law of Slovak Republic.

#### Carrying of weapons

CIT security staff has to observe the law of the Member State of origin, of the Member State of transit and of the host Member State in all ways, in regards, the carrying of weapons and the maximum permitted calibre too.

When entering the territory of a Member State the law of which does not allow CIT security staff to be armed, any weapons in the possession of the CIT security staff shall be placed in an onboard weapons strong-box. This box meets the European technical standard EN 1143-1 (Secure storage units - Requirements, classification and methods of test for resistance to burglary - Part 1: Safes, ATM safes, strongroom doors and strongrooms).

Weapons, which are not allowed, shall remain inaccessible to the CIT security staff throughout the journey across that Member State’s territory. They may be removed from the weapons strong-box when entering the territory of a Member State whose law allows CIT security staff to be armed. Opening the weapons strong-box is by the CIT vehicle’s control centre after verification of the vehicle’s exact geographical location [5]. The basic rule of the CIT is in compliance with the right of transit, host, Member State of origin and the Regulation. Carrying weapons is no exception.

#### The basic equipment of the CIT vehicle

The Regulation emphasizes the use of IBNS - intelligent banknote neutralisation system. The banknote container continuously protects the banknotes by means of a euro cash neutralisation system, from a secured area to the euro cash delivery point or from the euro cash pick-up point to a secured area [5, 9].

The CIT security staff is not able to open the container:
1. outside the pre-programmed time periods and/or locations or
2. to change the pre-programmed time periods and/or locations where the container can be opened once the euro cash transport operation has been initiated.

The container is equipped with a mechanism for permanently neutralising the banknotes if any unauthorised attempt is made to open the container [5, 7, 8, 10]. The basic equipment of the CIT automobile and basic types of CIT automobile are listed in Tables 3 and 4.

### Table 3

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global navigation system</td>
<td>The CIT company’s control centre has to be able continuously and accurately to locate its vehicles.</td>
</tr>
<tr>
<td>Communication tools</td>
<td>It allows contact at any time with the control centre and with the competent national authorities.</td>
</tr>
<tr>
<td>The emergency numbers</td>
<td>It allows contacting the police authorities in the Member State of transit or in the host Member State.</td>
</tr>
</tbody>
</table>
Types of CIT vehicles

<table>
<thead>
<tr>
<th>Type of cash</th>
<th>CIT vehicle</th>
<th>Armouring of the vehicle</th>
<th>IBNS</th>
<th>Marking of vehicle</th>
<th>Number of security staff</th>
<th>Special Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banknotes</td>
<td>unarmoured</td>
<td>No</td>
<td>yes</td>
<td>Ordinary</td>
<td>2</td>
<td>No</td>
</tr>
<tr>
<td>Banknotes</td>
<td>unarmoured</td>
<td>No</td>
<td>yes</td>
<td>Marked by Fig. 5</td>
<td>2</td>
<td>No</td>
</tr>
<tr>
<td>Banknotes</td>
<td>cabin-armoured</td>
<td>the cabin*</td>
<td>yes</td>
<td>Marked by Fig. 5</td>
<td>2</td>
<td>bulletproof vest**</td>
</tr>
<tr>
<td>Banknotes</td>
<td>fully-armoured</td>
<td>the parts with the CIT security staff*</td>
<td>no</td>
<td>without marking</td>
<td>3</td>
<td>Bulletproof vest**</td>
</tr>
<tr>
<td>Banknotes</td>
<td>fully-armoured</td>
<td>the parts with the CIT security staff*</td>
<td>yes</td>
<td>Marked by Fig. 5</td>
<td>2</td>
<td>Bulletproof vest**</td>
</tr>
<tr>
<td>Coins</td>
<td>unarmoured</td>
<td>no</td>
<td>no</td>
<td>Ordinary</td>
<td>2</td>
<td>no</td>
</tr>
<tr>
<td>Coins</td>
<td>cabin-armoured</td>
<td>the cabin*</td>
<td>no</td>
<td>Marked by Fig. 5</td>
<td>2</td>
<td>bulletproof vest**</td>
</tr>
</tbody>
</table>

*The armouring of the CIT vehicle is able to resist gunfire from Kalashnikov rifle with a calibre of 7.62 mm × 39 mm using full steel jacket iron core ammunition with a mass of 7.97 g (+/- 0.1 g) with a velocity of at least 700 m/s at a firing distance of 10 m (+/- 0.5 m).

**The cabin of the vehicle is equipped with a bulletproof vest for each member of the security staff on board. Bulletproof vest must respect at least the technical standard VPAM (class 5, NIJ IIIA) or an equivalent standard.

***Equipment beyond basic equipment of CIT vehicles (Fig. 5).

Part of the transport of valuables and cash is carrying of this special type of cargo. It means the physical transfer of cash and valuables to/from CIT vehicle by security case, bags, containers etc. These devices are equipped with mechanical, electronic, acoustic or other protection. The purpose of mechanical protection is to ensure that an unauthorized person cannot open this device with ordinary tools. For this reason, a standard safety locking system also belongs to standard equipment. The purpose of other protections is to alert to unauthorized manipulation or to mark or depreciate the content (money) that is transmitted in the security bag. Basically, security baggage for cash and valuables can be divided into two basic categories:

- **Non-hurtful** - These means after the accidental activation of the security system cannot injure the person handling the bag at that time. Such devices include a siren with a power output of up to 125 dB, smoke, IBNS, and extinguishing hubs.

- **Hurtful** - These are devices equipped, for example, with retractable telescopes, which change the safety bag to an almost non-transferable hedgehog. In addition, this may be acoustic barriers that develop a tone of about 145 dB. It is also an electrical paralyzing barrier that develops up to 50,000 volts, which can also have a fatal outcome in a person with a cardiac risk.

Type of security baggage, as well as all process of transport, depends on security risks, opportunities and competencies security service and client requirements.

4. Conclusions

The professional cross-border transport of euro cash by road must be dealt with at national and international level. In this article, we dealt with the legal regulation of private security in Slovakia, the development of the CIT in terms of a number of professional licenses in the Slovak Republic, as well as the Regulation of the CIT by the European Union. The Slovakia National Legislation is detailed because it governs the whole area of private security, not just the
CIT. The CIT is one of the private security services in Slovakia, and it was added to the Private Security Act in 2013. The Private Security Act describes in detail all activities linked with private security. The regulation takes the form of basic rules, which concern in particular the technical and personal aspects of the problem. The regulation partially regulates the tactics and methodology, e.g. CIT must be performed within one day, from 6:00 to 22:00 and below.

The area of cash and valuable transport is far wider and more complicated. There are rules, safety principles and approaches that must be followed to make transport, the crew of the vehicle and the unaccompanied person safe. These rules form the basis of the behaviour of single crew members. However, their empowerment must not be routine.

The transport of valuables and cash can be performed as well as personal protection during the transport. CIT could be carried by the PDCA model too. Risk assessment like part of the planning, alternative solutions, controlling and looking for faults, vulnerable places and improvements had to be an integral part of CIT.

By complying with the legislation at the national and international level, along with the adoption of safe and secure transport principles, from planning through implementation to ending and evaluating, it is possible to ensure security in the transport of valuables and cash. Ensuring this type of transport must be a continuous cycle that adapts to the current or expected security situation.

Acknowledgements

This paper is the result of the research supported by the project VEGA 1/0455/16.

References

5. Regulation (Eu) No 1214/2011 Of The European Parliament And Of The Council of 16 November 2011 on the professional cross-border transport of euro cash by road between the euro-area Member States

Tag Tracking with a Mecanum Wheeled Mobile Robot Using Ultra Wideband Signals

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Abstract

The article describes the possibility of using Ultra Wideband (UWB) technology for the purpose of trajectory tracking of a moving object equipped with a UWB transmitter (so-called tag). The discussed system consists of four receivers (so-called anchors) placed on an omnidirectional mobile robot with mecanum wheels and one tag attached to the moving object. UWB signals are used to determine the position of the tag, while the implemented control system realizes an estimated trajectory of the characteristic point of a wheeled mobile robot.

KEY WORDS: Ultra Wideband, UWB, mecanum wheels, wheeled mobile robot, location detection, Kalman filter

1. Introduction

Over the last decade, there has been a significant increase in wireless location technologies, which are beginning to play an increasing role in areas such as threat detection, navigation, surveillance, tracking of objects, etc. Various technologies are used for this purpose, i.e. Bluetooth, Wi-Fi, Zigbee, Ultrasonic, UWB, RFID, Cellular Based, WiMax, etc. It is required that the information of the location of such a system was reliable, accurate and delivered in near real-time (ideally real-time) [2, 3, 7].

The article focuses on the possibility of using UWB (Ultra Wideband) technology in the process of locating object having information on the distance from the used wireless modules. In order to determine the location of a target, a multilateration technique was used, while the Kalman filter was applied as the algorithm for filtering the obtained results. After determining the trajectory of the object’s movement, the task of a wheeled mobile robot with mecanum wheels is to repeat the mentioned path. The great advantage of the mentioned robot is the omni-directional movement, i.e. it has three degrees of freedom moving on a flat surface [5].

1.1. Ultrawideband Technology

UWB technology is based on the rapid sending of short pulses. The duration of a single pulse is on the order of tens of picoseconds (1 ps = 10⁻¹² [s]), which makes the emission spectrum very wide (over 500 MHz). UWB sensors operate at a low power level, which eliminates the occurrence of interference with other radio systems. An additional advantage of using the UWB technology is that it allows building devices with low power consumption, which is extremely important in the case of a wireless location. In addition, short-lived UWB pulses are easy to filter in order to determine which signals are correct for the analyzed case, and which are the result of signal reflections and dispersions. UWB transmitters and receivers don’t need expensive and large components such as modulators or demodulators. This fact leads to a reduction of costs, size, weight and power consumption of UWB systems as compared to conventional narrow-band communication systems. The signal penetrates easily through walls, clothing and can even to a certain degree penetrate some materials, i.e. concrete, wood, etc. This property is also useful for indoor positioning, when the sensor is not directly visible to the object and it allows tracking of such object [2, 7].

1.2. Kalman Filter

The Kalman filter (KF) is an widely used optimal estimator of the state of the dynamic system. It operates under following assumptions:

- a dynamic system is given in the form of a linear differential equations system (KF),
- system inputs and outputs are available for measurements,
- disturbances affecting the state of the system and measuring noise have a normal distribution with an expected value equal to zero and known variances,
- measurement noise vectors, disturbances affecting the state of the system and the state vector of the system are mutually independent [1].
Equations describing the Kalman filter can be divided into two parts:

- prediction part - predicts the state at time based on the state and control estimate from the previous moment.
- filtration part - updates the state estimate and state covariance error matrix on the basis of current inputs measurement [1].

Described filter is used primarily to denoise measurements and to reproduce state variables that are not measurable directly [1].

2. The Idea of the System

Four UWB receivers (called anchors) are mounted in the corners of wheeled mobile robot (abbreviated as WMR) and one UWB transmitter (called tag) is attached to the moving object (Fig. 1).

![Fig. 1 Scheme of trajectory of the object with UWB transmitter and WMR with four UWB receivers](image)

At first, object executes preset trajectory and WMR remains motionless. After target motion, created algorithm is calculating and filtering object trajectory measured by UWB sensors. In turn, the task of a mecanum wheeled mobile robot is to repeat the mentioned path with the use of PID controller.

3. Multilateration Technique

One of the most commonly used methods for determining the position of the tag is the use of trilateration technique. In turn, multilateration technique is an extension of the trilateration method when more receivers are available [3, 7].

The following variables describing the motion of the object (point T) and points K_1, K_2, K_3, K_4, which are the place of mounting UWB sensors on the mobile robot in the xy coordinate system, were adopted:

- Transmitter: T(x_T(t), y_T(t)),
- Receiver No. 1: K_1(x_1, y_1),
- Receiver No. 2: K_2(x_2, y_2),
- Receiver No. 3: K_3(x_3, y_3),
- Receiver No. 4: K_4(x_4, y_4).

The length of the section between the transmitter and each of the listed receivers can be written as follows:

\[ d_i^2 = (x_T - x_i)^2 + (y_T - y_i)^2, \]  

where \( d_i \) - the distance from the \( i \)-th anchor to the tag, \( i = 1, 2, 3, 4 \) [7].

In order to linearize the relationship (1), the following dependencies can be determined:

\[ d_i^2 - d_j^2 = 2x_T(x_j - x_i) + 2y_T(y_j - y_i) + c_i - c_j, \]  

where \( c_i = x_i^2 + y_i^2 \), \( c_j = x_j^2 + y_j^2 \), \( j = 2, 3, 4 \) [4, 7].

Dependence (2) can be simplified to the following matrix form:

\[ C_L = A_L B_L, \]  

where
In the analyzed case, where the number of anchors $n > 3$, the position of the tag in the 2D can be determined using the least-squares method:

$$B_L = \left( A_L^T A_L \right)^{-1} A_L^T C_L .$$

The anchors are placed at the corners of the mobile robot’s frame (Fig. 1), providing the transmitter with the largest possible line of sight (LOS) [4, 7].

4. Kinematics of the Mecanum-Wheeled Platform

The analysed platform of the considered WMR consists of a chassis frame, four DC motors with attached four mecanum wheels and four UWB receivers placed in points $K_1$, $K_2$, $K_3$, $K_4$ (Fig. 2). The mecanum wheels, which featured identically oriented rollers (pairs 1,3 and 2,3), were installed at the locations shown in Fig. 2 [5, 6].

$$\dot{x}_m \left( \cos \beta + \sin \beta \right) + \dot{y}_m \left( \cos \beta + \sin \beta \right) + \dot{\beta} \left( a + b \right) + R_s \dot{\phi}_i = 0 ;$$

$$\ddot{x}_m \left( \cos \beta - \sin \beta \right) + \dot{y}_m \left( \cos \beta + \sin \beta \right) + \dot{\beta} \left( a + b \right) - R_s \dot{\phi}_i = 0 ;$$

$$\ddot{x}_m \left( \cos \beta - \sin \beta \right) + \dot{y}_m \left( \cos \beta + \sin \beta \right) + \dot{\beta} \left( a + b \right) - R_s \dot{\phi}_i = 0 ;$$

$$-\dot{x}_m \left( \cos \beta + \sin \beta \right) + \dot{y}_m \left( \cos \beta - \sin \beta \right) - \dot{\beta} \left( a + b \right) + R_s \dot{\phi}_i = 0 .$$

where $\dot{x}_m$, $\dot{y}_m$ - projections of the velocity of a characteristic point M of the omnidirectional mecanum wheeled platform; $\dot{\beta}, \beta$ - angular parameters of the chassis frame; $\dot{\phi}_i$ ($i = 1, 2, 3, 4$) - angular velocities of $i$-th mecanum wheel; $R_s$ - radius of the mecanum wheels [6].

In turn, the transmittance of the DC motor could be expressed as a first-order element (neglecting electric time constant due to low value), assuming that the angular velocity of the DC motor's rotor ($\dot{\phi}_i$) was an output quantity, and the supply voltage ($U_i$) was an input value:
where $T_m$ - mechanical time constant; $K$ - velocity gain factor [6].

Finally, the solution to the simple kinematic problem can be obtained by applying the Moore-Penrose theorem [6].

5. Numerical Simulation

The block diagram of performed numerical simulation were shown in Fig. 3.

![Fig. 3 Scheme of the numerical simulation](image)

First, the considered object moves with the attached tag. As a result of the communication between the tag and the anchors, the distances $d_1(t), d_2(t), d_3(t), d_4(t)$ are obtained, which are the input variables to the multilateration algorithm. In turn, the mentioned algorithm, returns the trajectory of a moving object, which is then subjected to a filtration process using the Kalman filter. The filtered courses are then passed to the block of inverse kinematics solution problem, which signal is the input variable of the used control system (PID controller). Finally, using the block of forward kinematics solution problem, the resulting trajectory of a wheeled mobile robot with mecanum wheels is obtained.

Additionally, it was assumed that the duration of the simulation is equal to $10$ [s], trajectory of the object movement is linear, velocity of the object is equal to $1$ [m/s] the sampling frequency of the UWB modules is $f = 100$ [Hz], while the distance measurements of individual anchors are disturbed by Gaussian distribution with known variances. The following geometrical parameters of the WMR were assumed: $a = 0.5$ [m]; $b = 0.8$ [m]; $R_t = 0.1$ [m].

Figs. 4-11 show the results of the numerical simulation. "Torn" trajectory (Fig. 6) is the result of the Kalman filter and the effect of increasing non-linearly, with increasing distance from the transmitter to receivers, the position error (Fig. 5). In addition, the discussed trajectory is a problem for the implementation of WMR’s control system due to sudden changes and large amplitudes of individual control signals (Fig. 9).

![Fig. 4 Trajectory of the object’s motion](image)

![Fig. 5 Scatter plot of the trajectory of the object’s motion obtained by multilateration](image)
Fig. 6 Filtered trajectory of the object’s motion obtained by multilateration

Fig. 7 Measured distances: $d_1(t)$, $d_2(t)$, $d_3(t)$, $d_4(t)$ by UWB anchors

Fig. 8 Behaviors of calculated angular velocities of wheels no. 1, 2, 3, 4

Fig. 9 Behaviors of control signals: $u_1(t)$, $u_2(t)$, $u_3(t)$, $u_4(t)$
6. Conclusions

The main problems in case of locating objects using UWB technology are determining the number of receivers, their mutual placement and the related choice of positioning techniques. The minimum number of receivers necessary to unambiguously determine the position in 2D equals three. However, adding additional receivers reduces the location error and improves the stability of the system. For this reason, four receivers placed at the corners of the WMR were adopted at work, which provides them with a broad LOS and allows to use the multilateration algorithm.

The key process in this case is signal filtering. The application of the linear Kalman filter in the discussed process allowed to obtain a continuous and noisy shape of the trajectory of the object's motion, but it was strongly non-linear and "torn". The filtration also allows adjusting the signals to the requirements of the next actuator or to use them to control the analyzed device. The direction for further work is the possibility of using other varieties of the Kalman filter to improve the location accuracy during object's movement.

References

Strategic Management on Transport by Evacuation of Population in Case of Natural Disasters

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Abstract

This article gives a quantitative analysis of victims in earthquakes. It shows the ratio of victims to the population living in disasters areas. Using the normal law of probability distribution, it proposes a new approach and methodology for calculating the sanitary losses of the population and the required number of evacuation trains for evacuation by rail from the zones of natural disasters. The findings determine recommendations for predicting the possible health consequences of earthquakes and the need for evacuation trains that will significantly reduce human losses.

Keywords: Railway transport, medical-sanitary losses, evacuation trains, normal, probability distribution law

1. Introduction

The earthquake is the result of the ongoing billions of years of evolution of the earth's interior and earth's surface, it accompanies humanity throughout the history of its development. Victims of earthquakes around the world account for about 60% of all losses from various natural disasters.

Increasingly, it is confirmed that the improvement of logistics models leads to a reduction in the time of transportation operations and a minimal attraction of human resources to the fulfilment of tasks. These goals have attracted science in many fields, including the methods of transport management. At present, logistics cannot do without modern management theory tools, besides modelling it is also important to study management issues [1].

The transport complex of countries faces numerous and varied tasks. At the same time, the use of railway transport for evacuation of affected population in the event of natural disasters has not been fully studied. The analysis of disasters shows that the railway communication can be restored in a relatively short time. Therefore, railways as well as other modes of transport can be used quickly to respond to natural disasters [2].

Due to the severity of medical-sanitary consequences and the number of human victims, earthquakes take the leading place among natural disasters. This is due to the significant frequency of their occurrence, catastrophic consequences, the difficulty of their foresight and impossibility of reducing possible scales and consequences.

Natural disasters that occurred in recent years in the world were accompanied by significant human losses [3] (Fig. 1), which make it necessary to review many traditional approaches to the organization of evacuation of victims.

Some data on the ratio of the number of people living and injured in areas of earthquakes are given below in Table.
To reduce the medical-sanitary consequences of catastrophic earthquakes, it is necessary to carry out a set of activities in a variety of ways in terms of nature and content. In this article, a methodology is proposed for predicting in advance the possible health consequences of earthquakes and the need for evacuation trains, the intensity of delivery, which may determine the magnitude of sanitary losses.

2. Methodology

Having analysed the data on major natural disasters on the basis of the normal law of probability distribution, we calculate the evacuation of the affected population from the areas of natural disasters using railway transport [4].

We determine the probable sanitary losses ($\Pi_O$) as a function of the population in the earthquake region ($C$) and the earthquake factor ($\alpha$):

$$\Pi_O = f(C, \alpha) \quad (1)$$

and $\alpha$ is taken equal to 18-20% of $C$.

The probable number of the wounded to be evacuated by all modes of transport ($\Pi_E$), which is defined as a function of probable sanitary loss ($\Pi_O$) and the utilization factor of all modes of transport ($\beta$) for evacuation:

$$\Pi_E = f(\Pi_O, \beta) \quad (2)$$

The probable number of the wounded, to be evacuated by railway transport ($\Pi_E^r$), is defined as a function of the probable sanitary loss ($\Pi_O$) and the factor that takes into account the use of railway transport ($\gamma$):

$$\Pi_E^r = f(\Pi_O, \gamma) \quad (3)$$

The probable average daily need for evacuation trains ($\eta_C$) will be determined as a function of the probable number of the evacuated injured by rail ($\Pi_E^r$), the evacuation period ($T$), the capacity of the train ($m$):

$$\eta_C = f(\Pi_E^r, T, m) \quad (4)$$

The probable number of evacuation trains ($\eta$) taking into account their turnover is defined as a function of their daily average demand and turnover period ($T_{\text{to}}$):

$$\eta = f(T_{\text{to}}, \eta_C) \quad (5)$$

or in general form the formula will look as follows:

$$\eta = \frac{\Pi_E^r}{T \cdot m} \cdot T_{\text{to}} \quad (6)$$

the turnover time is determined from the expression:

$$T_{\text{to}} = \sum_{i=1}^{N} \left( \frac{L_i^r + L_i^u}{v_i^r + v_i^u} \right) + \frac{1}{24} \left[ \sum_{i=1}^{3} t_i + \sum_{i=1}^{2} T_i \right], \quad (7)$$

where $N$- the number of railway section; $L_i^r, L_i^u$ - length of railway sections, km; $v_i^r, v_i^u$ - the speed of the train in the laden and unladen state, km/day; $t_i$ - time for loading, unloading and equipping the train, hour; $T_i$ - time of delay of loaded and empty trains during regulatory actions, hour.

In this case, all the quantities occurring in expression (7) are random. The oligomeric law of distribution of random variables (7) will be denoted in the following form:

$$\varphi\left(L_i^r, L_i^u, v_i^r, v_i^u, t_i, T_i \right),$$
where the mean value $T_{ob}$ is defined as:

$$T_{ob} = \frac{1}{24} \left[ \sum_{k=1}^{3} \left( \frac{L_{o,k}^N}{V_{o,k}^N} + \frac{L_{o,k}^l}{V_{o,k}^l} \right) + \frac{1}{24} \left[ \sum_{k=1}^{3} l_{tk} + \sum_{k=1}^{2} T_{k} \right] \right] * \left( G_{o,k}^2 + G_{o,k}^l \right) dt \left( v_{o,k}^N \right) d \left( L_{o,k}^N \right) d \left( L_{o,k}^l \right) d \left( v_{o,k}^l \right) d \left( t_{tk} \right) d \left( T_{k} \right). \quad (8)$$

In what follows we assume that the random variables (7) are independent, distributed according to the normal law with the corresponding average variances:

$$L_{o,k}^N, L_{o,k}^l, V_{o,k}^N, V_{o,k}^l, t_{tk}, T_{k}; G_{o,k}^2, G_{o,k}^l, G_{o,k}^N, G_{o,k}^l, G_{o,k}^l.$$

Taking into account the assumptions made above, we obtain:

$$T_{ob} = \frac{1}{24} \left[ \sum_{k=1}^{3} \left( \frac{L_{o,k}^N}{V_{o,k}^N} + \frac{L_{o,k}^l}{V_{o,k}^l} \right) + \frac{1}{24} \left[ \sum_{k=1}^{3} l_{tk} + \sum_{k=1}^{2} T_{k} \right] \right]. \quad (9)$$

Then the variance of the random variable $T_{ob}$, taking into account the assumptions made above, is defined as:

$$G_{o,k}^2 = \frac{1}{24} \left[ \sum_{k=1}^{3} \left( G_{o,k}^N + G_{o,k}^l \right) + \frac{1}{24} \left[ \sum_{k=1}^{3} G_{o,k}^2 + \sum_{k=1}^{2} G_{o,k}^2 \right] \right]. \quad (10)$$

The law of distribution of random variables is also normal, since all the random variables entering into expression (9) are distributed according to the normal law.

$$\omega(T_{ob}) = \frac{1}{G_{o,k}^2 \sqrt{2\pi}} e^{\frac{-1}{2G_{o,k}^2} \left( \frac{T_{ob} - T_{o}}{G_{o,k}} \right)^2}. \quad (11)$$

The law of distribution of random variables will also be normal, since the distribution law is normal. Consequently, the law of distribution of random variables takes the form:

$$\omega(\eta) = \frac{1}{G_{o,k} \sqrt{2\pi}} e^{\frac{-1}{2G_{o,k}^2} \left( \frac{\eta - \eta_{o}}{G_{o,k}} \right)^2}. \quad (12)$$

On the basis of the law of distribution of random variables $\eta$, their given values and variances, the probability of hit of a random variable in the range of interest is $(\eta_1, \eta_2)$ determined by the formula:

$$P(\eta_1 < \eta < \eta_2) = \Phi \left( \frac{\eta_2 - \eta}{G_{o,k}} \right) - \Phi \left( \frac{\eta_1 - \eta}{G_{o,k}} \right), \quad (13)$$

where

$$\Phi \left( \frac{\eta - \eta}{G_{o,k}} \right) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\eta} \frac{1}{G_{o,k}} e^{-\frac{1}{2} \left( \frac{t}{G_{o,k}} \right)^2} dt; \quad (14)$$

$$\Phi \left( \frac{\eta - \eta}{G_{o,k}} \right) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\eta} \frac{1}{G_{o,k}} e^{-\frac{1}{2} \left( \frac{t}{G_{o,k}} \right)^2} dt. \quad (15)$$

Mathematical dependencies (6,7) can be used to determine the need for evacuation trains in the case of specific evacuation volumes. In this case ($T_{ob}^*$) - the specific amount of evacuation (the number of transported wounded).

Turnover of evacuation trains is possible, if the condition $\frac{T_{ob}^*}{T} < 1$, is met $\frac{T_{ob}}{T} \geq 1$, if, then $n = n_c$.

Further, the solution of the problem is reduced to the summation of numerical values of the indicators:
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\[ C_{ij} = \{A_{ij}\}_{i=1}^{m}, j=1,n \],

where \( A_{ij} \) - matrices of the values of the parameters of the entrance document of the norm of the completeness of sanitary trains, the norms for placing the wounded in sanitary trains; \( k \) - the number of completed sanitary trains; \( C_{ij} \) - results (final) matrix of the values of the output document indicators (information on staffing and material and technical support of sanitary trains). In the future, a solution using an electronic computer is possible.

3. Results

The proposed methodology will make it possible to solve the following tasks:
1) to plan rail transportation by medical evacuation by the forecasting method;
2) to forecast probable sanitary losses during earthquakes;
3) probable volumes of evacuation beyond the zones of natural disasters;
4) probable volumes of evacuation of the affected population by rail;
5) to calculate the average daily requirements for evacuation-sanitary trains;
6) to calculate the needs of evacuation-sanitary trains taking into account their turnover.

Below is a Diagram of the probable average daily evacuation volumes of the affected population in 3, 6 and 10 days by rail (Fig. 2), provided that \( C \) is the population of the earthquake in the area; \( \eta \) - the average daily need for evacuation-sanitary trains; \( T \) - evacuation period, day.; \( \beta \) - coefficient of evacuation of the wounded; \( \gamma \) - coefficient of evacuation of the wounded by rail.

![Diagram of the probable average daily evacuation volumes of the affected population in 3, 6 and 10 days by rail](image)

4. Conclusion

Moderate and even weak earthquakes can be catastrophic in the areas. The most important element of the organization of measures to eliminate the health consequences of catastrophic earthquakes is the prediction of the magnitude of sanitary losses among the population living in seismic regions and planning timely assistance to them. The developed methodology for calculating planning for the evacuation of the population by rail from earthquake regions will significantly reduce the number of population losses in the earthquake zone, since the dynamics of the magnitude of population losses in earthquakes directly depends on the intensity and pace of rescue operations.

References

Mergers and Acquisitions in the International Air Transport Industry

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Abstract

Bearing in mind the globalization processes, including the need to focus on international markets, intensifying competition, changing customer needs, fast pace of new technologies implementation, privatization processes cause changes in the management of enterprises in the aviation industry. Adapting to the turbulent environment forces air carriers to search for new organizational forms, such as alliances, mergers and acquisitions that enable enterprises to operate as a network.

Due to the specificity of the operation and growing competition in the international air transport sector, carriers were forced to enter into alliances offering a network of global connections that would allow geographic expansion or improve the efficiency and performance of the air organizations [14].

This article presents the results of studies which focused on defining the role and significance of merger and acquisition in airline strategies. These scientific considerations concentrate on the strategic aspects of airline management seen through the forms and methods of consolidations used by the carriers from Europe and the United States. In the final part of this article the author outlined global trends in the development of consolidation processes of merger and acquisition implemented by airline carries from different parts of the world.

The article tried to find an answer to the question - whether alliances, mergers or acquisitions carried out by airlines could be the right direction for strategic management of aviation organizations?

KEY WORDS: mergers, acquisitions, airline alliances, carriers, consolidation of operations, integration, cooperation, air transport market, aviation services

1. Introduction

Air transport is an important factor affecting the economy world: this applies to both industries, sectors of economy and farms households. We observe the mutual correlation of changes in the economy - on the one hand, changes in the economy have a big impact on the shaping of the aviation market, on the other hand, changes on the aviation market affect the economy [1]. In the last 30 years, the aviation industry has survived, among others recession, rising oil prices, war and the threat to aviation safety, and yet air traffic is on average increased by 5% per year (Fig. 1).

It is beyond doubt that every launch of an airline is an expensive enterprise - let alone its operation and maintenance costs. Given such conditions, it is no surprise that with so many variables regarding oil prices, economic crises, wars as well as changes in customer preferences and taste airlines run into financial difficulties from time to time. The need to recover from financial problems is the main reason behind mergers, acquisitions and purchases [8]. Following this mode of thinking, it can be predicted that in the future there will be even more attempts of such consolidation processes in the air transport industry [17]. They may eventually lead to a situation, where there will be only one or two major mega-carriers on each market.
2. The Notions of Merger and Acquisition

Mergers and acquisitions are one of the more common elements adopted in the development strategies by air carriers. In a broader perspective, these activities are conducted not only to achieve internal cohesion of the airline – their purpose is also to enhance the internal cohesion of the organizational structure through integrating its functions and activities [7]. In reading the literature on the subject, it can be noticed that mergers are classified as a form of acquisition while acquisition is defined as a form of purchase [21]. In Polish literature on the subject the notion of merger is typically considered equivalent to consolidation [5, 8]. With merger, this is the case only when the consolidation of companies results in the creation of a new legal entity [1]. Polish law regulations also allow for another form of merger, namely a situation, where one of the consolidating companies is the legally remaining entity.

In English-language literature on the subject, the common term used for describing mergers between companies is mergers & acquisition (M&A) alongside takeover, consolidation or buyout [6]. Merger typically describes a situation, where two or more companies, which were originally autonomous, merge together through an agreement in order to create a new business entity. An important aspect in this matter is the fact a merger causes each company to lose its existing autonomy and legal personality. The owners of the merging companies obtain ownership titles to the new business entity created as a result of the merger. Another important aspect lies in the fact that mergers are typically conducted between airlines of comparable size and economic potential. This can be well exemplified by the agreement between two companies from the airline industry: Boeing and McDonnell Douglas, which joined forces in order to become one of the biggest aircraft manufacturers in the world.

On the other hand, acquisition describes a situation, in which an economically stronger airline takes over (though not always) another company by purchasing a number of shares sufficient to allow them to control and manage that company. The acquisition may also occur through privatization of a public limited company or joint venture. Polish economists define such situations using two equivalents terms: incorporation and merger [10]. It should be noted here that acquisition is a transaction which guarantees more autonomy to one of the entities. In this case, one airline purchases the assets or shares of the other airline and the shareholders of the acquired company cease to remain its owners [11].

3. Characteristic of the Selected Mergers and Acquisition Between Air Carriers in Europe

One of the most well-known mergers in the air transport industry in Europe at the beginning of the 21st century was the merger of France’s flag carrier Air France with the Dutch air carrier KLM, which was concluded on May 6th, 2004. This consolidation was then deemed as the creation of the greatest airline group: Air France-KLM. The merger of these two airlines gave rise to a holding company, in which each party was able to operate for at least 5 years under its own name, retaining considerable autonomy and being able to use its own fleet as well as the existing network of connections. The agreement also allowed the parties to maintain their existing brand names and to independently take advantage of all the transport licenses obtained individually by each party. As a result of the establishment of a new airline, the French took over 89.22% of shares in the Dutch company. Due to the privatization of Air France, the shares of the French state in this company initially decreased from 54.4% to 44.7%. Later this share was further reduced to 20%. Moreover, the company became involved in partnership cooperation as a part of Sky Team alliance and split the CARGO transport market [11].

According to airline industry experts, the merger of the French and the Dutch carrier became a classic example of the one group, two airlines model. This way of functioning enabled the airline to better utilize airline hubs and provide higher service quality.

In addition, this merger became an inspiration for other carriers, especially those who struggled to survive on their own in the air transport industry. This was particularly the case with small carriers in the air service industry, which started to consolidate around large airlines such as Lufthansa, British Airways or Air France. Some of the airline industry experts went even further in their judgments, predicting that the merger of Air France and KLM ceased the era of national carriers while giving rise to the era of European carriers. Moreover, it has to be stated that this merger became a certain model for other consolidations we witnessed in the following years. An example confirming this statement can be the merger of British Airways and Iberia which was finalized in November 2009 despite the initial assumption that the consolidation process would have been closed before the end of 2011 [2].

On the basis of this merger, the British company British Airways and the Spanish Iberia “became as one”. The new entity was temporarily named TopCo. TopCo’s capitalization was initially valued at nearly €5 billion, which was significantly more than the capital of the Franco-Dutch group Air France-KLM (€3.3 billion). The newly established airline group became a Spanish business entity and it pays its taxes there. The main offices are located in London and Willie Walsh, the then-current Managing Director in BA, became TopCo’s first Chief Executive Officer.

As a result of the merger, the shareholders of British Airways had 55% of the new company’s shares whereas 45% was assigned to the shareholders of Iberia. Despite the fact that the new holding company adopted the name International Airlines Group (IAG), it was decided that each company would retain its own brand. The structure of the holding company was based on the merger between Air France and the Dutch KLM. It was deemed as the most effective since it allowed for maintaining domestic transport licenses while providing maximum synergy of activities of the two air carriers. After the consolidation, International Airlines Group is considered the third largest airline in Europe and the sixth in the world. Airline industry experts regard this merger as an effective answer of the British and the
Spanish aircraft carriers towards the growing competition of low-cost airlines and the plans of consolidation of other European carriers. The conclusion of these considerations could be that both carriers well complement each other in terms of the offered services. Iberia has an established position as the provider of flights to Latin America (106 cities in 43 countries) whereas British Airways remains competitive regarding flights to the USA, Canada and Persian Gulf countries (150 cities in 75 countries). Their main airports are Madrid and Barcelona as well as London-Heathrow, respectively [13].

Apart from the two described mergers between European aircraft carriers, we also have to mention another merger which became an important element of the aggressive strategy of operation adopted by Lufthansa. In this case the merger was merely a transitional phase in the acquisition of several smaller European carriers such as Swiss Air, Austrian Airlines and BMI. The second largest airline in Germany - Air Berlin - was also active during that period, initiating a series of acquisitions of several regional airlines which were not limited only to German carriers. In 2009 the German airline acquired the Swiss carrier Belair and in 2011 the Austrian carrier FlyNiki [4].

The conclusion of the above considerations could be that since the beginning of the 21st century we have witnessed the first wave of mergers in Europe (Air France/KLM, Lufthansa/Swiss Air Lines, British Airways/Iberia, etc.). However, the fact that they did not result in significant improvement in terms of profitability is rather alarming. Consequently, it is possible that we will witness a further process of consolidation, which will resemble one of the stages of the American scenario [15].

4. Mergers and Acquisitions in the Air Transport Industry of the United States

Apart from the mergers between the European aircraft carriers, we also have to mention the series of mergers which occurred in the air transport industry of the United States (Fig. 2). It has to be noted that the domestic air transport market in the United States has experienced numerous mergers and acquisitions, which were aimed towards consolidation while retaining strong competition among the main aircraft carriers. This series of mergers and acquisitions was initiated in July 1997 by ValuJet, which announced its plans regarding the takeover of Airways Corporation Inc., the holding company of AirTran Airways. The new airline was named airTran, with its airline hub being the Atlanta Airport. In April 2001 American Airlines was acquired by TWA, which at the time struggled with considerable financial problems. The estimated value of purchased assets was $20 billion [9].

After the terrorist attacks of September 11th in 2001 the company US Air ran into significant financial trouble, which was associated with the overly expanded network of connections and high cost of renewing the aircraft fleet. Consequently, US Airways declared bankruptcy in 2002 and started an intense search for a business partner the following year. With the unsuccessful attempt to find a company willing to do a merger, US Air once again filed a bankruptcy petition. After difficult negotiations the carrier was finally acquired by America West Airlines in 2005. The new airline adopted the name US Airways [16].

During the years 2005-2009 Republic Airways Holdings finalized the acquisitions of several local aircraft carriers such as Shuttle American and Midwest Airlines. In 2012 Midwest and Frontier were merged into one airline, maintaining the brand name Frontier. In April 2008, after ATA (formerly known as America Trans Air) declared bankruptcy, it was quickly acquired by Southwest for $7.5 billion. On April 14, 2008 Delta and Northwest Airlines announced a merger resulting in the creation of a new airline – Delta. This merger of two aircraft carriers gave rise to the largest commercial airline in the world, which has an operating fleet of 786 planes. The process of full integration of these two carriers was finalized in January 2010.

Only several months after the Delta/Northwest merger, in May 2010, other two American carriers, Continental and United, declared their willingness to join forces as a part of the planned merger. The process of consolidation ended in October 2012 with the transaction being cashless. The shareholders of Continental received 1.05 share in UAL per each of the company’s nearly 140 million assets. It has to be noted that the merged airlines had already cooperated under the aircraft alliance Star Alliance. This merger resulted in the creation of the largest airline in the world with an operating fleet of 692 planes flying to 370 airports in 59 countries. The company employs approximately 90,000 workers. The flights of the new carrier are organized only under the name United Airlines. In 2011 the new airline operating under the name United already surpassed Delta in the number of transported passengers, which gave it the status of the largest airline in the world in terms of the number of passenger flights. The last of the so-called mega-mergers in the air transport market of the United States was the merger between US Airways and American Airlines. I was initiated on November 29th, 2001 by the owner of American Airlines, the corporation AMR, which filed a bankruptcy petition regarding the airline. The petition was filed based on the Article 11 of the Bankruptcy Law of the United States of America, meaning that the airline shall be subject to restructuring program and may operate normally. It has to be noted that according to the United States Law, a declaration of bankruptcy does not result in the liquidation of the carrier – it only provides protection against the creditors, reduction of debt and restructuration. The management board of AMR guaranteed that American Airlines would operate normally during the bankruptcy procedure. On February 14th, 2013, AMR informed about the plans of a merger between American Airlines and US Airways, which was finalized on December 9th, 2013. But it was not the end of the reshuffle in the airline industry in the US because the largest low-cost carrier Southwest Airlines bought the airline AirTran.

In addition to mergers and acquisitions in the sector of air transport of passengers to similar methods of consolidation also occurs among air cargo carriers. A good example would be the action of FedEx Corporation, the world's largest air cargo line to the United States. In May 2016 years, they signed a contract in Amsterdam for the...
acquisition of TNT Express, the Dutch logistics group providing postal and courier services. The agreement must still be approved by the other shareholders and antitrust authorities. The purchase price of shares is 4.4 billion. According to experts of the aviation market is a historic and important event especially in the current market conditions, when the global e-commerce is growing at double-digit rates. As a result, the combined group will employ a total of 400 thousand. people. This acquisition is intended among other things, the launch of new investments, the development of technology, infrastructure, facilities and operational capabilities. Implementation of these projects is to strengthen the capacity of competitive and ensure long-term development.

Fig. 2 Airlines mergers in the U.S. since 2005 [22]

5. The Development of Mergers and Acquisitions in the Aircraft Industry

In the analysis of the development trends regarding consolidation of aircraft carriers we cannot exclude the increase of expansion to other continents and markets by Middle Eastern carriers such as Emirates, Etihad or Qatar. The carriers from this region of the world, aiming to extend the availability of their services in the West, may expand their current influence by securing mergers with each other or acquiring airlines from a given region, e.g. Europe. Moreover, we have to acknowledge the great potential demonstrated by Asian countries, both in the current and long-term perspective. For instance, the number of flights per week in China has increased from 2184 to 526512 over the years 1992-2012. These unfavorable tendencies undoubtedly weaken the European aircraft transport industry. According to the alerts issued in 2014 by Air France and Lufthansa, European airlines are now among the least profitable airlines in the world. Moreover, the lack of investments resulted in the overload of airports in the European Union, which may considerably limit their capacity to meet the increasing demand. In summary, it can be concluded that in the face of increasing pressure from the competition, European airlines may choose one of the two strategies of operation [19]. The first one is the implementation of large scale investments which would enable them to meet the increasing demand. The second option is consolidation enabling them to survive. Considering the broad spectrum of this problem, it seems that the second scenario is the most probable one, especially when taking into the account the evolution of the domestic market in the USA which has already experienced several spectacular large-scale mergers [20].

6. Conclusion

On the whole, the presented considerations may lead to a conclusion that there are few industries in the contemporary world being as changeable as the aircraft industry. The technological novelties, investments, oil price changes and law regulations have been affecting the economic situation for years. However, few have expected such a drastic transformation of the air transport market caused by the current wave of heavy competition originally initiated in the United States, where the domestic air transport market was deregulated as early as in 1978. The European Union has not decided to do so until 1997. The creation of a uniform market attracted numerous new players, mostly so-called low-cost airlines, which resulted in the significant decrease of ticket prices for domestic flights. Given such conditions, it is beyond doubt that every airline willing to develop and make profit or even survive on the market has to adopt a suitable strategy, with mergers and acquisitions being more and more frequent and integral parts thereof. It has to be emphasized, however, that the processes of merger and acquisition involve a high risk of failure. This is caused by their complex, multi-stage and, in many cases, unrepeatable nature. Moreover, such enterprises usually cause major changes in numerous areas of operation of the merged aircraft companies and strongly affect the external environment.

Despite certain dangers, mergers and acquisitions conducted in the air transport industry are mostly perceived as a method enabling more dynamic development of aircraft carries, which ultimately leads to the improvement of their competitiveness.
References

Employer Branding as a Part of Modern Personnel Marketing in a Transport Company

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Abstract

Brand building and strengthening its market position is not a simple process in the current competitive environment. The brand represents one of the most valuable assets of the company, its main functions include obtaining a competitive advantage, identification of the brand and ensuring the loyalty of consumers, the general public as well as the employees of the company itself. Companies are increasingly aware of the importance of employer branding in order to distinguish themselves from the competition, promoting their strengths and unique corporate identity. Employer branding is the process of building an employer's brand, which results in perceiving the company as an attractive employer not only for current but also future employees. It means that an employer's brand is being built both by the company management and employees themselves. The aim of the article includes to provide a literature review on the issue from several foreign and domestic authors. It discusses the essence of brand and employer branding, also analyses its use as a part of modern personnel marketing in practice through secondary research data. Based on this, in conclusions author highlights benefits of the employer branding as a part of modern personnel marketing in the specific conditions of the transport company, such as the loyalty of current and future talented employees that is one of the key assumption for company's success.

KEY WORDS: Employer Branding, Employee Value Proposition (EVP), Personnel Marketing, Transport Company, Brand

1. Introduction

A brand that has a high level of knowledge gives customers value and conversely customers trust it. It is much more attractive for them and, most of all, the first choice in buying decision. Precisely for this reason employer branding is currently hot topic. Today's young people want to be trendy, successful and are therefore strongly oriented to buy branded technology, clothing and other consumer goods. In this way they also behave when searching for a job. They are looking for an attractive company that has a strong brand name, where they can grow their career, be part of decision-making and technical innovation.

The aim of the article includes to provide a literature review on the issue from several foreign and domestic authors and analyse the use of the employer branding as a part of modern personnel marketing in a particular transport company through secondary research data. The secondary data for the analysis was obtained from annual company reports, statistical tables, published professional publications – both in print and electronic media. Based on this there were highlight benefits of the employer branding as a part of modern personnel marketing in the specific conditions of the transport company, such as the loyalty of current and future talented employees that is one of the key assumption for company's success.

2. Literature Review

Brand has always been one of the way for differentiation companies and their products. The issue of the brand, branding as well as personnel marketing and employer branding is currently dealt with by many foreign and domestic authors.

Keller highlights the brand as a further dimension of the product that distinguishes it from other products [6]. According to Kotler, brand represents the declared product quality [7]. The brand is a name, term, sign, symbol, design or a combination thereof, which shall identify the goods or services of one seller or group of sellers and to differentiate them from competitors' goods and services [8].

American Marketing Association and Marketing Accountability Standards Board agree, that a brand is a "name, term, design, symbol, or any other feature that identifies one seller's good or service as distinct from those of other sellers [17].

The concept of brand from marketing view is in many sources defined very similar. However, more interesting are subjective, more descriptive expressions of marketing experts on what they mean by brand. Toman indicates that a brand is still often seen as a symbol denoting a product or company. It is simplistically perceived as "notice board" over the entrance to the store. It then follows the effort to build the brand visible everywhere. [13].

The whole process of building brand, from brand design through its applications to the effective communication
with consumers, defines the term branding. It is not just about design but also marketing strategy, which is in the process even more important. The whole process should be carried out in a planned and responsible manner. The role of branding is therefore to give the name of a product, assign the importance to brand, and thus place the brand in the customer's mind to distinguish it from the competitor [6].

The main advantage of branding is the fact that customers can more rapidly remember the product. A strong brand helps keep the company's image in the mind of both the current and the potential customers [15, 14]. Many people see the brand as part of a product or service, which means that it proves its quality and value. This usually means that if we showed customers two products that are identical and only one was labeled, they will almost always believe that the branded product will be superior.

Merz et al. say that the importance of brands and branding in recent decades developed. Further he notes that this development has got closer the new conceptual approach, which looks at the brand in terms of joint activities of companies of all stakeholders and at the brand value in terms of perceived value of collective stakeholders. Marketing managers can benefit from investing resources in building strong brand relationships with stakeholders and then building a philosophy on these bases [10].

Nowadays, the brand building in order to gain the status of an attractive employer is a very important part of any company. Lack of quality workforce has all the industries, whether manufacturing, trading companies or service providers in all areas, including the transport sector [9]. An even greater problem is the loyalty of high-quality workforce.

Companies that build their brand in the eyes of customers have an easier way to get high-quality employees. For this reason, employer branding is now an important part of their strategy. Employer branding represents a strategic process that involves the activities and effort of the whole society, it is among the new modern forms of personnel marketing.

Personnel marketing is a relatively new area in the theory and practice of personnel activities, it represents a scientific approach that helps ambitious people to be visible and important in society [1].

According to Szarkova, it is primarily about how to understand what people as a workforce want and need, and understand the conditions affecting the need for the workforce in the company and the possibility to meet that need [12]. Borsikova defines personnel marketing as the purposeful acquisition, development and use of human potential in accordance with the strategic goals and business objectives as well as corporate culture, using marketing tools. It is part of the corporate dimension and ethical principles of leadership, expressing recognized values, standards and beliefs of company staff, where the employer branding represents the philosophical foundation [2]. Graeme et al. also confirm the relationship between branding and personnel marketing [5].

Personnel marketing tools, including employer branding, are a set of tools knowingly applied by company in both the internal and external labor markets.

According to Deepa and Baral, employer branding creates a sustainable relationship between an organization and its potential and existing employees by creating values for individuals, organization and the society at large [3].

Employer branding is a tool by which companies define, differentiate and universally support its signals sent to current and potential prospective employees. Employer branding is a marketing technique that builds a brand, image or goodwill organization in the field of personal work. It reflects into individual personnel marketing tools. An example may be the brand building of a well-sold site, the price advantages of a given location, a convenient way to communicate with potential customers as well as the creation of an image of the company through massive and well-targeted market communication [4].

Employer branding is based on employer value proposition (EVP), that represents the unique value offered by the company to its labor market as well as potential employees. The EVP provides an answer to the question of why to work in a company, why it should be chosen by a prospective employee, pointing to the attractiveness of the company in the eyes of employees and potential employees.

The EVP thus represents the values of the company that make the employer's brand unique and attractive to both employees and candidates. A well-defined EVP is not just a group of benefits, such as regular teambuilding, flexible working hours, mobile phones and private cars, the homeoffice option, or an education program. The benefits the employer provides to his employees are only half of the EVP. The second is the employer's expectations. The EVP is therefore a set of values, financial and non-financial benefits that companies give employees reciprocally for their loyalty, engagement and work performance. This is a promise given by the company to both current and future employees. EVP must be unique, comprehensible, relevant, authentic and motivating [4, 11].

3. Analysis of the Employer Branding as a Part of Modern Personnel Marketing in a Transport Company

We have examined the use of employer branding as a part of modern personnel marketing in Transport enterprise of the city of Zilina (DPMZ - Slovak abbreviation). The transport enterprise was established in 1949 under the name Communal Transport Company Zilina and it started to provide bus services for the public in city of Zilina in the same year. In the past, as the only one transport company in Slovakia, it also provided shipping. Since 1953 it has been called Transport enterprise of the city of Zilina. At present, DPMZ operates urban public transport on its 8 trolleybus lines and 13 bus lines (including the night line) [16].

DPMZ currently has 261 employees, including 50 managers, 134 drivers and 77 workers. Its fleet consists of 42 trolleybuses and 40 buses. Passenger services provide 2 retail outlets and 44 vending machines, most of which are able
to provide multiple types of tickets to the passenger [16].

Since 1996, the company has been focusing on the gradual electrонisation of public transport. As the first city in Slovakia it had the information system in all vehicles, which consists of a trip computer, electronic marker, electronic road signs and acoustic alarms for notification stops in the vehicle interior and in the exterior for blind and visually impaired people needs. The data obtained through this information system allows to evaluate the transport, technical and economic criteria of public transport. They are also the basis for optimizing traffic [16].

Company DPMZ has undergone changes in the organization with the necessity of the modernization of the fleet, electronization of work and the provision of new services.

DPMZ is one of the providers which provide transport also to KIA motors Slovakia factories in Teplicka nad Vahom. Another kind of business is coach transport. DPMZ also has coach buses by which it is able to offer to customers comfortable international or domestic transport according to customers wishes.

DPMZ runs two places of business which are 3,5 km away from each other: administration, trolleybus parking area and shops, bus parking area and pertinent shops. There are 2 sales points selling tickets and recharging smart cards in the downtown of Zilina as well as 44 ticket machines located at the bus stops all over the city. All of them provide tickets for more than one fare zone [16].

The organizational structure of the company represents the hierarchical relationships between the individual jobs within the company. It includes relationships of subordination and superiority, and resolves mutual competences, links, and responsibilities.

The statutory bodies of the company include:
1. General assembly - is entitled to act on behalf of the company or to decide on its internal affairs. The city of Zilina, as a 100% shareholder, exercises its rights at the general assembly in person or through an authorized representative on the basis of a written mandate.
2. Executive manager - ensures the management of the business, he acts and signs on behalf of, and at the same time serves as a director as the executive body of the company.
3. Supervisory board - oversees the activity of the company's executive manager, looks into the accounting documents and other documents where checks the data, examines the company's financial statements and reports to the general assembly.

DPMZ does not have a comprehensive strategy of the employer branding as a part of personnel marketing, but does a number of activities in this area. The company is aware of the importance of internal personnel marketing. In order for the company to be able to provide quality services, it must have high-quality staff. New staff is provided with quality training and consequently their qualifications are continuously increased.

As mentioned, the company's personnel marketing is primarily focused on social care for employees and their education. DPMZ regulates the company's employees' relationships arising from the implementation of both the strategic and business tasks of the company by the code of ethics.

A pleasant work environment and good communication with employees creates a long-term relationship employer - employee for the duration of the whole employment relationship where the employee is repeatedly trained, educated and constantly motivated.

Labor legislation, directives, regulations, standards of behavior and conducts, together with corporate culture and organizational rules of the company are governed by the applicable standards. These standards regulate the human potential of the company in accordance with its needs and the creation of versatile conditions and assumptions for a high level of work performance, behavior and responsibility.

The result of most company's provided services is difficult to measure by objective methods. The company's success is assessed especially by customers, who determine in part the company's goal and their satisfaction as well as satisfied and loyal employees who are involved in building a brand.

In the company, each employee must undergo a professional examination to ensure the safety of passengers. Essential training courses include training following the requirements of legislation, in particular regard to training of drivers, operator of the gas filler, stokers, electricians for maintenance of buildings and equipment, operator of lifting equipment and operator of pressure equipment.

The company has a draft training plan. All training courses in the company are based on valid legislation and standards.

Ensuring the health and safety protection at work is an important part of the personnel marketing and necessary to gain employees' loyalty. Employees of the company are repeatedly trained in occupational safety and awareness of legislation on OSH issues. On the basis of education workers are acquainted with the wording of policies of health and safety at work, accidents at work, causes of occupational accidents and measures. Training also includes informing employees about possible threats and risks arising from the work and the operation of the equipment used.

Employees have the right to participate directly in education or specifically to comment on the following topics:
• Health and safety policy at work and its implementation program;
• Proposal for the selection of protective equipment, organization of work;
• Workplace environment;
• Assessing the risk, identifying and implementing protective measures, including the provision of personal protective equipment and means of collective protection;
• Occupational accidents, occupational diseases and other health damage from work that occurred with the employer, including the results of their investigation and suggestions for measures;
• The manner and scope of employee information.

Other necessary professional training and education are provided by law and other staff regulations at prescribed intervals by persons with appropriate professional qualifications:
• Training of drivers;
• Training of referent vehicles;
• Training for driving trucks;
• Training of persons handling lifting equipment;
• Training of persons handling high-pressure equipment;
• Training of persons handling gas equipment;
• Training of stokers;
• Training of welders;
• Training of persons with electrotechnical qualifications.

DPMZ also offers employees a number of attractive benefits. They are among them:
• Birth grant for a child;
• Contribution on leaving for maternity leave;
• Jubilee contribution;
• Child's contribution to the camp;
• Retirement allowance;
• Health and relaxation program for employees;
• Technical and professional training;
• Collective corporate recreational and teambuilding events;
• Meals allowance;
• Reference program;
• Anniversary job announcement.

It is also necessary to pay attention to external personnel marketing. Collaboration with the University of Zilina and specialized high schools, such as the transport Academy in Zilina, has been developed.

Every year, DPMZ organizes the "Open Doors Day in DPMZ". The company is also actively involved in the "World Day without Cars" event in the framework of the European Mobility Week campaign, in the form of a free urban public transport.

Company has joined the Europe-wide campaign so called “European Mobility Week” to promote electric-powered transport where one of the campaign's part used to be also “The European Trolleybus Day”.

Since 2008, Zilina has become a partner of the international project "BENEFIT" - Progressive measures for an organization to intensify the use of public transport by its employees, together with the DPMZ and the University of Zilina.

DPMZ aims to make its employees satisfied and proud of the company brand that employs them. Satisfied employee is the best advertising of the company. DPMZ has so far achieved relatively good results in this area and thus has the chance to become a preferred employer, so called employer of choice. Becoming an employer of choice is closely related to the brand of the company and satisfied employees who disseminate positive references. The strong brand evokes the stability of the company, and the satisfaction of the employees and the pleasant work environment are important factors that can be taken into account when deciding a potential candidate for the benefit of the company.

4. Conclusions

Employer branding is the process of building an employer's brand, which results in perceiving the company as an attractive employer not only for current but also future employees. Employer's brand is not only being built by the management and human resources department of the company, but also the employees themselves, who become ambassadors because of the attractive corporate culture, education, professional growth and other benefits.

According to a Willis Towers Watson survey, companies that are actively building the employer's brand, in which employees feel the trust of their superiors, they fill their work and they are proud of it, they are five times more involved, have proven better results in terms of length of service and employee satisfaction. In particular, the attributes of work environment, culture, benefits, and in-house relationships are important. Up to 94% of candidates when finding a job choose the company that actively works with employer branding and 84% of candidates are willing to leave their job due to the offer from a company with a better reputation [18].

The goal of any company that wants to employ top quality staff is to become a preferred employer (employer of choice), that means to be an organization in which people want to work and they love it. References of current employees are of great importance because they support the reputation of the company and become a competitive element.

Based on the analysis of employer branding as a part of personnel marketing at DPMZ, we found out that the company is using marketing tools to build an image of the company as an attractive employer who is interested in the satisfaction, education and growth of its employees and also creates opportunities for building career. The main goal of personnel marketing strategy is to attract high-quality workforce and to persuade the best employees to stay. When comparing informations about DPMZ, we can say that employees' references to a company are very positive. Our suggestion in this area is to support this positive state of affairs and further increase awareness of DPMZ as a preferred
employer. This will be provided by ensuring the satisfaction of current employees with the use of traditional as well as new marketing tools. The main benefit of the employer branding as a part of modern personnel marketing includes the loyalty of current and future talented employees that is one of the key assumption for company's success.

References

Cost Forecast in a Shipping Company

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Abstract

The article describes the problem of cost forecasting in a shipping company. A number of time series of costs were analyzed and assessed. The results of the assessment were used to select a suitable forecasting method.

KEY WORDS: forecasting, expenditure, costs

1. Introduction

According to the authors of this article, forecasting remains a vital aspect for effective planning in numerous organizations, including local shipping companies.

The analysis of the literature on the subject as well as the experience of the authors of this article indicates that small and medium shipping companies, in most cases, do not plan their future costs in a precise manner. Costs are incurred in an unplanned manner and they often require taking out loans or credits with a high interest rate, which generates costs and reduces potential profits. Based on this premise, the authors of this article investigated the use of forecasting methods for cost planning in a shipping company. The cognitive gap is represented by the lack of an effective method for calculating planned costs in small and medium shipping companies. The methodical gap is represented by a change in the current approach to cost planning through the application of forecasting methods, which are suitable from the perspective of assessment and analysis of time series of costs.

The research question focuses around the selection of cost forecasting methods suitable for a shipping company with the objective to optimize its operational expenditure. The authors of this article formulated the following main research question: will analyzing and assessing time series of costs of transport enable selecting the optimal planned cost forecasting method?

The literature on the subject of forecasting is very extensive yet scattered. It lacks detailed descriptions and precise procedures for producing forecasting results. From the perspective of this article, the most useful publications on forecasting are [2-4, 6-13]. Nevertheless, they are not sufficient for carrying out an in-depth analysis and assessment of the time series of costs examined in this article. Additionally, intuition and experience in terms of similar research is required.

The main objective of this article is to provide a forecast for two upcoming years, i.e. twenty-four periods (months). The research period encompasses the time-frame from 2012 to 2017, whereas the research area corresponds to operation of a shipping company.

The object of the research is a shipping company, a leader on the local market, operating in the north-east region of Poland. The investigated shipping company was selected as the object of the research, as it is a leader on the local market in one of the districts of the north-east region of Poland. The subject of the research is the costs incurred by the shipping company.

The research methods applied in this article include analysis of the literature on problems related to costs, expenditure and their forecasting [1-15], analysis of source documents, computer simulation and comparisons. Additionally, Statistica software was used as a research technique. What is more, the following research tools were applied: quartile chart, autocorrelation, partial autocorrelation, multiple regression, bar chart, quartile to quartile chart, Shapiro-Wilk test and Grubbs test.

The article consists of the introduction, three main body sections, an afterword and conclusions.

2. Expenditure, Costs and Forecasting

Cost forecasting method is still a valid problem in terms of the role and importance of forecasting in managing such organizations as shipping companies. Both theoretical and practical studies regarding cost forecasting are important as well as searching for alternative solutions regarding this matter.
From the perspective of the subject of this article, the most important publications selected by the authors and describing the problem in question can be divided into those pertaining to: expenditure, costs and forecasting.

The analysis of the literature on the subject indicates that the discipline of management science uses several interpretations of the term “expenditure”. According to E. Nowak [1], expenditure represents any disbursement of funds from the cash register or a bank account of an economic entity with relation to the payment for particular goods or services and with relation to the settlement of various liabilities of that entity. Whereas H. Poetschke [5] defines expenditure as each reduction in the funds, regardless of what the payment is made for. The literature on the subject offers many other interpretations of the term and it is assumed that the notion refers, as its wording suggests, to disbursement of funds.

It is often emphasized that expenditure has a broader scope, as far as its meaning is concerned, than cost. According to G. K. Świderska [15], cost represents usage (utilization) of resources (funds) related to business activity carried out in given conditions, expressed in money or its equivalents, for the purpose of achieving current or future benefits for the organization. The available literature provides numerous definitions of costs. All these definitions share common qualities, including the following: representation by value, assignment to particular periods, juxtaposition of costs and revenue figures, intentional consumption of the production factors and aggregation of particular elements of the production factors. It should be added that costs are of great importance for any company, as costs affect the profit.

It is crucial for a company to secure sufficient funds for covering future operating expenses. One of the planning methods consists in forecasting based on the historical data of costs recorded on the recording accounts.

According to P. Dittmann, forecasting is a rational, scientific method of predicting future events [2]. Whereas the objective of forecasting is to minimize the risk related to making a mistake. It is vital for managing a shipping company, as faulty forecasting may lead to bad decisions and consequently to bankruptcy.

Most often, forecasts are classified based on their nature and structure with as well as the use of quantitative and qualitative methods. From the perspective of this article, quantitative methods will be used as well as ARIMA models considered the most accurate forecasting tool in the case of time series characterized by a trend.

3. Analysis and Assessment of Time Series of Costs of Transport

Table 1 presents a breakdown of costs by type as incurred by the shipping company in 2017.

<table>
<thead>
<tr>
<th>No.</th>
<th>Costs</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Depreciation</td>
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</tr>
<tr>
<td>2</td>
<td>Consumption of materials and energy</td>
<td>75000.00</td>
</tr>
<tr>
<td>3</td>
<td>Outsourced services</td>
<td>5000.00</td>
</tr>
<tr>
<td>4</td>
<td>Taxes and fees</td>
<td>20200.00</td>
</tr>
<tr>
<td>5</td>
<td>Pay</td>
<td>75253.00</td>
</tr>
<tr>
<td>6</td>
<td>Company Social Benefits Fund</td>
<td>6001.08</td>
</tr>
<tr>
<td>7</td>
<td>Other costs</td>
<td>5616.07</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>217070.15</strong></td>
</tr>
</tbody>
</table>

Table 1 indicates that the greatest share of total costs of the shipping company was incurred for: consumption of materials and energy as well as pay. These items represent 69.22% of the total costs of the analyzed company.

The following table presents monthly costs incurred by the shipping company in the period between 2012 and 2017.

<table>
<thead>
<tr>
<th></th>
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</tr>
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<tbody>
<tr>
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<td>13</td>
<td>11813.50</td>
<td>25</td>
<td>13150.19</td>
<td>37</td>
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<td>15201.34</td>
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<td>24820.63</td>
<td>51</td>
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<tr>
<td>4</td>
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<td>16</td>
<td>16446.60</td>
<td>28</td>
<td>17273.31</td>
<td>40</td>
<td>17360.30</td>
<td>52</td>
<td>18182.43</td>
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<tr>
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<td>14655.64</td>
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<td>15931.98</td>
<td>29</td>
<td>15469.84</td>
<td>41</td>
<td>16817.09</td>
<td>53</td>
<td>16284.04</td>
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<tr>
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<td>15589.21</td>
<td>18</td>
<td>14698.91</td>
<td>30</td>
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<td>15515.52</td>
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<td>18626.97</td>
<td>32</td>
<td>18165.11</td>
<td>44</td>
<td>19661.81</td>
<td>56</td>
<td>19121.17</td>
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<td>13020.40</td>
<td>21</td>
<td>13121.09</td>
<td>33</td>
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<td>13850.04</td>
<td>57</td>
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<td>13223.97</td>
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<td>13363.19</td>
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<td>13958.63</td>
<td>46</td>
<td>14105.59</td>
<td>58</td>
<td>14693.30</td>
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<tr>
<td>11</td>
<td>14488.36</td>
<td>23</td>
<td>15636.62</td>
<td>35</td>
<td>15293.27</td>
<td>47</td>
<td>16050.32</td>
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<td>16098.18</td>
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<tr>
<td>12</td>
<td>18926.53</td>
<td>24</td>
<td>19321.13</td>
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<td>20394.53</td>
<td>60</td>
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<tr>
<td>∑</td>
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<td>∑</td>
<td>195363.14</td>
<td>∑</td>
<td>200395.27</td>
<td>∑</td>
<td>206216.65</td>
<td>∑</td>
<td>210942.39</td>
</tr>
</tbody>
</table>
The data on the total costs incurred by the shipping company, presented month by month for the period 2012-2017, was analyzed and assessed using the available research tools. For this purpose, a chart was prepared presenting the time series of costs of transport and a trendline was drawn (Fig. 1).

Fig. 1 Transport costs from 72 periods, month by month, Grubbs test and box plot - median, quartiles, data scatter

The transport costs as presented in Fig. 1 indicate an upward trend of multiplicative nature. This is evident by the trendline observed in Fig. 1. Additionally, the time series of costs indicates no extreme values and only slight deviations - this results from the Grubbs test at $p = 0.27$ (Fig. 1).

As the next stage, correlations existing in the analyzed time series of costs of transport were examined. For this purpose, such tools as autocorrelation (Fig. 2) and partial autocorrelation (Fig. 3) were applied.

Fig. 2 Autocorrelation of costs of transport

Fig. 3 Partial autocorrelation of costs of transport

Based on Fig. 2 it was concluded that delays No. 2, 4, 6, 8, 10, 12 and 14 are interdependent and thus applying the forecasting method for the time series of costs of transport is valid.

Partial autocorrelation (Fig. 3) carried out for the time series of costs of transport at delay 12 demonstrates seasonality through a visible significance of partial correlation for delay No. 11 and 12.

Another stage was to verify the normality of distribution of the analyzed time series of costs of transport. Quartile-quartile chart was used for this purpose.

Fig. 4 Quartile-quartile chart for costs of transport

In Fig. 4, empirical quartiles are close to theoretical ones. The distribution differs slightly from the normal
distribution, which does not disqualify the model. By the same token, it is valid to forecast costs of transport following an in-depth analysis and assessment of the time series of costs of transport in terms of possible seasonality and trend. For this purpose, a model composed of 14 predictors was prepared and multiple regression was applied. The constructed model contained eleven zero-one variables corresponding to particular months, without a reference month, a time variable, a time variable to the 2nd degree and an Int. variable. Fig. 5 presents multiple regression results.

Fig. 5 presents significant predictors. These include 11 predictors for zero-one variables. This proves the existence of seasonality (Fig. 5). As the next stage, the constructed model residuals were analyzed through the use of the following tools: a chart of predicted and observed values (Fig. 6), a linear chart of model residuals (Fig. 7), a normality chart (Fig. 10) and a bar chart (Fig. 11).

Fig. 6 Linear chart for multiple regression model residuals

Fig. 7 Linear chart for multiple regression model residuals

Fig. 8 Autocorrelation of multiple regression model residuals

Fig. 9 Partial autocorrelation of multiple regression model residuals

Fig. 10 Normality chart of multiple regression model residuals

Fig. 11 Bar chart of multiple regression model residuals

Fig. 6 indicates that the points are characterized by a distribution similar to the normal one. Whereas the time series presented in Fig. 7 points to fairly long periods, where residuals are negative up to the halfway mark of the chart and positive beyond that mark. This proves autocorrelation of the residuals, which should be eliminated. This is
confirmed by Fig. 8, where white noise phenomenon is evident. Fig. 9 confirms seasonality at delay 12.

Figs. 10 and 11 represent good matching of the model. This was confirmed with the Shapiro-Wilk test. The Shapiro-Wilk statistical value amounts to 0.98, whereas the test value amounts to 0.3087. Therefore, one can assume that on a reasonable level of significance, there are no reasons for rejecting the hypothesis regarding the normality of distribution of residuals.

Based on the applied research tools, i.e. autocorrelation, partial autocorrelation and multiple regression, it was observed that the analyzed time series of costs is characterized by an upward trend of multiplicative nature (Fig. 1). What is more, seasonality is evident in the analyzed time series of costs of transport, which is confirmed by the partial autocorrelation of the time series of costs at delay 12 (Fig. 9) as well as the constructed zero-one model of multiple regression (Fig. 5).

Therefore, it is valid to carry out forecasting with the most accurate forecasting models, i.e. SARIMA models, while allowing for the seasonality and the trend. This was proven by Makridakis and his M3 Competition research in 2002, which demonstrated that the best forecasting results, with such assumptions, are obtained through the use of SARIMA models. From that point, SARIMA have been considered the reference models in cases where the above-mentioned limitations apply.

4. Forecasting

The analysis and the assessment of the examined time series of costs of transport, carried out in the second main body section of this article, allowed us to select the suitable forecasting method. SARIMA models were selected for this purpose. Fig. 12 below presents the forecast for the time series of costs for 24 periods using SARIMA (3,1,1)(1,0,0) model with delay 12 and time series adjusted with ln(x) logarithmic function.

The standard error for the forecast carried out based on SARIMA (3,1,1)(1,0,0) model with delay 12 and ln(x) adjustments equals MS 0.01174 (Fig. 12), the forecast was prepared for 24 periods (Fig. 13). As the next stage, the constructed model was verified in terms of analysis and assessment of forecast residuals. The following research tools were applied for this purpose: autocorrelation (Fig. 14), partial autocorrelation (Fig. 15), quartile-quartile chart (Fig. 16) and bar chart (Fig. 17).
Fig. 14 Autocorrelation of residuals of the forecast of time series of costs of transport

Fig. 15 Partial autocorrelation of residuals of the forecast of time series of costs of transport

Fig. 16 Quartile-quartile chart of residuals of the forecast of the time series of costs of transport

Fig. 17 Bar chart of residuals of the forecast of the time series of costs of transport

The application of autocorrelation (Fig. 14) to the time series of residuals of the SARIMA model of costs of transports demonstrates that autocorrelation coefficients are within the [-0.25; 0.25] range, which proves that there are no interrelations within the examined time series and by the same token that the analyzed SARIMA model was prepared correctly. Where partial autocorrelation was applied (Fig. 15), only one autocorrelation coefficient was slightly over the 0.25 threshold – coefficient 5, the value of which reached 0.268. The other partial autocorrelation coefficients, as in the case where autocorrelation tool was applied, are within the [-0.25; 0.25] range, which proves that the constructed model is correct.

Additionally, the quartile-quartile chart (Fig. 16) confirms normality of the time series of residuals of the constructed SARIMA model of costs of transport and the bar chart confirms good matching of the model in relation to the bar chart matching distribution curve (Fig. 17). The Shapiro-Wilk test as well as the Kolmogorov–Smirnov test confirm the normality of residuals of the constructed model. The Shapiro-Wilk statistical value amounts to 0.9251, whereas the test value amounts to 0.00000 (Fig. 17). Therefore, one can assume that on a reasonable level of significance, there are no reasons for rejecting the hypothesis regarding the normality of distribution of residuals.

Table 3
Forecast data for the time series of costs of transport as estimated with SARIMA (3,1,1)(1,0,0) model with delay 12 and the time series adjusted with ln(x) logarithmic function

<table>
<thead>
<tr>
<th>Periods</th>
<th>Forecast</th>
<th>Periods</th>
<th>Forecast</th>
</tr>
</thead>
<tbody>
<tr>
<td>73</td>
<td>13,714.38</td>
<td>85</td>
<td>14,305.74</td>
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<td>74</td>
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<td>86</td>
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<td>75</td>
<td>26,291.05</td>
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<td>26,350.09</td>
</tr>
<tr>
<td>76</td>
<td>18,758.23</td>
<td>88</td>
<td>19,192.27</td>
</tr>
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<td>77</td>
<td>18,231.84</td>
<td>89</td>
<td>18,685.66</td>
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<td>16,882.02</td>
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<td>∑ - 24 months</td>
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</table>
5. Conclusions

This article provides local companies with solutions in terms of streamlining their current cost planning processes. Improving these processes requires a change in the current approach by implementing effective tools for calculating future costs. The forecast described in the article was carried out based on the available time series of costs as provided by the shipping company and encompasses twenty-four future periods.

The answer to the main research question, provided based on the conducted analyses, validates the analysis and assessment of time series of costs with the objective to select a suitable forecasting method for planned costs.

An in-depth analysis and assessment of historical data on the time series of costs was required for the purpose of selection of the suitable forecasting model. ARIMA class models are considered the most accurate forecasting models for quantitative methods. Both trend and seasonality were observed in the course of the analysis and assessment of the time series of costs of transport. Therefore, SARIMA models were selected for the purpose of forecasting based on the time series of costs of transport, as such models are the most effective and accurate tools where such assumptions apply.

Table 3 presents the results of the forecast for the time series of costs of transport as carried out with SARIMA (3,1,1)(1,0,0) model with delay 12 and the time series adjusted with the logarithmic function. The forecasted costs of transport to be incurred throughout 24 future periods amount to PLN 450,743.73, with PLN 222,825.40 to be allocated to the first 12 periods, according to the applied SARIMA model, and PLN 227,918.32 to be allocated to the subsequent 12 periods.

The analysis and assessment of residuals of the SARIMA model used for the purpose of forecasting costs of transport, presented in the third main body section of this article, confirm its effectiveness. The said effectiveness was demonstrated through the application of autocorrelation to SARIMA model residuals, which revealed no interrelations among the obtained autocorrelation coefficients, which were with the [-0.25; 0.25] range.

The information obtained with the forecast of planned costs of the shipping company is of paramount importance, as it allows the said company to dynamically distribute its funds in order to be able to aptly cover its planned costs and generate profit.

References

Technological Features of Creating Nanostructured Decorative-Protective Coatings

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Abstract

Nanotechnologies in transport engineering are particularly related to the creation of different protective coatings as a result of particle flows acting upon structural materials in vacuum. Nature of effect depends on the type of particles (electrons, ions, atoms, molecules), on their energy and chemical activity as well as on product materials (metals, semiconductors, dielectrics). The work analyses the properties of decorative, protective multi-component coatings on the basis of Ti-Al-N, which are obtained by vacuum ion-plasma sputtering. There has been carried out a series of experiments aimed to obtain single-layer coatings according to a certain pattern of sputtering modes in argon and nitrogen environment. The obtained coatings have a wide variety of colors. Different properties of the created coatings including spectral characteristics, at different angles of incidence of light as well as chemical composition have been investigated.

KEY WORDS: ion-plasma deposition in vacuum, decorative and protective coatings, technological features of creating

1. Introduction

The protection of metals and composite materials from corrosion and erosion is a topical issue that affects all areas of the world's economy [1-4]. The method of ion-plasma sputtering is widely used in industry to create coatings for different purposes. Existing technologies allow to create coatings based both on fine metals and fine metal compounds (nitrides, carbides). Titanium-based coatings, for instance, have good corrosion- and wear-resistant properties. In atmospheric air conditions, water, many salt solutions, inorganic and organic acids, in terms of corrosion resistance, titanium is substantially superior to many other metals, while under the effect of sea water, for instance, it is inferior only to noble metals (gold, platinum, etc.). Besides, the chemical activity of the metal allows it to be used in many compounds, and makes it possible to obtain coatings in a wide range of colours. Thus, golden spectrum coatings (titanium nitride) allow to simulate noble metals. In turn, on the basis of aluminum, it is possible to create, for instance, reflective coatings. Being sputtered by ion-plasma method, aluminum has good technological and adhesive properties. Compounds based on Ti-Al-N system are more and more widely used for creating wear-resistant coatings. Such compounds are prospective also from the point of view of applying them as decorative or protective decorative coatings.

The work analyses the properties of Ti-Al-N based protective decorative single-layer coatings obtained by the method of vacuum ion-plasma sputtering [1, 5-7]. Vacuum ion-plasma sputtering is a final operation, so subsequent mechanical treatment of protective decorative coatings is excluded. The quality of coatings in this case is determined by the quality of workpiece surface (roughness, texture etc.), as well as the quality of preliminary cleaning (presence of contamination, oxide films, etc.).

2. Technological Equipment

Were conducted a series of experiments to create multi-component ion-plasma coatings by vacuum deposition on Ti-Al-N basis.

Fig. 1 The vacuum chamber deposition scheme of the ion-plasma installation NNV-6,6-II. C1 – first electric arc vaporizer (Ti) with a protective screen; C2 – second electric arc vaporizer (Ti); M – magnetron (Al).
Ion-plasma sputtering of the coatings was carried out with the help of a modernized vacuum installation NNV6.6-II [5-7]. The experimental investigation involved the use of two sources of plasma – arc evaporator (Ti) and magnetron (Al) (Fig. 1). Electromagnetic shift stabilization, cathode spot focusing in the end face of the cathode being evaporated as well as separation of sputtered material flow from the drop phase were provided in the process of sputtering by using the arc evaporator. The use of two independent sources of deposition as well as controlled feeding of reaction gas (N) into the vacuum chamber made it possible to adjust the composition of the multicomponent layer being deposited.

3. Spectral Characteristics of Protective Decorative Coatings

The colours of protective decorative coatings are usually presented in so called 'Cielab' units received through processing the data of coating reflection from the source of light which is the closest to the spectral distribution of daylight (of 'С' type) based on the following parameters: L* (coating lustre); +a* (red colour component); -a* (green colour component); +b* (yellow colour component); -b* (blue colour component).

The spectral analysis of decorative coatings was carried out according to RGB (Red, Green, Blue) additive colour measurement system by using graphics editor Paint.NET v3.5.6. RGB parameters characterize the saturation of red, green and blue shades of a colour, respectively, and vary within the range from 0 to 255.

The results of the spectral analysis of decorative coatings according to RGB system for 8 studied samples are shown in Table 1. The experimental data are presented in the order of Ti content increase.

Main colour characteristics include the following (see Table 1):
- $H_{ac}$ determines a shade for red, green and blue components of a selected colour within the range from 0 to 360;
- Saturation ($S_{ac}$) varies within the range from 0 to 100. The higher the value of this parameter, the 'purer' is the colour, therefore this parameter is sometimes called colour purity. As the value of Sat parameter is approaching zero, the colour is approaching to neutral grey.
- Colour brightness ($V_{ac}$) also varies within the range from 0 to 100.

Table 1: Spectral characteristics of protective decorative coatings

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>$H_{ac}$ (0-360)*</th>
<th>$S_{ac}$ (0-100)*</th>
<th>$V_{ac}$ (0-100)*</th>
<th>Red (0-255)*</th>
<th>Green (0-255)*</th>
<th>Blu (0-255)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>43</td>
<td>35</td>
<td>49</td>
<td>128</td>
<td>116</td>
<td>83</td>
</tr>
<tr>
<td>2</td>
<td>28</td>
<td>35</td>
<td>31</td>
<td>81</td>
<td>66</td>
<td>52</td>
</tr>
<tr>
<td>3</td>
<td>213</td>
<td>17</td>
<td>54</td>
<td>115</td>
<td>125</td>
<td>139</td>
</tr>
<tr>
<td>4</td>
<td>247</td>
<td>20</td>
<td>30</td>
<td>68</td>
<td>66</td>
<td>83</td>
</tr>
<tr>
<td>5</td>
<td>206</td>
<td>29</td>
<td>37</td>
<td>68</td>
<td>82</td>
<td>95</td>
</tr>
<tr>
<td>6</td>
<td>214</td>
<td>22</td>
<td>37</td>
<td>74</td>
<td>83</td>
<td>96</td>
</tr>
<tr>
<td>7</td>
<td>109</td>
<td>96</td>
<td>61</td>
<td>43</td>
<td>43</td>
<td>42</td>
</tr>
<tr>
<td>8</td>
<td>54</td>
<td>11</td>
<td>48</td>
<td>124</td>
<td>122</td>
<td>110</td>
</tr>
</tbody>
</table>

Note: * - range of possible parameter values.

An energy dispersive electron microprobe analysis was carried out by the methodology described in work [5] with the aim to determine the chemical composition of the created coatings. Due to a large relative error of the analysis in terms of nitrogen N content, the spectral analysis was carried out by two elements – Ti and Al. Table 2 contains the data on the chemical composition of the created protective decorative coatings.

Table 2: Percentage ratio of Ti and Al content in protective decorative coatings

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Ti, (%)</th>
<th>Al, (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>64.25</td>
<td>35.75</td>
</tr>
<tr>
<td>2</td>
<td>49.35</td>
<td>50.65</td>
</tr>
<tr>
<td>3</td>
<td>40.86</td>
<td>59.14</td>
</tr>
<tr>
<td>4</td>
<td>23.16</td>
<td>76.84</td>
</tr>
<tr>
<td>5</td>
<td>36.87</td>
<td>63.13</td>
</tr>
<tr>
<td>6</td>
<td>38.89</td>
<td>61.11</td>
</tr>
<tr>
<td>7</td>
<td>21.32</td>
<td>68.68</td>
</tr>
<tr>
<td>8</td>
<td>19.17</td>
<td>80.83</td>
</tr>
</tbody>
</table>

Table 3: Results of the evaluation of linear regression models for the values Red, Green, Blue

<table>
<thead>
<tr>
<th>Variable</th>
<th>Effect factor</th>
<th>$\beta$ coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x_1$</td>
<td>Ti %</td>
<td>2.2</td>
</tr>
<tr>
<td>$x_2$</td>
<td>$I_{el,ok}$</td>
<td>2.8</td>
</tr>
<tr>
<td>$x_3$</td>
<td>$I_f$</td>
<td>-1756.3</td>
</tr>
<tr>
<td>$x_4$</td>
<td>$I_{ni}$</td>
<td>42.3</td>
</tr>
<tr>
<td>$x_5$</td>
<td>$P_{tor}$</td>
<td>-8765.7</td>
</tr>
<tr>
<td>$x_6$</td>
<td>$P_{N}$</td>
<td>47400.1</td>
</tr>
<tr>
<td>$x_7$</td>
<td>$U_{in}$</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: $\beta$ - regression coefficients.
The work also includes an analysis of the effect of some technological parameters on the increase of the amount of red, green and blue hues in the formation of coating colour. A statistical analysis of the data was carried out with the help of STATISTIKA 7 software package. Correlation of main components in coating composition — Ti/Al; strength of arc evaporator current (I_{el.lok}), strength of magnetron current (I_m), focusing current strength (I_f), magnetron voltage (U_m), argon reactive gas pressure (P_{Ar}), nitrogen reactive gas pressure (P_{N}) were taken as technological parameters to be evaluated. Based on the results of statistical processing, three linear regression models were built respectively for Red, Green and Blue values. The results of model evaluation are presented in Table 3.

The adequacy of the models was evaluated by Fisher criterion ($F$), $p$-error and sum of squared deviations ($R_0$). The corresponding data for the three obtained models are presented in Table 4.

$$Y_{\text{red}} = 508.4 + 2.2x_1 + 2.8x_2 - 1756.3x_3 + 42.3x_4 + 87659.7x_5 + 47400.1x_6;$$  

$$Y_{\text{green}} = 411.9 + 1.6x_1 + 3.0x_2 - 11575.0x_3 + 40.0x_4 - 68943.6x_5 + 60915.2x_6;$$  

$$Y_{\text{blue}} = 682.6 + 1.1x_1 + 1.2x_2 - 527.9x_3 - 27756x_4 + 25657.45x_5 - 1.7x_6.$$  

<table>
<thead>
<tr>
<th>Model</th>
<th>$F$</th>
<th>$p$</th>
<th>$R_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>8.06</td>
<td>0.02</td>
<td>60.89</td>
</tr>
<tr>
<td>Green</td>
<td>20.28</td>
<td>0.05</td>
<td>14.74</td>
</tr>
<tr>
<td>Blue</td>
<td>3.36</td>
<td>0.08</td>
<td>64.66</td>
</tr>
</tbody>
</table>

The results of the correlation analysis of analytical models are shown in Table 5. The obtained data show that the Red value is directly proportional to Ti content in the created coating. The Green value is directly proportional to Ti content and arc evaporator current strength. The Blue value is directly proportional to the pressure of reactive gases $N$ and $Ar$ in the sputtering chamber, and inversely proportional to the strength of magnetron current and focusing current. The effect of Ti content in the coating on the Blue value is quite small.

<table>
<thead>
<tr>
<th>Effect factor</th>
<th>Red</th>
<th>Green</th>
<th>Blue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ti %</td>
<td>0.63</td>
<td>0.59</td>
<td>0.18</td>
</tr>
<tr>
<td>$I_{el.lok}$</td>
<td>0.12</td>
<td>0.42</td>
<td>-0.29</td>
</tr>
<tr>
<td>$I_f$</td>
<td>-0.10</td>
<td>-0.36</td>
<td>-0.63</td>
</tr>
<tr>
<td>$I_m$</td>
<td>-0.22</td>
<td>-0.21</td>
<td>-0.51</td>
</tr>
<tr>
<td>$P_{Ar}$</td>
<td>-0.25</td>
<td>0.01</td>
<td>0.48</td>
</tr>
<tr>
<td>$P_{N}$</td>
<td>-</td>
<td>0.10</td>
<td>0.69</td>
</tr>
<tr>
<td>$U_m$</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Figs. 2 and 3 show the results of the evaluation of Ti content effect on the value of Red and Green respectively, while Fig. 4 demonstrates the effect of nitrogen pressure in the sputtering chamber on the Blue value. The data are presented in comparison with linear prediction.

<table>
<thead>
<tr>
<th>Fig. 2</th>
<th>Fig. 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Fig. 2" /></td>
<td><img src="image2" alt="Fig. 3" /></td>
</tr>
</tbody>
</table>

**Fig. 2** The effect of Ti content on the change of Red value according to RGB  
**Fig. 3** The effect of Ti content on the change of Green value according to RGB
4. Conclusions

The work considers the peculiarities of the technology for depositing Ti-Al-N based protective decorative single-layer coatings. There has been carried out a series of experiments on the creation of single-layer multi-component ion-plasma coatings through vacuum sputtering in argon and nitrogen environment. Various coating properties – spectral characteristics, chemical composition – have been studied.

The effect of the chemical composition of protective decorative coatings on spectral characteristics determined with the help of RGB system has been revealed. The obtained coatings have a wide variety of colours.

The research results can be used in practice for the production and repair of vehicles.

Acknowledgement

This work has been supported by the European Regional Development Fund within the Activity 1.1.1.2 “Post-doctoral Research Aid” of the Specific Aid Objective 1.1.1 “To increase the research and innovative capacity of scientific institutions of Latvia and the ability to attract external financing, investing in human resources and infrastructure” of the Operational Programme “Growth and Employment” (No. 1.1.1.2/VIAA/1/16/176 “Multifunctional Nanostructured Coatings for Aircraft Structures (NANOCOAIRS)”).

References

**Drawbar Performance of a Hybrid Agricultural Vehicle**

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**Abstract**

Natural gas from agriculture can be used in agricultural vehicles. Developing a hybrid tractor requires that typical properties of a farming machine would be ensured. This study evaluates drawbar pull force achievable with the given vehicle. Variables as speed, rolling resistance and vehicle mass is estimated, differences described by given values is compared. The results allow to get a better understanding of a performance in fields of an electric drive tractor.

**KEY WORDS:** natural gas, agriculture, hybrid tractor, electric drive, rolling resistance, drawbar pull

1. Introduction

Since machines came into play of agriculture, nearly every operation requires fuel. By “Faostat” statistics, over 2% of all energy consumed in the world in 2009 was for agricultural needs [1], and, by “Eurostat”, this consumption was even greater at 2016 in Europe and reached 2,7% [2]. Even if biodiesel is widely used, dependence of fossil fuel is remaining [3].

It is already known that farmers can grow fuel [4]. It is time to step further and start collecting it. A methane gas is produced from animal waste. And it is also the main component of a natural gas. This leads to a solution – to use gas powered engines in agricultural vehicles. Add up the hybrid conception, and emissions will be reduced even greater.

The whole electric drive tractor concept is based on renewable resources. The purpose is to organize a closed loop of energy usage by collecting it from farming and using it for the same.

The vehicle in development intends to work mostly on softer ground, at normal or higher speeds, suitable for cultivating. Performance of this tractor will be evaluated by drawbar pull force achievable at different speeds and soil conditions [5]. Results will be compared to the same class diesel tractor to evaluate the competitive ability of the electric drive vehicle.

2. Method of a Drawbar Pull Force Estimation

To estimate performance of the electric drive tractor, drawbar pull (DP) force needs to be defined. The study of drawbar pull force is based on vehicle modifications [6] and changing working conditions (Table) described with “Matlab”.

The original tractor has an 8.8 L 266 kW diesel engine to power systems. A modified version (Fig. 1) has CNG engine, alternator and electric motors (EM).

![Fig. 1 Scheme of a series-hybrid vehicle: 1 – CNG engine; 2 – alternator; 3 – electric motor; 4 – axle; 5 – CNG cylinders; 6 – batteries](image-url)
This vehicle (Fig. 1) is based on series-hybrid model. CNG cylinders 5 fuels the 8.8 L CNG engine 1 which runs the alternator 2. Generated electricity is used to power up two 100 kW electric motors 3 to run the axles 4. Excess amount of generated electric power is stored in batteries 6 until there are boosting demand. The difference between comparable vehicles is what the original ICE tractor uses same power to drive, pull and operate hydraulics. The modified tractor has separate energy source for hydraulics. As a result, it’s driving and pulling performance is not dependent regardless hydraulics is off or full powered.

Working conditions of a typical tractor is working speed and roll resistance coefficient of soil. These values are variables in drawbar pull estimation process [7]. In addition, acceleration and vehicle mass are included. Variables are shown in Table.

<table>
<thead>
<tr>
<th>Variables in “Matlab” model</th>
<th>$v$</th>
<th>0 – 15 km/h</th>
<th>$a$</th>
<th>0.5 – 1.5 m/s$^2$</th>
<th>$f$</th>
<th>0.06 – 0.2</th>
<th>$m$</th>
<th>12 – 18 t</th>
</tr>
</thead>
</table>

Working speed is usually 4 km/h – 15 km/h. Works what require deeper soil tillage are performed at lower speeds. Land preparation works like cultivating are performed at higher speeds. To reach higher speeds smoothly, a proper acceleration must be ensured. Standard working acceleration is 0.5 m/s$^2$ and higher.

Another variable is rolling resistance coefficient. It is most dependent on soil type and condition and tire influence only minor changes. $f = 0.06$ describes wet hard soil, $f = 0.1$ – soft soil and $f = 0.2$ – sandy soil.

The last variable is vehicle mass, and it is crucial parameter on green land working technologies. A lighter vehicle reduces soil compression and forms better growing conditions. The aim is 12 t; however, the fully prepared modified vehicle could weigh up to 14 t, and with ballast weights – up to 16 t. The original tractor weighs up to 18 t.

### 3. Results

The drawbar pull force in Fig. 2 was defined at working acceleration 0.5 m/s$^2$ and maximum vehicle mass, which is 18 tones. It is crucial to acknowledge that this case, no power usage for hydraulics is estimated. These conditions allow to state that the force shown in Fig. 2 is the limit force at named conditions.

Comparison of a drawbar pull at the maximum vehicle mass (Fig. 2) shows that ICE has an advance driving on a hard soil ($f = 0.06$). At 5 km/h speed DP is 169 kN, at 10 km/h – 74 kN and at 15 km/h – 43 kN. Using electric motors, the drawbar pull force reaches 122 kN at 5 km/h, 51 kN at 10 km/h and 27 kN at 15 km/h. The difference between developed forces is from 28% to 37% compared to 25% difference between engines.

Both ICE and EM have difficulties operating at maximum working speed (15 km/h) on sandy soil ($f = 0.2$). Performance of ICE vehicle with 18 kN is like other vehicles in a same tractor power class [8]. EM vehicle is not suitable for operating at high working speed on such a challenging soil.

It is assumed that the tractor with electric drive will weigh about 14 t. Drawbar pull force under predictable working conditions of the EM vehicle is shown in Fig. 3.
Fig. 3 Drawbar pull of EM vehicle

Fig. 3 shows no considerable difference between the heaviest and the lightest working conditions and the gap between the latter is no more than 8 kN. The average DP is 123 kN at 5 km/h speed, 51 kN at 10 km/h and 28 kN at 15 km/h, when working acceleration is 0.5 m/s².

Initial conditions of ICE and EM comparison are imitating normal working conditions: vehicle mass – 14 t to 16 t, acceleration – 0.5 m/s², soil rolling resistance coefficient – 0.1. Hydraulic systems are working on full load. Results are shown in Fig. 4.

Fig. 4 Comparison of ICE and EM vehicles

When hydraulics is on, the electric drive outgrows ICE performance. At lowest speed drawbar pull force (Fig. 4) of the EM is about 120 kN, at highest – about 25 kN. DP of the ICE is 103 kN and 19 kN respectively. Difference between vehicles is equal (14%) by mass at 5 km/h speed. As the speed rises, the difference rises to 17% – 18% at 10 km/h and 22% – 25% at 15 km/h for 14 t and 16 t vehicles, respectively.

Drawbar pull force of electric drive vehicle depending on acceleration is shown in Fig. 5. Initial conditions of this comparison are these: vehicle mass – 14 t, $f = 0.06$. This describes light working conditions.

At the lowest speed DP is 151 kN to 135 kN at 5 m/s² to 15 m/s². At 10 km/h the force drops to 55 kN to 40 kN, which is 33%. At the highest speed drawbar pull is 32 kN to 16 kN and it is 89% down comparing to the lowest speed. Difference between forces by acceleration is from 10% at 5 km/h speed to 49% at 15 km/h speed.
If hydraulics is off, the drawbar pull force reaches 122 kN at 5 km/h with electric motors when vehicle weighs 18 t, and it is 28% less than ICE.

The average DP force of a hybrid tractor is 123 kN at 5 km/h speed, 51 kN at 10 km/h and 28 kN at 15 km/h.

If hydraulics is on, the drawbar pull force of a hybrid vehicle is 14% greater at 5 km/h than the force of ICE vehicle.

The force of EM vehicle influenced by acceleration drops from 10% at 5 km/h speed to 49% at 15 km/h speed.

The performance of a hybrid tractor is not influenced by hydraulics, so it has an advance while perform multiple operations at once.

References
Inspection of the Honeycomb Sandwich Panel Using Ultrasonic Phased Arrays

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Abstract

The Objective of this research is an analysis of ultrasonic wave interaction of defects in honeycomb sandwich material. The initial stage of research is modelling and analysis of material using CIVA computer software. Using CIVA software the sample was designed, and computer-generated ultrasonic inspections performed using a phased array transducer with a different frequency range. Possible range frequencies of ultrasonic transducer were selected based on results of CIVA simulation. The design and optimization of inspection methods and the prediction of the characteristics of the ultrasonic wave propagation in the material for realistic configurations were performed. The simulation was used in order to notice the required parameters and configurations to run the practical experiment. An experimental analysis of honeycomb carbon fiber sandwich sample using the ultrasonic technique was performed. By using Omni-scan measurement system and linear phased array transducer the impact damages on honeycomb carbon fiber sandwich material were detected. The sizing of the defects on the carbon fiber sandwich material was performed. It is shown that the using of the phased array transducer, impact damages in sandwich type honeycomb material can be detected and their size can be determined.

KEYWORDS: Ultrasonic technique, Carbon fiber sandwich, Linear array transducer, CIVA software

1. Introduction

In the contemporary world, composite materials are playing the key role in the aerospace sector and other engineering applications due to the superior qualities such as stiffness, High strength, lightweight. The fabrication of material is attaching two skins and the thick core. The honeycomb materials are mainly used where they need flat or slightly curve locations. The high specific strength property makes the use in the aerospace industry. In the aerospace sector, the different type of composite structures used. The performance of commercial and military aircraft constantly developing and improving high-performance structural materials [1, 3, 6, 7].

The practical experiments are conducted in order to find the delamination between the two layers of the specimen. The simulation plays an increasing role in NDE, allowing helping the design of inspection methods, their qualifications or the analysis and understanding of inspection results while reducing the number of physical mock-ups and trials. A lot of validation efforts have been put around the CIVA software to give evidence of model’s validity in order to be fully considered as a reliable element to support technical decisions and justifications [4, 5].

Extensive parametric analyses are required in order to identify essential parameters that can affect the NDE performance. Such studies need a large amount of data which is often difficult and costly to obtain with a set of purely experimental results. Probability of Detection methods, that links the probability to detect a detrimental flaw to its size is generally used for NDE reliability evaluation in the aerospace sector [2].

This study focused on the impact damages on honeycomb carbon fiber sandwich material. The impact damages on composite honeycomb structure tendency to develop the delamination. The ultrasonic inspection of carbon fiber sandwich material in the aeronautic industry motivates the development of dedicated simulation tools able to predict the propagation of ultrasonic wave on complex materials. The delamination between the composite layer abnormalities have been created artificially and the ultrasonic scan results obtained in CIVA simulation software.

The honeycomb carbon fiber sandwich material is selected to analyze the small impact damages and size of the damages precisely. There are few other NDT techniques are available to test the material, but the ultrasonic method is accurate in the small impact damages and it is cost effective and reliable. Let us consider the radiography test, this test can provide results but difficult to find small defects and defect size.

2. Design

The multilayer composite material has been designed. The thickness of single-ply composite layer is 1.5mm and it is made of carbon fiber epoxy, the fiber density is 60%, fiber diameter is 0.007mm and it is fully homogenized. The second layer is the core material, the thickness of the core material is 27mm and it made of aramid epoxy. It is fully homogenized. The geometry of the defect is rectangular, length is 10 mm and height is 10 mm.
The Fig. 1 shows that the geometry of the specimen, the position of flaws, sensitivity zone, and transducer position. The first layer is single ply composite material and the symmetry of layer is transversely isotropic, that is an axis of material symmetry in addition to three planes of symmetry. A ply is fully characterized by four layers which are longitudinal stiffness, transverse stiffness, shear stiffness, poison’s ratio. The Table 1 shows that, the stiffness matrix of single ply laminate.

**Table 1**

<table>
<thead>
<tr>
<th>Stiffness matrix (GPa) – elastic properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>142.171</td>
</tr>
<tr>
<td>5.235</td>
</tr>
<tr>
<td>5.235</td>
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<tr>
<td>0</td>
</tr>
<tr>
<td>0</td>
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<td>0</td>
</tr>
</tbody>
</table>

The core material is an aramid-epoxy orthotropic material. An orthotropic material is completely defined by nine independent elastic constants. The most common elastic constants are elastic modules in three orthogonal directions, Poisson’s ratio, shear modules $G_{12}$, $G_{23}$, $G_{31}$ in the 1-2, 2-3, 3-1 planes respectively [4]. The Table 2 shows that, the stiffness matrix of orthotropic(core) material.

**Table 2**

<table>
<thead>
<tr>
<th>Stiffness matrix (GPa) – elastic properties of orthotropic material</th>
</tr>
</thead>
<tbody>
<tr>
<td>77</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>0</td>
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<tr>
<td>0</td>
</tr>
</tbody>
</table>

3. **Probe**

The probe is an electronic device, it converts the electrical signal into mechanical signal. The Phased array has the unique quality to use all the elements simultaneously while applying different delays to each element. The design of transducer included by crystal shape, whole aperture, grid and gap of elements and dimension of elements. Wedge is used for the better propagation of ultrasonic wave into the specimen, the Plexiglas material is used as a wedge. The wedge dimensions are front length ($L_1$) = 64, back length ($L_2$) = 64, width ($L_3$) = 33, height ($L_4$) = 22. The 3.5 and 5 MHz frequency have been used with the choice of the gaussian signal, these signals are generating more cryptic signals than any other signals. The bandwidth of the signal is 65% and phase is 90 degrees.

The Table 3 shows that, the transducer crystal shape parameters for both 3.5 and 5 MHz frequency. The probability of defect detection is completely based on the transducer parameters.
The transducer crystal shape parameters

<table>
<thead>
<tr>
<th>Transducer Crystal shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incident dimension</td>
</tr>
<tr>
<td>Orthogonal dimension</td>
</tr>
<tr>
<td>Number of elements</td>
</tr>
<tr>
<td>Gap between elements</td>
</tr>
<tr>
<td>Elements width</td>
</tr>
</tbody>
</table>

The Ultrasonic phased array is consisting of a series of individual elements, each element radiates the signal with time delay. Elements are acoustically insulated from each other and pulsed with precalculated time delay each other. Appropriate delays introduced electrically during emission to generate a specific beam and it is generated by Huygens principle. Appropriate delays are introduced electronically during the reception. Signals satisfying the delay law shall be in phase and generate a significant signal after summation.

The artificial rectangular delamination defects are created with the dimensions of 10 mm length and 10 mm in height. The position of the defect is length along x-axes from the surface. The gap between each defect is 25mm and it is along the normal direction.

4. Simulation Results

The direct control computation configuration is selected because the direct type computes contributions from flaws, with no skips on the specimen and direct skips from selected surfaces of the specimen. The longitudinal wave modes been involved. The interactions of the wave with the specimen is front and interface, the bottom and sides are neglected. The sensitivity zone is enabled concerns defects and the depth direction of sensitivity zone is along local normal. The 3D computation mode is enabled to get precise results. The field reflector interaction is plane wave approximation for incident beam. The accuracy field, the defect is one each and account for attenuation is activated. Attenuation is a natural consequence of signal transmission over long distances.

The Fig. 2 shows that, the 3.5 Mhz and 5 Mhz E-scan view of ultrasonic phased array simulation. E-scan is a single focal law multiplexed across a group of elements for a constant angle beam stepped along the probe length. The three rectangular delamination defects are placed from single plate laminate surface to core interface. The depth of the defects 0.5 mm, 1 mm, 1.5 mm respectively.

![Fig. 2 a - Scan view of identified defects with different depth using 3.5 MHz frequency; b - Scan view of identified defects with depth using 5 MHz frequency](image)

The results are obtained from the CIVA simulation, (a) shows that the results with 5 MHz frequency clear compare to 3.5 MHz the quality of scanning with frequency difference is presented.

The Fig. 3 shows that, the A-scan view of 3.5 MHz and 5 MHz CIVA simulation results. The A-scan presents that the amount of signal received with respect to time. The function of time on the horizontal axis and the amount of received amplitude on the vertical axis. The difference of amplitude with 3.5 MHz and 5 MHz presented and compared.
5. Experimental Results

The practical experiment has been conducted by using the CIVA simulation parameters. The experimental setup is 3.5 and 5 MHz transducer, Omni scan setup and specimen. The transducer is connected to the Omni scan setup and it is placed on the specimen. The contact gel applied to get better wave propagation in order to take quality results. The transducer moved gently on the surface of the specimen.

The Figs. 4, a and b shows that, The B-scan view of 3.5 and 5 MHz Omni scan results. The abnormalities on the specimen have been shown with different frequency. The difference of defect detecting quality with various frequency presented. B-scan refers to the image produced when the data collected from an ultrasonic inspection is plotted on a cross-sectional view of the component. Scanned Image of the results of an ultrasonic examination showing a cross-section of the test object perpendicular to the scanning surface and parallel to a reference direction.

6. Conclusion

The artificial delamination defects have been created between the skin and honeycomb structure using CIVA software. The required parameters have been selected and applied to simulation settings. During the simulation, various parameters noticed in order to see the variation in ultrasonic wave capability. The ultrasonic wave interaction with rectangular delamination defect between two layers has been obtained and interpreted. Simulation tools gathered in the CIVA platform provide an efficient solution to support NDE reliability study.

The CIVA is used to design an experiment in the computer for a practical experiment campaign. The CIVA simulation software helped to notice the optimistic inspection parameters to find the defect on the specimen. The followed parameters are applied to practical experiments in order to estimate the defects on carbon fiber material. Using the computer-generated parameters, the practical experiments have been conducted with 3.5 and 5 MHz frequency. The obtained results have been presented and discussed.
Acknowledgment

Authors thankful to the Prof. K. Barsauskas Ultrasound Research Institute for providing equipment for practical experiments and computer simulation software.

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Renewable Sources of Electric Energy in Mobile Assets

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Abstract

Mobility of renewable sources of electric energy is a precondition for operability of their deployment in crisis regimes. Renewable sources of electric energy are perspective sources; they are cheap, available and perspective. When combined they can supply in a decrease of intensity of energy supplies from other sources. The paper deals with use of energy from wind, water sources and solar energy. Possibility and intensity of supplies can be monitored in a form of PC application software and based on them then switched for activity. The energy can be stored in accumulators and modified through regulators and convertors. The whole device is placed into containers, it means, that it is mobile and applicable in any conditions.

The device was constructed based on the project being solved in a prototype and nowadays it has been measured and tested. The paper contains preliminary results of the operation. The paper results from cooperation of the university with practice.

KEY WORDS: Mobility of sources, crisis regime, renewable sources of electric energy, container, photovoltaic collector, wind turbine.

1. Introduction

A decade ago, the idea of driving an electric car seemed inconceivable, but these cars with plugs are definitely here to stay. Finality of fossil fuels and environmental concerns prompt consumers to think more about the future. Technological improvements, stricter emissions standards, and changes in consumer tastes are driving electric cars further. Many of the most promising cars are still trucking down the long road toward production, but there are plenty on the market [1]. They are so different and it makes them difficult for comparison. That is why the carmakers prepare a car right by consumer requirements. The best electric cars for 2018 year include Tesla Model 3, Chevrolet Bolt EV, Nissan Leaf, BMW i3, Kia Soul EV. Hybrid cars are intermediate between electric cars (Table 1) and gasoline engine cars.

Table 1

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Tesla, California, US</th>
<th>Nissan, Japan</th>
<th>Core, China</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>Tesla 3 S</td>
<td>Nissan Leaf</td>
<td>Core CIS</td>
</tr>
<tr>
<td>Layout</td>
<td>Rear wheel drive, all wheel drive</td>
<td>Front mounted electric engine</td>
<td>Rear drive</td>
</tr>
<tr>
<td>Electric motor</td>
<td>258 hp (192kW)</td>
<td>110 hp (80 kW)</td>
<td>7.5 kW</td>
</tr>
<tr>
<td>Battery</td>
<td>50 or 75 kWh (180 or 270 MJ)</td>
<td>40 kWh</td>
<td>14kWh</td>
</tr>
<tr>
<td>Electric range</td>
<td>350 km (standard)</td>
<td>270 km</td>
<td>130 km</td>
</tr>
<tr>
<td></td>
<td>500-800 (long range)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acceleration</td>
<td>5.6 s (0-97km)</td>
<td>9.9 s (0-97 km)</td>
<td></td>
</tr>
<tr>
<td>Top speed</td>
<td>210 km/h standard</td>
<td>150 km/h</td>
<td>60 km/h</td>
</tr>
<tr>
<td>Price</td>
<td>35,000 USD</td>
<td>25.190 GBP</td>
<td>7,300 USD</td>
</tr>
</tbody>
</table>

Some governments support a purchase of electric cars, for example the UK government is still offering up to £4500 off zero-emissions cars via its Plug in Car Grant, making the higher purchase price and showroom costs much
more bearable. Promising fact is, that ongoing fuel bills are likely to be dramatically lower if you take the plunge and go for an electric vehicle, plus you'll never have to visit a petrol forecourt again [1].

The primary difference between a hybrid car and an electric car is that the hybrid car derives some of its power from a conventional gasoline engine. On the other hand, a true electric car gets all of its power from electrical sources, and thereby is a completely non-polluting zero-emission vehicle (ZEV).

2. Electric Cars

In most cases, electric cars are created by converting a gasoline-powered car. An electric car is a car powered by an electric motor rather than a gasoline engine. When you drive an electric car, often the only thing that clues you in to its true nature is the fact that it is nearly silent and it produces no emissions. Under the hood (Fig. 1), there are a lot of differences between gasoline and electric cars: Electric cars create less pollution than gasoline powered cars, so they are an environmentally friendly alternative to gasoline-powered vehicles, especially in cities [2]. The gasoline engine is replaced by an electric motor. The electric motor gets its power from a controller. The controller gets its power from an array of rechargeable batteries. A gasoline engine, with its fuel lines, exhaust pipes, coolant hoses and intake manifold, tends to look like a plumbing project. An electric car is definitely a wiring project.

Battery electric vehicles (BEVs) come in all shapes and sizes, and which electric vehicle is best for you will depend on a variety of factors. A proper access to charging points at work and/or home is needed, to top up the battery enough to meet a typical daily range. Tesla electric car uses its own recharging station or plugging it into an electrical outlet (Fig. 2). A small battery, like in the VW e-Up, will be limited to 160 km or so. But the bigger batteries, like in the Tesla 100D and suchlike, will boast a much longer range, typically upwards of 480 km. However, these in-the-lab figures may not translate to real-world range [2].

3. Regular Hybrid Cars Versus Plug in Hybrids

There are a couple of types of hybrid cars available for purchase. A regular hybrid has a gas engine and an electric motor and usually can get up to 5.6 l/100 km of fuel efficiency. The plug in hybrid also takes advantage of having a gas engine and an electric battery. However, the battery can be charged at a normal household power outlet. The advantage of a plug in hybrid is the increased fuel economy.
4. A Solar Car

A solar car is a solar vehicle used for land transport. Solar cars are usually run on only power from the sun, although some models will supplement that power using a battery, or use solar panels to recharge batteries or run auxiliary systems for a car that mainly uses battery power.

![Fig. 3 The Sunswift solar car](image)

The Sunswift (Fig. 3) solar car, which holds an FIA world record and in 2016 was Australia's first road legal solar car. Solar cars combine technology typically used in the aerospace, bicycle, alternative energy and automotive industries. The design of a solar vehicle is severely limited by the amount of energy input into the car. Solar cars depend on a solar array that uses photovoltaic cells (PV cells) to convert sunlight into electricity. Unlike solar thermal energy which converts solar energy to heat, PV cells directly convert sunlight into electricity. When sunlight (photons) strike PV cells, they excite electrons and allow them to flow, creating an electric current. PV cells are made of semiconductor materials such as silicon and alloys of indium, gallium and nitrogen. Crystalline silicon is the most common material used and has an efficiency rate of 15-20%.

Some solar cars use gallium arsenide solar cells, with efficiencies around thirty percent. Other solar cars use silicon solar cells, with efficiencies around 20 percents.

5. Hydrogen Versus Hybrid Cars

Hybrid cars are widely available now, as opposed to the still developing hydrogen fuel cell car. To many, the idea of hydrogen vehicles not only sounds cleaner but even seems like it would be less expensive since water is a free resource. Ultimately, the hydrogen fuel cell may be the power source of the future [3].

6. Hydrogen Fuel Cell Cars

The concept of the hydrogen fuel cell is great. Hydrogen and oxygen do not burn but are create a chemical reaction that converts the two into an electric charge. Water is the only byproduct. Hydrogen is one of the most common and abundant elements on the planet and so it would not be exhausted as quickly as fossil fuel. Hydrogen is also extremely efficient. Up to 90 percent of the energy produced in the fuel cell would be able to be converted to electric. It was reported in July of 2009 that students built a hydrogen car that got 1,336 mpg, (211.4 l/100 km) although that is not the norm. Toyota has been working on a hydrogen run Prius that is expected to see 125 mpg (2.3 l/100 km) and produce zero emissions. Hydrogen cars have not been developed to the degree that electric hybrids have. Part of this is due to the fact that right now, it does take natural gas to produce hydrogen, which is seen by many to defeat the purpose of using hydrogen [4].

7. Cars with Wind Energy

To limit or, even better, reduce the emission of CO₂ and the corresponding global warming effects, measures should be taken in the two most polluting economic sectors: the energy and transport sectors. Wind power has become a popular form of renewable energy, alongside solar power. In 2008 a group of German students built a wind powered car known as the Ventomobile (Fig. 4). It carried a two meter wind turbine with two blades on the top for extra power. It had three wheels and a design that was more similar to a bicycle than a car. While it could not reach great speeds it worked surprisingly well. Many consider this build to be the first wind powered car as it runs solely on the energy generated by the wind [5].
Argued to be the first official wind powered car, it is actually a hybrid and uses electric power as well as a turbine that has been placed outside of the car. The turbine will produce wind energy to help supply the car with energy, especially if the battery starts to run low. It was found to be more effective when the turbine was placed on the outside as opposed to the inside of the vehicle.

A wind-powered car converts wind power into electric energy, thereby helping the car to move forward. The concept of wind energy has been derived from the fact that, whenever we put our hands out from the windows of a fast-moving car, the tremendous force of the wind can be felt. This force can be used as a clean source for running cars. However, there are several wind power pros and cons. Vehicles powered by wind energy use wind turbines and valves which are placed in such a position that the turbines can start moving. The valves absorb wind which is needed to power the car. There is an alternator connected to the valves which in turn changes kinetic energy into electric energy. The electric energy so generated is stored in a DC battery, and it's connected to a controller. The controller is responsible for converting DC to AC voltage. The controller is assisted by power diodes in this conversion of DC to AC.

8. Conclusions

The most exciting vehicle on the market isn’t a milion-dollar supercar, a broad-shouldered truck, or a seven-passenger SUV. No, the car the world cannot wait to drive are all-electric cars that never need to visit the gas station. Fuel concerns make a wind-powered car an excellent vehicle to be used in these days of global warming. However, these cars are still in the developmental phase, and there has been no mass production of such cars, as it is with a wind-powered car, which converts wind power into electric energy. Vehicles with renewable source of energy can be plugged to grid, which allow to supply a household with the energy stored in the battery (e.g. a new Nissan LEAF’s battery). The battery is charged up at night and then uses the electricity as your daytime power source to avoid consumption in peak periods.

References

Selected Aspects of Medical Transport in Poland on the Example of Ambulances

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Abstract

The paper discusses medical transport in Poland. An ambulance was defined and the way in which emergency medical services in Poland were operated. In the further part of the paper an analysis of the research related to the registration of travel times of specialized vehicles such as ambulances was shown. The time of traveling of cars of the Medical Rescue Team (ZRM) in a small healthcare facility has been registered, which has two ambulances. In the period of registration of ambulance transport carried out by the authors, a total of over 1,000 measurements were made.

KEY WORDS: ambulance, Emergency Medical Transport Services, specialist car

1. Introduction

Nowadays transport is indispensable in all areas of human life. A lot of research has been carried out in the field of transport for increasing safety, reducing costs and its impact on the environment or many other situations that are very important in transport and our everyday life. When it comes to transport, e.g. a specialized car, it refers to a very wide area of research. According to the Road Traffic Act, a specialized vehicle is a motor vehicle or a trailer intended to perform a specialized function, which makes it necessary to adjust the car body or to have it specially equipped, so that people and things connected with this function can be transported in this vehicle. During the research, the authors focused on specialized cars, such as ambulances [3, 4, 6, 7, 10, 20-22].

It is worth noting that as far as this area of specialist transport is concerned, no research and analysis have been carried out to improve the situation in this area of transport. Changes that are introduced in this type of transport usually involve only the change of regulations [1, 2, 5, 8, 9, 11-19], which often results in even greater difficulties in managing this type of transport. This paper answers the question: what is an ambulance and how and on what basis does medical emergency transport in Poland function? In the further part of the article, an analysis of the research related to the registration of travel times of specialized vehicles, such as ambulances, is shown.

Due to the fact that we deal with sensitive personal data, the article maintains anonymity as to the transport unit, which allowed for measurements concerning the registration of ambulance response times [22].

2. Ambulance

According to the definition, an ambulance (fr. ambulance) is a means of transport to the place of a sudden illness or accident, intended for providing assistance, transporting patients or the injured from the place of the incident to the hospital, and often also for medical and inter-hospital transports. Ambulances are operated by specially trained rescue teams and are part of an emergency assistance system. During emergency response, an ambulance is a privileged vehicle in traffic and may not comply with traffic regulations.

The originator of the first ambulance was Dominique-Jean Larrey, a military doctor who in 1792 together with a team of surgeons and nurses gave first aid to wounded soldiers and prepared their evacuation from the battlefield. Those ambulances were very light, because they had only one axis. They were one horse-drawn ambulances horse. Initially, ambulances were used by the military to transport the wounded and sick. That changed after the outbreak of smallpox in 1882 and cholera in 1884. After that, horse-drawn ambulances began to transport civilians. In 1798, camels were used in Egypt. During Napoleon's campaign in Russia in 1812, the wounded were transported by sleigh. In Warsaw, the first horse-drawn civilian ambulances appeared in 1897 (as the first in the Russian Empire). The first ambulances with medical equipment, in which the injured person was provided with help during transport to the hospital, appeared in the 60s of the 20th century.

In the Polish emergency medical system there were several types of ambulances - often marked with a letter inside the circle painted on the car's body. After 2010, in accordance with the Act on State Emergency Medical Services, the old division was gradually replaced by a division into ambulances:

- specialized ambulances ("S" ambulance, so called “eski”) with minimum three crew members, in which at least one person is a doctor (Fig. 1). In the event that none of the other team members have entitlement to drive
privileged vehicles, the fourth person in the team may be a driver. Fig. 1 shows the photo of a specialist vehicle - specialist ambulance.

Fig. 1 Specialized ambulance

- basic ambulances ("P" ambulances) with a crew consisting of at least two persons being paramedics or nurses of the system without a doctor (Fig. 2). In the event that none of the other team members have entitlement to drive privileged vehicles, the third person in the team may be a driver

Fig. 2 Basic ambulance

- transport ambulances ("T" ambulances) are used to transport patients who do not require intensive supervision or to transport e.g. blood (Fig. 3). The crew usually includes a driver and a paramedic. Currently, they are called patient transport ambulances. Before the reform in 2010, they were called transport ambulances (P ambulance). There are also medical transport ambulances (Figure 3), and then a doctor also enters the crew. They are used to transport patients requiring medical supervision (in severe conditions). These ambulances carry different markings depending on the region (combination of the letter T, e.g. "RT", "ST" or "TL").

Fig. 3 Transport ambulance

- veterinary ambulances sometimes used for providing assistance and transportation of animals to a veterinary clinic. Most often they are yellow in colour with red stripes and blue at the back.

The old division distinguished:
- resuscitation ambulances ("R" ambulances, so called ‘erki’) were used in situations of immediate threat to life. The doctor had to be in the resuscitation ambulance. Most often, the crew consisted of a doctor (it should have been a specialist physician of certain specialties or a doctor specializing in emergency medicine), two medical paramedics and a driver who was also often a paramedic. After 2010, all "R" ambulances were replaced by "S" specialized ambulances (Fig. 1),
- accident ambulances ("W" ambulances), were sent to injuries, accidents and illnesses in which it was not necessary for the ambulance R to respond, or when the ambulance R was needed but the dispatcher did not have any R
team at the moment. In terms of equipment, the accident ambulance did not much differ from the R-ambulance, sometimes it had the same equipment. The ambulance crew consisted of three people: a nurse or a paramedic, a physician and a driver. After 2010, all "W" ambulances were replaced by basic "P" ambulances,

- transport ambulances ("P" ambulances), were used to transport patients who do not require intensive supervision or to transport e.g. blood, usually with a driver and a paramedic. Currently, ambulances are called transport ambulances and are marked with a letter "T", because under the Act on Emergency Medical Services after 2010, the letter "P" is reserved for basic ambulances "P" (Fig. 2).
- neonatal ambulances ("N" ambulances, called "enki"), were used in similar situations as "R" ambulances, but for transporting newborns and infants (up to 1 year old). Often marked as NR (Neonatal "eRka").
- cardiac ambulances ("K" ambulances) that were very close to accident or resuscitation ambulances (denoted then as Rk), but had a physician specializing in cardiology or internal diseases, equipped with better quality equipment for diagnosing cardiovascular diseases (e.g. high-class ECG monitor with the possibility of transmitting the records to a specialist center, specialized defibrillator, infusion pumps, a set of additional medication).

In addition, independently of the reforms, so-called "POZ ambulances" (POZ – an abbreviation from Polish "Podstawowa Opieka Zdrowotna" meaning basic health care) or "NPL" (NPL – an abbreviation from Polish "Nocna Pomoc Lekarska" meaning night medical assistance). They secure the aid of a family doctor 24 hours a day, making house visits in the event of illness in people who cannot get to the family medicine clinic, but not in life-threatening situations. The operators of these teams may be emergency medical stations, family doctors' practices or private companies. They are on duty during the night hours on weekdays and 24 hours on non-working days.

A characteristic type of ambulance is a military ambulance - most often adapted to carry more than one person in a lying position by placing a stretcher near the walls of the vehicle.

The definition of a specialized car says that such a car should be expertly equipped. The basic ambulance equipment, regardless of its type, almost always includes a stretcher - sometimes alongside the so-called main stretcher, in the ambulance is an additional scoop stretcher, a collapsible transport chair, a backboard, a Kendrick vest and other transport equipment. The ambulance is equipped with a set of life-saving medication, medical equipment, and usually there is a possibility of feeding oxygen from the oxygen cylinder. Specialized ambulances are also equipped with a respirator and defibrillator, whereas ambulances designed for transporting newborns – with a transport incubator. Most commonly an ambulance is made by adjusting the standard car body, such as a van, or building a characteristic sanitary compartment in the form of a container. This applies mainly to specialized, basic, cardiac and neonatal ambulances - transport ambulances are also built on the basis of passenger cars, due to their more limited equipment and smaller amount of space needed.

3. Functioning of Emergency Medical Transport Services in Poland

Emergency medical transport services in Poland operate on the basis of the Act of 8 September 2006 on State Emergency Medical Services (Journal of Laws of 2016, item 1868 with later amendments). This article deals with the subject of transport in reference to specialized cars, such as emergency medical teams (Zespoly Ratownictwa Medycznego - ZRM - a Polish abbreviation). These are units of the State Medical Rescue system which, outside the hospital, respond to emergencies that appear to be immediately life-threatening. In such situations as, for example stroke, heart attack, fall from a height or a communication accident. The exact division of emergency medical teams in terms of land transport has been described in the previous chapter of the article.

Medical emergency teams can be divided into: specialist, basic and air teams. The main task of the medical rescue team is to transport a person requiring medical care from the scene of the incident to:

- the nearest hospital emergency department,
- a hospital indicated by a medical dispatcher or a physician coordinator of emergency medical services,
- a hospital providing services in accordance with the type and severity of the injury or illness, e.g. to a trauma center, burn center, stroke center or intervention cardiology center.

In order to determine the indications for admitting a patient in a specialist center, emergency medical teams use telemedicine solutions for remote data transmission to the target hospital (e.g. ECG record). As for the data on the total number of ZRM operating in Poland in 2017, there were exactly 1533 of them, including seasonally functioning teams.

Information on contracts for the tasks of emergency medical teams (ZRM) is available in the "Information on concluded contracts" published on the website of the National Health Fund. In order to improve the management of medical transport, the Command Support System for National Emergency Medical Services (System Wspomagania Dowodzenia Państwowego Ratownictwa Medycznego - SWD PRM - a Polish abbreviation) was created. It is an ICT system that enables:

- receiving emergency calls and incident notifications from emergency numbers (112, 999);
- commanding emergency medical teams (EMT);
- recording medical incidents;
- localization of individual accidents, whereabouts of ZRM and their status on the map, which is a module integrated with the system (Universal Map Module).

The development of a unified SWD PRM system for the whole country is to ensure the implementation of tasks by:

- medical dispatchers;
- members of medical emergency teams;
- doctors coordinators of emergency medical services;
- authorized representatives of the Ministry of Health.

The maintenance and service of SWD PRM in the country falls within the competence of the minister for public administration. In the voivodeship, the voivode is responsible for maintaining the system.

The main assumptions of the SWD PRM system are the central way of managing ZRM. The system allows:
- monitoring and managing the forces and resources of the State Medical Rescue;
- managing reports and incidents;
- creating complete medical documentation.

In the future, the SWD PRM system is to enable:
- handling emergency situations, and in case of failure - substitutability of individual medical dispatch offices;
- communication with the NFZ through the reporting module for the National Health Fund;
- communication between ZRM members and medical dispatchers and doctors coordinators about emergency medical services;
- integration with a telephone and radio communication system using any technology;
- managing air emergency medical teams - ZRM by a medical dispatcher;
- transmission of current physiological parameters of the patient (e.g. ECG) from ZRM to the target hospital for a given patient;
- the ability to support an open communication interface to notify the disposer's systems about the acceptance of a new notification.

Due to the launch of medical dispatch offices based on SWD PRM, their number is decreasing throughout the country.

In 2018 there will be 42 concentrated dispatch offices with 226 stations. Ultimately, in 2028 only 18 medical dispatch offices will operate.

The concentration of the dispatch offices is to:
- improve management of information on saving citizens' lives and health;
- ensure efficient transmission of data between emergency and public order services (receiving calls from the emergency number 112 and other emergency numbers and directing them to the appropriate Police, PSP and PRM units);
- contribute to the development of the State Emergency Medical Services system based on modern ICT technologies.

Medical dispatch offices will have an increased number of emergency medical teams. In practice, it means that the team that is closest to the sick or injured person will be sent to the incident.

4. Data Analysis of the Conducted Registered Travel Times of ZRM Cars

The travel times of ZRM cars have been registered in a small healthcare facility that has two ambulances in its ambulance service fleet. The facility does not have a signed contract with the National Health Fund, so services related to the provision of health care by Medical Emergency Units are provided on the basis of a sub-contract with Ambulance Station in Radom. In the tested facility there is one specialized and one basic ambulance. It is worth mentioning here that the ambulances are not stationed in one place. A specialized ambulance is stationed in the place where the facility is located, whereas the basic ambulance in the village about 10 km away from the facility. The year of production of both ambulances is 2007 which means that both ambulances in the study period were already 10 years old. During the registration of their trips, each ambulance had at least one failure and did not reach the place of notification and these trips were not shown in our work. We also did not take into account false calls during the study period, of which there were about 47.

The registration of the trips was carried out for 4 months, i.e. September, October, November and December 2017 with the use of specialized devices:
- autologger (GPS Logger Holux rcv-3000);
- video recorder with built-in GPS.

During the research period (i.e. September - December 2017) we managed to register 1062 ambulance trips from the Ambulance Station (Table 1). The table below presents a numerical summary of ambulance departures broken down into months and the type of ambulance.

<table>
<thead>
<tr>
<th>Month and year</th>
<th>Specialist ambulance Departures</th>
<th>Basic ambulance Departures</th>
</tr>
</thead>
<tbody>
<tr>
<td>September 2017</td>
<td>139</td>
<td>133</td>
</tr>
<tr>
<td>October 2017</td>
<td>134</td>
<td>127</td>
</tr>
<tr>
<td>November 2017</td>
<td>130</td>
<td>127</td>
</tr>
<tr>
<td>December 2017</td>
<td>144</td>
<td>137</td>
</tr>
</tbody>
</table>
Analyzing the above tables, it can be seen that a specialist ambulance had more trips in each month under study. However, these are very small differences ranging below 10 trips per month. The number of registered trips in particular months ranged from 127 to 144 trips. It is worth noting that the number of the trips in individual months is similar. During the registration process there was one long weekend, which fell in November from November 1 to 5, which resulted in the spread of heavy traffic from 2 to 5 days, however an increase in ambulance calls related to holidays was not observed.

Analyzing the collected data, it can be noticed that the ambulances under study have less than 10 trips per day. There are days when an ambulance does not go out in 24 hours. In September 2017, a specialist ambulance travelled on average 5 times a day, the basic ambulance 4 times a day. In October 2017, a specialist and basic ambulance departed on average four times a day. In November 2017, a specialist and basic ambulance departed on average four times a day. In December 2017, a specialist ambulance travelled 5 times a day on average, a basic ambulance 4 times a day. It can be seen here that the data regarding the number of trips in particular months and days are very similar to each other.

Further data obtained as a result of the registration of specialized and basic ambulance trips are the data showing:

- the team's departure time (i.e. the team's departure);
- the time of arrival at the place of the accident (i.e. the time of arrival at the place);
- the time elapsed since departure to arrival (i.e. time);
- the number of kilometers driven (i.e. km).

Analyzing the above data, it can be stated that these ambulances travelled the following number of kilometers in a month:

- September 2017 - 6428.42 km;
- November 2017 - 3892.26 km;
- October 2017 - 5003.38 km;
- December 2017 - 4094.15 km.

The large discrepancy between the kilometers travelled in relation to the months studied, results from the centralization of the dispatch offices, which equals low knowledge of the area by persons who forward the order to the ZRM. This is connected with the problem of determining by the staff which ambulance should be sent to the place of the incident. It often results in the fact that the ambulance has to cover a considerable distance. The selection of routes by ZRM is ineffective because for the time being, drivers are not supported by modern technologies that are able to set a fast route, moreover, very often drivers do not know the area they need to move around.

The longest route that the ambulance had to cover was 39.81 km and was covered within 20 minutes, and the longest time that the ambulance rode from the station to the injured was 60 minutes, however it covered only 22.64 km. Analyzing video images here, it was noticed that in the first case, that is 39.81 km in 20 minutes, the trip was made at night, just a few minutes before midnight, therefore the intensity of traffic was very small, which resulted in the ambulance being able to move quite fast. The second trip - 22.64 km in 60 minutes, was a trip after 3:00 pm, that is in the rush hours and the unskilled behavior of the drivers caused an extended time of the ambulance journey to the injured party. During the period of the registration of ambulance journeys carried out by the authors, a total of over 1,000 measurements was made.

5. Conclusions

Safety and protection of human health and life are one of the main tasks of the state. The Polish healthcare system has undergone many reforms. Changes have also taken place in medical emergency services. Key changes in the medical emergency system were regulated in 2006 by the State Emergency Medical Services Act. The whole system of assistance to the injured in the state of health threat was defined. The aim of the cooperation of rescue services is to reduce mortality, e.g. peritraumatic mortality.

Over the last decades, a rescue system in Poland has been built. Special emphasis has been placed on the emergency medical system. In modern medical emergency, great attention is paid to the aid at the scene of an incident and, subsequently, during transport. Proper organization of tasks allows saving lives at the scene of an accident, proper evacuation and treatment of the victim in a specialist center in accordance with health guidelines.

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The Stand Simulation of Stability of a Car with a Trailer

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Abstract

As the number of vehicles in the streets increases, accidents are also increasing. More and more vehicles with trailers are found on the road. Trailer towing strongly affects the dynamics of the train and can lead to even more emergency situations. This paper presents the results of a study on the stability of a car with a trailer in a special stand. Dangerous and optimal operating conditions for a car with a trailer have been detected, i.e. load on the coupling device and trailer geometric parameters. It has been estimated that the optimal load on the hook is about 6\% of the total weight of the trailer.

KEY WORDS: car stability, trailer, dynamic model

1. Introduction

Passenger cars are designed for the transport of passengers, and the goods can only be transported to a certain size and weight. For the transport of bulky or massive loads, it is often necessary to use semi-trailers. Trailers have different sizes, masses and lifting capacity. For trailers under 750 kg gross weight, self-propelled trailer brakes, which are usually inertia, are mandatory. The trailer attached to the passenger car essentially changes its driving and behaviour on the road. The dimensions of the trailer and the load position of the trailer are especially important. These things have a particular effect on the stability of the car with the trailer unit while traveling under real road conditions. The layout of the load is described by the load on the car and trailer coupling, and the geometrical parameters – by the traverse wheel rim and the distance of axle of the trailer to the coupling. Driving speed is very important for driving a car with a trailer. Having lost the stability of a car with a trailer on the road, it is very difficult to return it to a stable movement. Loss of stability of the car with a trailer on the road usually ends in an accident, and the consequences of such an accident can be catastrophic [1].

The aim of this work was to determine the hazardous and optimal operating conditions of a car with a trailer (load on the coupling device and trailer geometry).

2. Dynamic Model of a Car with a Single Axle Trailer

The dynamic model of a car with a trailer is presented in Fig. 1. Car coordinate system is $X, Y, Z$. The position of the transportable coordinate system of the trailer, closely connected to the trailer body, is obtained by moving the centre to a point $C_2$ with coordinates $(X_p, Y_p, Z_p)$ in the fixed coordinate system. $X_{0p}, Y_{0p}, Z_{0p}$ – the intermediate coordinate system. The intermediate coordinate system $X_{1p}, Y_{1p}, Z_{1p}$ is obtained by turning coordinate system $X_{0p}, Y_{0p}, Z_{0p}$ by angle $\varphi_1$ about the axis $Z_p = Z_{0p}$. The intermediate coordinate system $X_{2p}, Y_{2p}, Z_{2p}$ is obtained analogically by turning coordinate system $X_{1p}, Y_{1p}, Z_{1p}$ by angle $\varphi_2$ about the axis $X_{1p}$. The coordinate system $X_{2p}, Y_{2p}, Z_{2p}$ coincides with the moving coordinate system that is tied to the trailer body and is called a moving base [2].

Fig. 1 Dynamic model of a car with a trailer [3]
So 7 degrees of freedom:
1) Longitudinal motion of the centre of mass of the car is characterized by the linear velocity $V_x$ in the axis $X_1$ of the moving base;
2) transverse movement of the centre of mass of the car is characterized by the linear velocity $V_y$ in the axis $Y_1$ of the moving base;
3) turning the car around the vertical axis is characterized by the angle $\Psi$;
4) trailer opening angle (in the coupling) $\Delta \Psi = \Psi_1 - \Psi_2$;
5) transverse tilt of the car body is characterized by the angle $\phi_1$;
6) transverse tilt of the trailer body is characterized by the angle $\phi_2$;
7) transverse displacement of the coupling device in relation to the longitudinal axis of the vehicle.
The transverse displacement in the coupling is due to the transverse forces acting on the train.

3. Study of Train Stability and Results

The study of stability of the car with a trailer under real conditions is complicated and dangerous. For the study of certain stability parameters, it is possible to successfully use special stands where model of a certain scale of the car with a trailer is used [4].

Fig. 2 demonstrates a schematic diagram and a general view of a stability simulation stand.

![Schematic diagram and general view of a stability simulation stand](image)

The stand consists of an electric motor (1), a belt drive / gear unit (2), a drive shaft (3), a belt (4) and a guide shaft (5).

In real-life experiments controlled trailers are used to change the weight of a load and its distribution (Fig. 3, a). A special trailer made on a test stand, which also provides for the possibility of changing the mass, its distribution and distance from the axle of the trailer to the coupling device (Fig. 3, b).

![Trailer models: natural size (a) and reduced one (b)](image)

A maximum stroke speed of about 10 m/s can be achieved on a manufactured stand. Since a car with a trailer is used in a reduced model (scale 1:24), this speed is not correct as the actual one, so the results are expressed in percentage terms. 100% equivalents to 10 m/s speed.

From the results obtained (Fig. 4, a), we can say that the load on the hook is less than 4%. Driving such a train is very dangerous. When you reach the 6% load limit, the train becomes clearly more stable as it stays stable even when the stand runs at 88 % capacity.

When the load on the hook is 7.9%, the test stand is no longer able to develop a rate so as to detect apparent instability, only very weak fluctuations of the train are observed. So it could be stated that the higher the load on the
hook the more stable the train, but this is not true. With a very heavy load on the hook, the tip of the car is heavily loaded and, as a result, the wheel grip of front axle and road surface deteriorates.

From Fig. 4, a we notice that increasing the distance from the axle to the hook of the trailer increases the overall stability of the train. Increasing the distance by only 30 mm the overall stability of the train increases twice. Also, a steep jump of 120 mm is noticeable as the stand can no longer develop a higher speed and bring the train out of stability. The distance was no longer increased. Therefore, it could be stated that increasing the axial distance the stability of the train improves as well.

![Fig. 4 Results of study](image)

4. Conclusions

Stability of a car with a trailer is an actual problem. The trailer reduces vehicle stability. For stability studies of the train special stands can be used that use car-trailer models of a certain scale.

Trailer load on the hook strongly affects the stability of the train. The optimal load on the hook is 6% of the weight of the trailer. A lower load significantly reduces the stability of the train.

The distance from the axle of the trailer to the hook also has a significant impact on the stability of the car with the trailer. The greater the distance, the better the stability of the train.

References

Requirements for Helicopter’s Planer Construction Fatigue Testing

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Abstract

This paper determines the requirements for fatigue testing of full scale bench test to define the service life of helicopter structures. Which have direct influence on flight safety. So the research focus on solutions for how to extend total service life which have limited service life. In order to reasonably extend resource of limiting elements, presented close to real data about loading of these elements during the regular flight mode, as well as data of real scale model testing, strength analysis. Using this data evaluation of short time strength and durability of parts can be achieved.

KEY WORDS: helicopters, service life estimation, full scale bench tests, requirements for fatigue testing

1. Introduction

One of the most important exploitation criteria related to helicopter's structure is service life [1]. The structure consists of elements with limited service life. These elements have direct influence on flight safety. For example, these elements are: some separate structural elements of planer, blades and joints of main rotor, tail rotor, main gear-reducer, sub-reducer, tail reducer, main and tail shafts, etc. [2].

The only solution how to extend total service life of helicopter is rapid extension of the service life of those elements, which have limited service life till they match the value of helicopter planar service life value. In order to reasonably extend resource of limiting elements (elements which set the limits), there must be presented close to real data about loading of these elements during the regular flight mode, as well as data of real scale model testing, strength analysis, etc. [3,4]. Nowadays, there is limited selection of such materials, so it is necessary to perform real full scale testing in laboratory / stand in order to identify service life values of structural elements in flight mode. The obtained data should be used in additional (double check) calculation of service life of parts of structural elements of helicopter. These calculations must be pointed on evaluation of short time strength and durability of parts. As a result, a final report must be prepared with conclusions of reasonable extension of service life [5-7].

2. Main and Major Tasks during Full Scale Stand Experiments

The aim of fatigue testing is to choose the method of fastening mid and tail reducers in precise position and same is applied for planer construction (tail beam and fin) as well, with in are placement of reducers according fatigue requirements.

According to results of testing, following actions must be taken:

- The value of technical lifetime should be stated (period of lifetime, when it is possible to operate planer of helicopter due to economic considerations).
- The period of operation till first maintenance/observation.
- The duration of maintenance work must be defined in order to operate helicopter safely.
- The proper parameters of exploitation loads must be defined (ability to withstand loadings within particular period, with some fatigue cracks in construction).

Although the solutions of all above tasks are not possible only by “stand” testing of isolated parts (reducers, engine etc.), because such tests don’t take into account the influence of “neighbouring” parts.

Planer constructions must be loaded in such a way that each zone is subjected to indicated load.

3. Description for Selected Method of Loading

The aim of work related to calculation for method of loading of construction and method of fixing model, are defined conditions applied to planer, which are equivalent to fatigue during in-flight modes.

There are several methods, which are used to:

- Test isolated (stand-alone) aggregates on separate stands.
- Make evaluation of fatigue resistance of aggregates.

In case of real task, it is necessary to evaluate all construction: fastenings, aggregates, which are calculated according safety resource; elements of construction, which are calculated due to operational state and lifetime.

Fatigue testing is being carried out on helicopter’s planer (Fig. 1).
Tail beam and fin beam of helicopter’s with installed mid and tail reducers are objects of testing. Reducers are installed according regular (original) fastenings.

Joint points (with test objects) of testing stand must be identical to real model dimensions and technical solutions.

The coordinate system used in this experiment is shown in the Fig. 2.

X axis is aligned to flying direction (it is located in the middle of the fuselage), Y axis is perpendicular to X axis and is oriented up, X and Y axis are located in the middle of the fuselage (narrow plane), Z axis is perpendicular to XY plane, zero point of coordinate system is located on X axis, where it is being crossed by power frame.

Parameters to be measured: Number of loading cycles, measurement of strain in defined points during loading. In case of detection of cracks, damage and other defects during testing:

- full number of loading cycles must be noted, as well as values of applied loadings, defects sizes, location
places and photos;
  • defects must be checked with nondestructive analysis methods, as well as object must be checked for compliance with drawings (especially in the area where defect occurred);
  • proper act (documentation) must be filled.

4. Requirements for Testing Equipment

All measuring equipment must be certified and must have proper precise rate. This equipment must not exceed +/-5% error in measurements.
Laboratory is responsible for selecting type of deformation sensors. Error measurement for deformation sensors must not exceed +/-5% from maximum value of tension.
Requirements for testing stand:
- testing stand must have all necessary equipment, which provide possibility to do testing, if planer is fixed in one of the following ways:
  a. [on power floor] structural chassis frame is being used,
  b. planer is fixed by tail rotor shaft, landing gears do not touch the ground.
- Stand equipment must be able to apply static load (Fig. 1):
  a. to tail rotor at points FPBx,FPBY,FPBZ,
  b. to the joint point of fin,
  c. to spread load Ffinz, which is applied to fin.
- Stand must be equipped with system, which allows rapid control of applied loads and automatic registration of results.

5. Conclusion

In this paper basic technical requirements of bench test for real time full-scale testing of helicopters are formulated. The scheme of the device for bench test is shown. Requirements for the conditions of loading for testing are formulated. The adopted coordinate system, in which the X-axis is directed in the direction of flight of the helicopter and lies in the construction plane of the fuselage, maximally corresponds to the operating conditions.
Requirements for testing and measuring equipments are formulated. The obtained results of bench tests can be used in testing calculations of the resources of helicopter elements according to the criteria of short-term strength and endurance.

References

Study of the Transport Plan of Metro Trains Using Fuzzy Linear Programming Method

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Abstract

The important task in organization of transport in metro network is to elaborate a methodology for optimization the transport plan of metro trains. The establishment of a transport plan includes the routing of metro trains and the number of trains. In the study is elaborated a methodology based of uncertainty of passenger flows. In research is applied fuzzy linear programming method that has been solved by membership function. The methodology was experimented for Sofia’s metro network and was proposed an organization of metro trains. In the study have been compared the results of the methodology and the real situation. The presented approach could also be used for solving the transport plan in other type of transport.

KEY WORDS: fuzzy linear programming, metro, train, passenger flow, optimization

1. Introduction

The determination of the transport plan of metro trains includes establishment of the routing and the number of trains for each route which is an optimization task depending of number of passenger flows. The metro network consists of metro lines which are infrastructural track between initial point and finishing point. A metro train route is an organization of train movement between the first station and the final station.

The scientific researched connected with the problem of transport plan are mainly aimed at examining the interval between trains, [1, 2]; optimizing the timetable, [3]; simulation modelling of passenger flows in stations, of movement of trains and other problems. The minimization of transport cost is the main criterion of optimization of transport plan for other types of public transportation, [4, 5]. A combined simulation-optimization model for transport scheme selection of metro trains has been developed in [6]. The interval between trains according the incoming passenger flows in stations has been simulated. The number of trains has been determined by linear optimization.

It can be summed that the optimization of transport plan of trains in the metro network is an important task for investigation.

Fuzzy sets theory allows describing real situations, taking into account the uncertainty of processes. In the organization of transport, this is the determination of passenger flows, which are characterized by different types of irregularities. The applying fuzzy sets to linear optimization allow elaborating a mathematical model by fuzzy linear programming approach (FLP) in which to increase the adequacy of the solution. For this purpose, when developing an optimization model for choosing a transport plan, a suitable optimization method is linear optimization by applying the fuzzy set theory. The FLP problems can be solved by several approaches [7, 8].

In [9] authors applied the fuzzy linear optimization to reschedule high-speed railway timetable. In [10] is solved the train pathing problem and determined the admissible maximum tonnage of trains. In [11] is investigated the optimal allocation of passenger train services on an intercity high-speed rail line.

The aim of the study is to develop a methodology for optimizing the transport scheme of metro trains, considering the uncertainty of the processes. The example of application of methodology is for Sofia’s metro.

2. Methodology

The methodology of research contains the following steps:
- First step: Forming the variant schemes. The variant schemes differ on the routes of movement of trains. This depends on the network infrastructure. The metro routes are formed between initial and end stations.
- Second step: Making optimization for each variant scheme to identify the number of trains according selected optimization criterion and taking into account of uncertainty of passenger flows.
- Third step: Choice of the optimal transport plan of metro network. This step includes comparison of the variants based on the optimization criterion.

The aim is to optimize the movement of metro trains by routes. The optimization criterion is minimal value of train kilometers:

\[ R_{opt} = \min \{ R_1, \ldots, R_n \}, \text{train.km/h}; \] (1)
\[ R_f = \sum_{k=1}^{K} x_k \cdot l_k \rightarrow \min \text{ train.km/h.} \]  

(2)

Here \( k = 1, \ldots, K \) is the number of routes of movement of trains; \( x_k \) is the number of trains for route \( k \), train/h; \( l_k \) is the length of route \( k \), km; \( f \) is the number of variant schemes.

The optimization function \( R_f \) is represented by membership functions in fuzzy linear programming:

\[
\mu_{R_f}(f) = \begin{cases} 
1 & \text{if } R_f \leq R_{f,U} \\
\frac{R_{f,U} - R_f}{R_{f,U} - R_{f,L}} & \text{if } R_{f,L} \leq R_f \leq R_{f,U} \\
0 & \text{if } R_f \geq R_{f,U}
\end{cases} \]

(3)

Here \( R_{f,U}, R_{f,L} \) are the highest and lowest acceptable levels of optimization function, that can be achieved with individual optimization, respectively with maximum \( P_{m_{j,U}} \) and minimum \( P_{m_{j,L}} \) values of fuzzy numbers of incoming passenger flow.

The optimization is performed for each variant scheme.

The restrictive conditions for objective function (2) are:

1. Frequency of trains.

Frequency of trains depends on value of passenger flows. To determine its value it is necessary to determine the minimal number of trains which has been defined according to passengers in the platform of the train arrival and incoming passengers in station.

\[ \sum_{k=1}^{K} x_k \cdot \gamma_{jk} \geq \frac{60}{I_{m_j}}, \text{ train/h,} \]

(4)

Here \( \gamma_{jk} = 1 \), if a train of route \( k \) moves in section \( j \); \( \gamma_{jk} = 0 \), otherwise; \( I_{m_j} \) is the interval between trains for section \( j \), min.

The right side of condition (4) shows the number of trains determined according to interval \( I_{m_j} \). The interval \( I_{m_j} \) depends by the minimum value of the intervals of stations in the section \( j \), i.e.:

\[ I_{m_j} = \min_{p=1, \ldots, P} \{ I_{m_{jp}} \}, \text{ min,} \]

(5)

Here \( P = 1, \ldots, P \) is the number of stations in section \( j \); \( I_{m_{jp}} \) is the interval determined by relationship received in [6] as follows:

\[ I_m = 0,143 + 142,85 \frac{P_p}{\lambda}, \text{ min; } 1,5 \leq I_m \leq 15, \text{ min,} \]

(6)

Here \( P_p \) is the average number of passengers in the platform of the train arrival, pass./train; \( \lambda \) is incoming passengers in station, pass./h; \( I_m \) is the interval between trains, min.

Formula (6) is used when: \( P_p < \lambda; \lambda > 0; P_p \geq 0 \).

The fuzzy set theory has been applied to represent the process of uncertainty of incoming passenger flows. In this case the condition (3) is changed as follows:

\[ \sum_{k=1}^{K} x_k \cdot \gamma_{jk} \geq \bar{F}_{m_{j,U}}, \text{ train/h,} \]

(7)

Here \( \bar{F}_{m_{j,U}} \) are the fuzzy values of the necessary frequency of transport obtained at the fuzzy values of the incoming passenger flow \( \bar{P}_{m_{j,U}} \) for the relevant period, train/h. The fuzzy values are represented by the highest values \( P_{m_{j,U}} \) and the lowest values \( P_{m_{j,L}} \) of acceptable level of incoming passenger flows for the relevant time period, i.e.:

\[ \bar{F}_{m_{j,U}} = \frac{60}{I_{m_{j,U}}}, \text{ trains/h;} \]

(8)

\[ \bar{F}_{m_{j,L}} = \frac{60}{I_{m_{j,L}}}, \text{ trains/h;} \]

(9)

Here \( F_{m_{j,U}} \) is the highest acceptable level of the necessary frequency of transport obtained at the lowest level of the
interval between trains $I_{m,j,k}$, trains/h; $F_{m,j,k}$ is the lowest acceptable level of the necessary frequency of transport obtained at the highest level of the interval between trains $I_{m,j,\ell}$, trains/h.

In condition (8) and (9) is used formula (6).

The fuzziness of condition (7) is represented by membership functions. The membership functions that can be applied are linear, nonlinear, triangular, and trapezoidal. Linear membership functions are used in this research.

$$
\mu_{Ff} = \begin{cases} 
1 & \text{if } \sum_{k=1}^{K} x_k \cdot \gamma_{jk} \geq F_{m,j,\ell} \\
\frac{\sum_{k=1}^{K} x_k \cdot \gamma_{jk} - F_{m,j,\ell}}{F_{m,j,\ell} - F_{m,j,\ell}} & \text{if } F_{m,j,\ell} < \sum_{k=1}^{K} x_k \cdot \gamma_{jk} < F_{m,j,\ell} \\
0 & \text{if } \sum_{k=1}^{K} x_k \cdot \gamma_{jk} \leq F_{m,j,\ell} 
\end{cases}
$$

(10)

Figs. 1 and 2 present membership functions for minimization of objectives (2), for constraints (7).

Fig. 1 Membership functions for minimization of objective $R_f$ 
Fig. 2 Membership functions for constraints $F_{m,j,\ell}$

2. Transfer station.

In transfer station can be change the route on the same platform. The methodology take into account those transfer stations where pass more than two metro routes. If a given section the station with a maximum incoming passenger flows is transfer station can be written the following condition:

$$
\frac{1}{r} \sum_{k=1}^{K} x_k \cdot \gamma_{jk} \geq \frac{60}{I_{m,j}}, \text{train/h,}
$$

(11)

here $r$ is the number of the number of outgoing routes from the station.

3. Maximum passenger flow between two stations in the section.

$$
\sum_{k=1}^{K} x_k \cdot \gamma_{jk} \cdot a_k \geq P_j, \text{pass./h,}
$$

(12)

here $a_k$ is the number of seated and standing places in train from route $k$; $a_k = 0.9$ is the coefficient of utilization of seats in train from route $k$, $P_j$ is the maximum passenger flow between two stations for section $j$, pass./h.


In this study the optimal transport plan have been determined according available compositions in exploitation.

$$
\sum_{k=1}^{K} x_k \leq W, \text{train/h,}
$$

(13)

here $W$ is the number of available compositions in exploitation.

5. Values of unknowns.

$$
x_{ks} \geq 0, x_{s} - \text{integer; } \forall k = 1, \ldots, K; \forall s = 1, \ldots, S; \text{train/h.}
$$

(14)

The methodology can be used for each peak and other period separately.

The fuzzy linear programming model has been solved by introducing a new variable $\lambda$.

$$
\max \lambda;
$$

(15)

$$
\lambda \leq \mu_{Rf} = \frac{R_{f,\ell} - R_f}{R_{f,\ell} - R_{f,\ell}}, \text{for objective function;}
$$

(16)
\[
\lambda \leq \mu_{ij} = \sum_{k=1}^{K} x_k \gamma_k = \frac{F_{nj,l}}{F_{nj,l'}} - F_{mj,l}, \quad \text{for each fuzzy constraint;}
\]
(17)

\[
0 \leq \lambda \leq 1
\]
(18)

and constraints (11), (12), (13) and (14).

The developed model applies to each peak period separately.

### 3. Results and Discussion

The presented methodology was applied for Sofia’s metro. Fig. 3 presents the metro routes, the initial/final stations. The scheme contains two transfer stations. The metro network is divided into four sections, according to its infrastructure characteristics. Three variant schemes have been studied, according to the infrastructure of the Sofia’s metro.

The studied variant schemes are as follow:
- Scheme 1: It includes two routes X1 and X2. These routes are like to the existing organization of trains in Sofia’s metro.
- Scheme 2: In this variant the routes X1 and X2 are reversed.
- Scheme 3: It includes three routes. The routes X1 and X2 are as in Scheme 1. The route X3 is additional to service the sections with the greatest passenger flows.

![Variant schemes of transportation](image)

The methodology has been applied for two peak periods - morning and evening. The morning peak period is from 07:00 to 09:00, the evening peak period is from 17:00 to 19:00.

The number of passengers waiting on the platform in the stations has been determined by observations. The average value is 80 passengers. The maximum number for the interval between trains at a peak period is about 160 passengers.

Table 1 shows the length of sections and the number of passengers between two stations for morning and evening peak period. Table 2 presents the fuzzy values of incoming passenger flows; the values of the interval between trains, determined by formula (6). They have been determined for the restrictive station in section \( j \). It is those with maximum incoming passenger flows.

### Table 1

<table>
<thead>
<tr>
<th>Section ( j )</th>
<th>From - To</th>
<th>Length ( m )</th>
<th>Morning peak period</th>
<th>Evening peak period</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Slivnitsa - Mladost I</td>
<td>15452</td>
<td>8230</td>
<td>10377</td>
</tr>
<tr>
<td>II</td>
<td>Mladost I - Business Park</td>
<td>2511</td>
<td>6493</td>
<td>8560</td>
</tr>
<tr>
<td>III</td>
<td>Mladost I - Sofia Airport</td>
<td>5832</td>
<td>7053</td>
<td>9213</td>
</tr>
<tr>
<td>IV</td>
<td>Slivnitsa - James Bower</td>
<td>10053</td>
<td>7727</td>
<td>8906</td>
</tr>
</tbody>
</table>

### Table 2

<table>
<thead>
<tr>
<th>Section ( S )</th>
<th>Morning peak period</th>
<th>Evening peak period</th>
</tr>
</thead>
<tbody>
<tr>
<td>( p_{mj,l} )</td>
<td>( l_{mj,l} )</td>
<td>( P_{mj,l} - I_{mj,l} )</td>
</tr>
<tr>
<td>pass./h min</td>
<td>pass./h min</td>
<td>pass./h min</td>
</tr>
<tr>
<td>I</td>
<td>3162 3,75 300</td>
<td>3462 3,44 4627 2,61</td>
</tr>
<tr>
<td>II</td>
<td>1771 6,63 200</td>
<td>1971 5,94 2213 5,31</td>
</tr>
<tr>
<td>III</td>
<td>1683 7,00 200</td>
<td>1883 6,21 2213 5,31</td>
</tr>
<tr>
<td>IV</td>
<td>1768 6,60 200</td>
<td>1968 5,95 1719 6,79</td>
</tr>
</tbody>
</table>
Tables 3 and 4 show the results of individual optimization models made for the lower and upper limit of the incoming passenger flow, and fuzzy linear optimization model.

### Table 3

<table>
<thead>
<tr>
<th>Peak period</th>
<th>No. trains</th>
<th>X1</th>
<th>X2</th>
<th>( R_{f,L} )</th>
<th>( R_{f,U} )</th>
<th>( \lambda )</th>
<th>No. trains</th>
<th>X1</th>
<th>X2</th>
<th>( R_{f,L} )</th>
<th>( R_{f,U} )</th>
<th>( \lambda )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear optimization model with lower passenger flow limits</td>
<td>10</td>
<td>10</td>
<td>463</td>
<td>-</td>
<td>-</td>
<td>12</td>
<td>12</td>
<td>556</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear optimization model upper passenger flow limits</td>
<td>11</td>
<td>11</td>
<td>-</td>
<td>509</td>
<td>-</td>
<td>13</td>
<td>13</td>
<td>-</td>
<td>602</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuzzy linear optimization model</td>
<td>10</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>12</td>
<td>12</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 4

<table>
<thead>
<tr>
<th>Peak period</th>
<th>No. trains</th>
<th>X1</th>
<th>X2</th>
<th>X3</th>
<th>( R_{f,L} )</th>
<th>( R_{f,U} )</th>
<th>( \lambda )</th>
<th>No. trains</th>
<th>X1</th>
<th>X2</th>
<th>X3</th>
<th>( R_{f,L} )</th>
<th>( R_{f,U} )</th>
<th>( \lambda )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear optimization model with lower passenger flow limits</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>463</td>
<td>-</td>
<td>-</td>
<td>12</td>
<td>12</td>
<td>0</td>
<td>556</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear optimization model upper passenger flow limits</td>
<td>11</td>
<td>11</td>
<td>0</td>
<td>-</td>
<td>509</td>
<td>-</td>
<td>13</td>
<td>13</td>
<td>0</td>
<td>-</td>
<td>602</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuzzy linear optimization model</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>12</td>
<td>12</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 4 shows a comparison of the results for the optimal Scheme 1 for the individual optimizations and the fuzzy linear optimization model.

![Comparison of the results for the optimal Scheme 1](image)

**Metro route**

Fig. 4 Comparison of the results of individual optimizations and fuzzy linear optimization model

In Table 5 is shown the interval, the number of trains for the two peak periods obtained by the methodology and the existing condition of the Sofia’s metro.

### Table 5

<table>
<thead>
<tr>
<th>Section</th>
<th>Morning peak period</th>
<th>Evening peak period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>By methodology</td>
<td>By methodology</td>
</tr>
<tr>
<td></td>
<td>( I_m, \text{min} )</td>
<td>( I_m, \text{min} )</td>
</tr>
<tr>
<td>I</td>
<td>3.75</td>
<td>3.75</td>
</tr>
<tr>
<td>II</td>
<td>6.06</td>
<td>6.06</td>
</tr>
<tr>
<td>III</td>
<td>6.06</td>
<td>7.00</td>
</tr>
<tr>
<td>IV</td>
<td>6.60</td>
<td>6.60</td>
</tr>
</tbody>
</table>
The results show:
- The metro trains for Scheme 1 and Scheme 2 for both peak periods are identical.
- For Scheme 3 is not required third route (X3) for both peak periods.
- Scheme 1 is optimal for both peak periods, which coincides with routes to the existing transport organization.
- The application of the fuzzy linear optimization model shows identical results with the individual optimization by a linear model with the lower limits of the incoming passenger flow.
- It is necessary to increase the number of trains for the evening peak period. This will satisfy the needs of the passengers, Fig. 4.

4. Conclusions

In this research has been developed a methodology of optimizing the transport plan of metro trains based on fuzzy linear programming method. This approach allows taking into account the uncertainty of the passenger flows. As a criterion for optimization we applied the minimum train kilometers. The application of fuzzy linear optimization allows achieving a greater adequacy of the solutions.

The methodology has been tested for the optimization of transport plan in Sofia’s metro network. As a result of using the methodology has been proposed an increment of the number of metro trains for evening peak period.

The methodology can be applied to optimize the transport plan of metro trains for each period of the day. It can be also applied for others metro networks according the specificities of routes, passengers flows and variant schemes.

References

Creation of the Image of the New Generation Freight Car Bogie

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Abstract

Analysis of the operating problems of freight car bogies are carried out, analysis of the reasons for low dynamic qualities, which do not allow to increase the speed of movement. The main directions of the development of the bogies constructions are substantiated. The image of the new generation freight car bogie is formulated based on analysis, ideas of car building projects using the method of intellectual decision support. Concept image and patented technical solutions for implementation are solving the problem of minimizing the weight of the bogie (increasing of coefficient of mass utilization) by using a modular design, application of elastic-damping structures, prestressed state of structural elements. Technical solutions improve the strength characteristic and dynamic properties of the freight car bogies on the basis of the above principles of engineering.

KEY WORDS: freight car, bogie, pre-stressed structures, creation of a specialized profile, elastic-damping multifunctional elements

1. Introduction

Improvement of dynamics and strength of freight car bogie is an actual task for industrial and scientific organizations. Studies are carried in the mainstream of the EU Road Map, according to which, in order to reduce the energy dependence of the transport sector and to reduce emissions of harmful substances into the atmosphere, it is planned that by 2030 30% of goods transported by road will be redirected to river and railway transport, and by 2050 50% of freight will be transported by river and railway transport [1]. This background requires the introduction of significant innovations and modernization of the fleet of cars, for example, the working program Shift2Rail [2] aims to achieve:

- reducing the weight of the body up to 30% and the weight of the bogie (reducing unsprung weight, which allows to reduce wear, noise and vibration and will reduce by 20% the life cycle cost of the bogie);
- reducing the dynamic impact on the track through the use of active suspension;
- reducing maintenance costs by 20% through the introduction of monitoring systems, mechatronic systems, etc.;
- reducing wheel and rails wear by 25%, including when passing the curved track sections;
- increasing the speed of movement, especially for freight rail transport demonstrates the dynamic development of passenger rail transport and the “stagnation” of freight rail transport in terms of speed on the example of Sweden [3].

Constantly used in the European Union and Commonwealth of Independent States countries bogie designs, such as Y25, G-type, UIC Link suspension, Barber (type 18-100), have a long history and have undergone only minor transformations during their existence, their schematic development history is shown in Fig. 1 and was created by article authors. The innovation matrix created as a part of SUSTRAIL project [4] has shown that the leading research centers in Europe consider Y25 bogie as the basis of the freight bogie of the future. Within the framework of the conventional approach, it should be modified in the primary spring suspension, use two Lenoir dampers, material with good damping properties, new wheel contour and new wheel steel type. Within the futuristic concept, in addition to the outlined, the use of wedges, hydraulic dampers, and changes in the stiffness of the supports are supposed. Yet it should be noted that the Y25 bogie is very sensitive to the track irregularities, and also requires the improvement of the dynamic qualities for the passage of curved track sections (Fig. 2) [5].

Unlike the authors [4], S. Stichel and P. A. Jonsson consider it promising to use Link suspension bogie with hydraulic dampers [8], which allows to achieve speeds of up to 160 km/h. Authors in their previous works suggest the
development of the Barser cart (18-100), as well as the use of elastic-dissipative bearing elements [6, 7].

In the countries of Central and Eastern Europe, a three-piece bogie is widely used (18-100 type or Barber) which is no better: maximum operating speed does not exceed 90-100 km/h, the high dynamic impact on the railway track is one of the main causes of its wear and damage, high dynamic loading of the supporting members, absence of the pedestal bogie primary suspension, cast bogie frame [9]. In different years, attempts have been made to optimize the characteristics of bogie suspension [10], the use of elastic elements in the pedestal [11, 12], transition from cast to welded elements [13], but no significant breakthrough and tangible results have been achieved.

![Fig. 1 Development of bogie constructions](image)

Fig. 1 Development of bogie constructions

![Fig. 2 The angle of attack and the dissipation energy of the first wheel pair of different types of bogies when passing curves of different radii [6, 9]](image)

Fig. 2 The angle of attack and the dissipation energy of the first wheel pair of different types of bogies when passing curves of different radii [6, 9]

2. Methods for Creating a New Design for a Freight Car Bogie

In this way and relying on [6], actual task is to introduce new concepts and technologies, to create a new bogie design, with the implementation of advanced construction techniques, such as multi-functional components, design modularity, the use of innovative materials, the use of pre-stressed elements. In the near future, it is almost impossible to introduce significant changes in the design of widely used bogies due to the repair base, therefore there is a need for creating a new design for a freight car bogie and upgrading a freight car bogie.

The authors of the article suggest a number of ways to improve freight car bogies of different types on the basis of the approach outlined above:
- using of pre-stressed structures;
- using of rolling materials, the creation of a specialized profile;
- using of elastic-damping multifunctional elements with modularity units.

2.1. Methods for Upgrading a Freight Car Bogie

The causes of lateral frame fractures are found out. Following reasons are known from the literature: 1. Excess value of load (impact loads) for jaws on the sorting roller coaster (up to 100 kN on the jaw). 2. Fatigue failures due to the running of the side frames (if technically faulty bogie). 3. The presence of internal defects in side frames. 4. Operation of bogies after stairs from rails. [7, 8] 5. Combination of longitudinal jaw loading and bends of the side frames. Skewed wheel pair during impact are accompanied longitudinal force on the jaw up to 100 kN and force moment 4.5 kNm. This reason is established experimentally during impact tests. Scheme of strain gages and the general view of the car are shown in Fig. 3.
The authors developed and patented constructions of pre-stressed elements of the bogie design: truck bolster (Fig. 4) [6], side frame (for upper and lower belts – Fig. 5) [6]; side frame pedestal jaw opening (Fig. 6) [6].

Fig. 3 Scheme of strain gages and the general view of the car

Fig. 4 Pre-stressed bolster of a three-piece bogie: 1 - truck bolster; 2 - bolster bowl; 3 - support bearing; 4 - rod

Fig. 5 Pre-stressed side frame of three-piece bogie concept: 1 - top sole bar member; 2 - lower sole bar member; 3 - vertical columns; 4 - spring opening; 5 - bearing surface; 6 - diagonal sole bar member; 7 - jaw pedestal; 8, 9 - rod

Fig. 6 Pre-stressed pedestal jaw opening of a three-piece bogie concept: a) pre-stressing circuit in pedestal jaw opening, 1 - top sole bar member; 2 - pedestal jaw; 3 - pedestal brace; $\alpha$ - angle of inclination, providing the preliminary tension of the structure, $F$ - force providing pre-stressed state of a structure; b) dependence of the level of maximum stresses in the zone R55 (at maximum vertical and axial loads) on the force of preliminary tightening of the jaws with pedestal brace (metal string), 1 - stress level in the existing side frame, 2 - stress level when using a pedestal jaw, cross-section 20 sm², 3 - dependence of stress level when changing the cross-section of the pedestal jaw
As a result of strength calculations, by the finite element method (general view (a) and side frame (b) of calculation model is presented in Fig. 7), it was found out that by changing the force creating a preliminary stress in the pedestal jaw opening, it is possible to reduce the level of maximum stresses in the most stressed zone by 1.5 to 2 times - Fig. 8.

As the development of the idea of using a load-bearing element that closes the pedestal jaw opening, the authors developed technical solutions for the creation of primary bogie suspension in a three-piece bogie. An examples of a design with coil springs is shown in Fig. 9 [7, 9]. A preliminary calculation of the distribution of equivalent stresses in the side frame of the created structure is shown in Fig. 8: the change in the scheme of application of forces did not lead to an increase in the level of stresses.
According to the previous calculation and other studies [7, 9], applying in the primary bogie suspension allows to reduce resistance to movement (increase of energy efficiency) of the freight car by 11%, and also to increase the speed of movement by 30% with an equivalent level of impact on the track. Visualization of the dynamic model is shown on Fig. 10, structural scheme of the model is shown on Figs. 11 and 12.

\[ m \ddot{z} + \beta \dot{z} + \mathcal{K} z = 0, \]

where \( m \) – mass, \( \beta \) – attenuation coefficient of vibration, \( \mathcal{K} \) – elasticity.

The first stage of verification is using simple model:

\[ m \ddot{z} + \beta \dot{z} + \mathcal{K} z = 0, \]

where \( m \) – mass, \( \beta \) – attenuation coefficient of vibration, \( \mathcal{K} \) – elasticity.

The second stage of checking the computer model of the car's dynamics is comparison with testing results in an empty and loaded state. Places of installation of accelerometers in tests is shown on Fig. 13. As the estimates of the adequacy of the mathematical model, the difference coefficient is used:

\[ \varepsilon = \frac{\sqrt{\sum_{i=1}^{n} (x_i' - x_i'')^2}}{\sqrt{\sum_{i=1}^{n} (x_i')^2 + \sum_{i=1}^{n} (x_i'')^2}}, \]

where \( x_i'' \) and \( x_i' \) – predicted and experimental values; \( n \) – the number of verifiable values.

Obtained values below 0.11, this indicates a slight difference in calculation and experimental data. The total relative average deviation of calculated and received by results of measurements of frequencies is 7.47%.
The average value of reducing the resistance of the car is 11%. Reduction of the coefficient of side frame dynamics is 21%. Increase in the coefficient of stability of the wheel from rolling on the head of the rail for 3%.

2.2. Using of Elastic-Damping Multifunctional Elements with Modularity Units

The most promising approach to the creation of a freight car bogie from a number of technical solutions developed by the authors is the use of modular multifunctional load-bearing structural elements. The authors developed new technical solutions and concepts:
- concept of bogie with an elastic-dissipative frame with cradle suspension – Fig. 14 [7];
- concept of bogies like type Barber/18-100 (a) and type Y-25 (b) with an elasto-dissipative frames – Fig. 15 [6].

Fig. 14 Concept of bogie with an elastic-dissipative frame with cradle suspension: 1 - frame with 2 - leaf springs; 3 - clamp; 4 - axle-boxes; 5 - wheels; 6 - central suspension (7 - springs); 8, 9 - tie and balk; 10 - primary spring suspension (11 - springs); 12 - braking equipment; 13, 14 - support nodes

Fig. 15 Concepts of bogies with an elastic-dissipative frame
Considering the international experience in the field of contact evaluation of wheel and rail stresses [14], bench and road tests of wheel-rail contact [15], dynamics modeling of a bogie etc., the object of further research is the simulation of the dynamics of cars with new types of bogies and their testing.

3. Conclusions

To achieve the priority tasks of transport formulated in the Shift2Rail work program, it is necessary to develop and implement new technical solutions.

The authors developed a technical solution for a bogie type 18-100 with pedestal jaw opening reinforcement by closing it with a pre-stressed element, which allows to reduce the level of maximum stresses in the most stressed zone R55 by 1.5-2 times, and also by creating on this basis a primary bogie suspension with a minimal change in the existing structure; this technical measures will improve the dynamics characteristics, reduce the resistance to movement by 11%.

The use of pre-stressed elements of the bogie makes it possible to reduce its weight and maximum operating stresses, increase reliability.

Perspective approach is the creation of freight car bogie is the use of elastic-dissipative elements (for example leaf springs) as multifunctional bearing elements, with the aim of minimizing the mass of the bogie, improve dynamics.

4. Acknowledgement

This research was funded by a grant (No. S-LU-18-12) from the Research Council of Lithuania and Ministry of Education and Science of Ukraine. This research was performed in cooperation between Volodymyr Dahl East Ukrainian National University, Ukraine and Vilnius Gediminas Technical University, Lithuania.

References

Security Problems in the Operation of Unmanned Transport Platforms

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Abstract

The use and capabilities of unmanned ground vehicles (UGVs) have increased significantly in recent years. This applies to both the national economy and the army. More and more commercial vehicles are being used to perform tasks that are considered dangerous for personnel, such as chemical and biological monitoring of military installations, firefighting, probing unidentified areas and disposal of explosive devices. The application of the UGVs also allows to minimize requirements regarding soldiers’ presence in such tasks as border patrolling and supply transports in military active areas. Although the benefits and uses of UGVs are very desirable, the use of Unmanned Transport Vehicles (UTV) introduces new concerns about the safety of soldiers and manned vehicles. These fears are all the greater because in UTV service the role of the operator is significantly reduced. The following paper presents the areas of application and discusses concerns related to the safety of UTVs and the analysis of requirements aimed at ensuring their safe use.

KEY WORDS: unmanned transport vehicles, system security, exploitation

1. Introduction

Unmanned Ground Vehicles (UGV) meet different needs, regardless of whether they perform tasks that are dangerous to personnel or automate repetitive tasks. The UGVs are defined as vehicles that operate in autonomous mode or remote control in rough terrain. Autonomous means that the vehicle can operate in its environment without direct human involvement. A set of sensors, cameras and specialized equipment allows the autonomous operation of the vehicle. The unmanned aspect concerns the absence or optional presence of a human in the vehicle. UGV are a subset of Mechatronic Unmanned Systems (MUS). MUS is defined as a mechatronic system that is able to exert its power to carry out designed missions and includes unmanned systems on board, which allow it to be fully or partially operated in an autonomous mode [1].

MUSs include unmanned aerial vehicles (UAVs) that operate in the air, unmanned ground vehicles (UGVs), Unmanned Surface Vehicles (USVs) that operate on water, and Unmanned Underwater Vehicles (UUVs) which operate below the surface of the water. The main topic of this paper are UGVs. Some applications for UGVs include patrolling missions, detection of improvised explosive devices (IEDs), logistic support and supervision. The vehicle or system is equipped with necessary equipment to carry out planned tasks in the UGV’s use environment [2].

2. Designed Solutions of Unmanned Transport Vehicles

One of the priority directions of work on the development of UGVs is to provide logistical support for sub-branches in urbanized areas and on direct approaches in open areas. It should be noted that the maximum crossing speed in these applications is not a priority (more important is the ability to reach the destination) and it is enough to reach 30-40 km/h.

Fig. 1 A two-unit transport vehicle developed as part of a research project [3]
Due to the required capacity to take large palletized loads (with dimensions and weight of 2 euro pallets), these units come equipped with special forklift systems, which in combination with their load locking systems enables transportation of loads up to several tons. This ensures a low position of the center of gravity, very high lateral stability and with the use of appropriate tires - a great off-road capability (Fig. 1).

Infantry support UGVs are designed to transport equipment and supplies for a small number of soldiers. Therefore, these units carry out “follow” commands independently of the area the soldier is operating in. This requires the ability to move in a variety of terrain conditions: on roads, in the field, and in very rough terrain, difficult to access for other, standard types of vehicles (Fig. 2).

![Infantry unit support vehicle](image)

Fig. 2 Infantry unit support vehicle developed as part of the research project [3]

A soldier-guide should be able to control the vehicle remotely if he so chooses. He can order that the vehicle waits in the designated area (while the soldiers are moving), and call him in, to deliver supplies to the designated place. It is required that this type of vehicle be able to operate for at least 48 hours non-stop, with its weight being less than 250 kilograms and sometimes be capable of transporting an injured soldier. In addition, these unit server support roles, by providing power to special equipment, e.g. radio stations or computers, and sometimes have their own communication links.

Each of those UGV types should provide both support for soldiers as well as the safety of operating regarding the equipment installed on them (Table 1).

<table>
<thead>
<tr>
<th>UGV</th>
<th>Speed</th>
<th>Weight</th>
<th>Vehicle Frame</th>
<th>Level of autonomy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>max 80 km/h</td>
<td>800 – 10000 kg</td>
<td>wheeled</td>
<td>autonomous</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Operating environment</th>
<th>Operating area</th>
<th>Type of terrain</th>
<th>Operating conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>unknown environment</td>
<td>outdoor</td>
<td>concrete, asphalt, dirt road, sand, gravel</td>
<td>day and night, all weather conditions, and chemical and radiological hazards</td>
</tr>
</tbody>
</table>

### 3. Analysis of the Safety System of Using Unmanned Transport Vehicles

The system security analysis required for UGVs will vary in a fundamental way depending on the type of an unmanned system. The analysis presented in the article was carried out based on the MIL-STD-882E standard [4]. The standard identifies eight stages in the process of analyzing system security (Figure 3). The article focuses on the second and third stage of the process, i.e. identification and documentation of hazards, and presents the risk assessment methodology for unmanned transport vehicles (UTVs).

Hazard identification is initiated during learning about the system and its activities. When starting a new program of unmanned vehicles, one first needs to understand the purpose of the vehicle and determine the environment of its use.

The level of operator (user) involvement will need to be documented to assess how the user can and will interact with the system. Potential operational roles of user integration are listed in [3]. Three typical ways of controlling the unmanned vehicle by the operator include: following the designated navigation point, following the operator (follow me) and teleoperation. The unmanned vehicle can be controlled using all methods or a variation thereof.
After selecting the type of work "going to the waypoint", the operator selects points on the map or enters GPS (Global Positioning System) coordinates to determine the route to be followed by the vehicle. The vehicle will move along the route until it reaches the final point of its destination. In the "follow-me" mode, the vehicle will follow the operator by following the lantern that is held or attached to the operator. In this mode, the issue of safety concerns the maintenance of a safe distance between the vehicle and the operator. There may be injuries to personnel if the vehicle approaches the operator without his knowledge. In teleoperation mode, the operator controls the vehicle with a handheld controller or console. The controller can be connected to the vehicle both via a wired and wireless connection. The properties of the controller used and the functions available in the vehicle controller depend on the solution used. The operator plays a greater supervisory role in the vehicle in which the level of control and interaction decreases when the vehicle operates autonomously [3].

3.1. Identification of Hazards in the Operation of Unmanned Transport Vehicles

After documenting the purpose of the UTVs operation, operating environment and type of control, the vehicle block diagram is the key to understanding both the entire system and its components and potential threats. If no flowchart is available for analysis, information collected from the bill of materials may be provided. An exemplary block diagram of a remote-controlled transport vehicle system is shown in Fig. 4.

The block diagram indicates the main subsystems and components. From its analysis, you can start considering systemic threats. The risks associated with the operation of BPT can be divided into four main categories: energy, hazardous materials, software and threats related to performed tasks. The mentioned division may not apply to all BPT systems and additional risk issues may not be considered here.

Energy risks relate to a variety of threats. The power source can vary and include thermal, potential, electric, hydraulic, mechanical and other energy conversion methods. The considerations relate to questions of what should be included in the system to support system security analysis. The presence of energy is a threat, because an unrestricted release of energy can cause personal injury, equipment damage or environmental damage. Thermal energy must be properly monitored and controlled in the system to ensure proper cooling of the components. Overheated components and exposure to high temperatures may cause damage or fire.

Electromagnetic radiation present in UTVs refers to hazards related to electromagnetic radiation emitted from antennas, radios and radars present in the system, used for communication and data transfer. The hazards associated with the analysis of the electromagnetic radiation of the emitter determine the minimum separation distance that must be kept between the emitter and the object to which the problem relates to prevent the occurrence of a dangerous...
condition. Dangerous materials may be in the form of liquids, solid or loose materials. Each unmanned system should be evaluated for hazardous materials used or needed to support the system. Liquids such as fuel, coolant and engine oil are common in vehicles and can be a source of leaks. In addition, vehicles use batteries, including lead-acid and lithium-ion batteries.

Software is the main component of any unmanned system. Basically, all UTVs functionality is implemented using software. Software security analysis provides its assessment to ensure and verify that the software project takes positive steps to increase system security and eliminate or control risks that could reduce system security. Errors due to design, coding, integration or production of software or hardware may result in missing or delayed signals, data corruption, events out of order, deadlocks and process failures. These effects may lead to incorrect UTV activity.

Hazards associated with unintended operation of the device may cause damage to the equipment, damage to the environment and personal injury. The environment can affect the system or pose a threat to it in many ways. Hanging vegetation can become a risk of entanglement of upper elements and sensors. The components must be securely fastened and closed to prevent damage during operation. BPT water exposure may prove to be dangerous in the event of insufficient sealing of the elements and damage. The emergency stop system is a serious safety problem to ensure that the vehicle is stopped in case of undesirable movements or dangerous operations. The method of enabling the safety system must be evaluated to ensure that it is sufficient and that additional hazards are not created when attempting to shut down the system.

Situational awareness for observers is another operational issue. The staff must be aware when a UTV is operating and when it’s in an unpowered state. It is essential that the transported load is safely loaded on the vehicle. There need to be mechanisms implemented which would ensure that the load is evenly distributed on an UTV and the vehicle is not overloaded, which may affect the center of gravity of the vehicle and increase the risk of tipping over.

Another problem is the installation of new equipment and the assurance that it is properly secured on the vehicle. Human factors highlight a different operational aspect. Concerns about lifting heavy objects, access to control elements or subassemblies and the arrangement of on-board controls should be taken into account.

In addition to the control signals, the effects of delays should also be understood. The delay may occur in the form of a delayed image transfer from the camera or a delayed execution of the command. These effects can cause a dangerous condition if the operator repeats the command or correction without knowledge of the delay. Therefore, the operator interface should be carefully evaluated to understand and minimize the effects of delays.

The presented analysis contains basic questions that should be considered and understood in order to start the UTV security analysis. Further tests, methodologies and system assessments will need to be defined to support a full system security analysis to ensure that the benefits delivered using UTV are carefully evaluated for unsafe conditions.

3.2. Risk Assessment for the Use of Unmanned Transport Vehicles

After the identification of threats to the use of a UTV, which may be caused by causal factors, threats and fortuitous events, it is possible to define the risk assessment methodology. Risk assessment is the activity of examining each identified hazard in order to clarify the risk description, identify and verify mitigation actions, determine the effects and assign a risk assessment code (RAC). Based on all these factors and any changes to these factors, a reassessment of the risk may be necessary. A single object may require many risk and acceptance assessments throughout the life cycle [5-6].

The severity category and probability level of potential random events for each hazard in all system modes is assessed using the criteria in Table 2. To determine the appropriate severity category defined for a given threat at a given moment, the potential risk of death or injury, impact on environment or monetary loss. An event can potentially affect one or all of the defined areas.

To determine the appropriate level of probability specified in Table 3 for a given threat at a given moment, the probability of a random event should be assessed. The level of probability F serves to document cases in which the risk no longer occurs. Any action taken: regulations, training, warnings or personal protection measures cannot transfer the likelihood of an accident to F level.

### Table 2

<table>
<thead>
<tr>
<th>RISK CATEGORIES</th>
<th>Name</th>
<th>Danger category</th>
<th>Description of the effects of the threat</th>
</tr>
</thead>
<tbody>
<tr>
<td>CATASTROPHIC</td>
<td>1</td>
<td>Death, permanent total disability, irreversible significant impact on the environment or a large monetary loss.</td>
<td></td>
</tr>
<tr>
<td>KRITICAL</td>
<td>2</td>
<td>Lasting partial inability to work, injury or occupational disease, resulting in at least three hospitalization, a reversible significant impact on the environment.</td>
<td></td>
</tr>
<tr>
<td>MARGINAL</td>
<td>3</td>
<td>Injury or occupational disease resulting in redundancy, reversible moderate environmental impact.</td>
<td></td>
</tr>
<tr>
<td>NEGLIGIBLE</td>
<td>4</td>
<td>Injury or occupational disease that does not result in redundancy, minimal impact on the environment.</td>
<td></td>
</tr>
</tbody>
</table>
Probability levels of events

<table>
<thead>
<tr>
<th>FREQUENCY OF EVENT</th>
<th>LEVEL</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequent</td>
<td>A</td>
<td>Probably that often occurs in the life of the object.</td>
</tr>
<tr>
<td>Likely</td>
<td>B</td>
<td>He will perform several times in the life of the object. It will occur often.</td>
</tr>
<tr>
<td>Occasionally</td>
<td>C</td>
<td>It probably occurs during a certain period of the object’s life. It will appear several times.</td>
</tr>
<tr>
<td>Unlikely</td>
<td>D</td>
<td>Unlikely, but possible to occur in the life of the object.</td>
</tr>
<tr>
<td>Unbelievable</td>
<td>E</td>
<td>It is unlikely that it can be assumed that an event may not occur in the life of the object.</td>
</tr>
<tr>
<td>Eliminated</td>
<td>F</td>
<td>This level is used when potential threats are identified and then eliminated.</td>
</tr>
</tbody>
</table>

The assessed risks are expressed as a risk assessment code (RAC), which is a combination of one severity category and one level of likelihood. For example, a RAC valued at 1A is a combination of catastrophic risk categories and frequent probabilities. Table 4 assigns a high, serious, medium or low risk level for each RAC.

<table>
<thead>
<tr>
<th>DANGER</th>
<th>CATASTROPHIC</th>
<th>CRITICAL</th>
<th>MARGINAL</th>
<th>NEGLIGIBLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>FREQUENT A</td>
<td>HIGH</td>
<td>HIGH</td>
<td>SERIOUS</td>
<td>SERIOUS</td>
</tr>
<tr>
<td>PROBABLE B</td>
<td>HIGH</td>
<td>HIGH</td>
<td>SERIOUS</td>
<td>AVERAGE</td>
</tr>
<tr>
<td>OCCASIONAL C</td>
<td>HIGH</td>
<td>SERIOUS</td>
<td>AVERAGE</td>
<td>AVERAGE</td>
</tr>
<tr>
<td>UNLIKELY D</td>
<td>SERIOUS</td>
<td>AVERAGE</td>
<td>AVERAGE</td>
<td>LOW</td>
</tr>
<tr>
<td>UNBELIEVABLE E</td>
<td>AVERAGE</td>
<td>AVERAGE</td>
<td>LOW</td>
<td>LOW</td>
</tr>
<tr>
<td>ELIMINATED F</td>
<td>ELIMINATED</td>
<td>ELIMINATED</td>
<td>ELIMINATED</td>
<td>ELIMINATED</td>
</tr>
</tbody>
</table>

4. Conclusions

Introduction and utilization of unmanned ground vehicles (UGV) fills many gaps in the implementation of the required capabilities of modern military and civilian formations. It’s capable of introducing a new quality in task performance, however increased security-related considerations need to be taken into account. Certain new mechanisms in both the design and evaluation methodology must be used in order to ensure that UGVs (and Unmanned Transport Vehicles - UTVs especially) can safely perform tasks without interfering with personnel, equipment or the environment. After understanding and documenting the details of the system, the potential hazard notes can be divided into four main categories: energy, hazardous materials, software and risks associated with operations. Threats must be carefully assessed to ensure the safe integration of UGVs and UTVs, given the reduced role of their operator.

The presented considerations are the first stage of works related to the commencement of research on the development of a methodology for conducting safety risk assessments of the operation of UGVs. The benefits of advanced security risk assessment techniques will reduce the risk of unfortunate accidents that the user experiences. The system's security will be able to accurately convey a complete set of risk factors covering all possible events and will provide decision-making bodies with accurate and cost-effective strategies for minimizing it. The ability to identify significant risk factors, such as those that affect multiple random events, increases the ability to focus on the most-influenced risk factors to achieve a significantly greater reduction in safety risks.

References

Sources of Electric Energy for Logistic Means in ISO 1C Containers

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Abstract

Use of renewable sources of electric energy and utility and potable water is nowadays still an up-to-date issue. Containers are mobile assets, that can be adjusted to particular needs and provide autonomous self-sufficiency in hostile or inaccessible environs. Use of renewable sources of electric energy penetrates into mobile assets and surely it would be beneficial in ISO 1C containers being used as mobile logistic assets. The mobile repair asset would be independent through an application of unconventional sources from external mains or from a power source, even it would solve its own production of electric energy. The logistic system in a field and medical support would increase its deployment operability using sources of potable and utility water being embedded in mobile containers. The paper deals with an issue of provision with electric energy and water for container working places on special equipment. The paper provides particular examples of new equipment, constructed in cooperation of the Faculty of Special Technology of the Trenčín University called by Alexander Dubček in Trenčín with particular facilities and organizations in the Slovakia

KEY WORDS: Crisis situations, renewable sources of energy, photovoltaic collectors, logistic container, power systems, mobile assets of crisis management, water mobile systems

1. Introduction

The Slovak troops experienced a deployment as autonomous field hospital. The lessons learnt show that the unit needs to be independent from a logistic point of view with energy and water. Most of European countries are dependent form import of fossil fuels, even though their power security is very high thanks to a sufficient source diversification and recently also to a transformation of economy towards renewable sources of energy, that bring not only positives but negatives as well. In recent years, the role of the UN refugee agency UNHCR and other humanitarian agencies has changed significantly. Originally, these institutions were focusing on the provision of short-term, temporary emergency relief and operated under the premise that forcibly displaced people may eventually return home. However, statistics show that forcibly displaced people who find refuge in a camp remain there for an average of 17 years, which means that managing the corresponding settlements is a medium to long-term obligation that requires a dedicated strategy and novel operational competences. From a technical point of view, the largest problem will be an implementation of smart networks and solution of problems connected with a decentralized production and electromobility.

2. ISO Containers

MSM company produces standardized containers designed for all types of transport [1], fully stackable, adaptable for any kind of climate (-30°C to +40°C) equipped for different purposes:
- Workroom;
- Medical;
- Delaboration of ammunition;
- Monitoring;
- Laboratory;
- Office;
- Residential;
- Kitchen;
- Sanitary;
- Water treatment;
- Storage etc;

3. Field Hospitals

Mobile Field Multi-Profile Hospitals provide for complex health care including serious surgery operations in field conditions. (Fig. 1) Various medical installations use containers ISO 1C equipped with modern medical technology and equipment. The Mobile Field Hospital has large potential in peace support operations, natural disasters, humanitarian catastrophes and elsewhere where it is not possible to ensure health care in classic hospitals.
4. Container Power Generators

Diesel generators (Figs. 2 and 3) are suitable for a containerized solution [2], providing maximum flexibility and reliability. The containers are made from sheet metal, together with CE-compliant protection against accidental contact with all hot and moving parts, heating, electrical installation, RCD-protected sockets, interior lighting, fire extinguishers and warning signs, a number of different attenuation sizes available to provide low sound levels in emergency operation.

Diesel generator sets placed in ISO – 1C container with output (standby) 110kVA, 200kVA, 550kVA. The ISO-1C containers are developed to provide the Armed Forces self-sufficiency power supply when deployed in field conditions such as:

- Field hospitals;
- Field camps;
- Accommodation and sanitary facilities, etc.

![Fig. 2 Power generators placed in ISO 1C container](image1)

![Fig. 3 Power generators placed in ISO 1C container](image2)

4.1. Integrated Power Generators

The APG 20 diesel generator is specially designed for military purposes, it consists of diesel combustion engine started by an electric starter. The fuel tank and automatic fuel pump is integrated within canopy. Generator is designed to power wide range of military loads during transport and stationary. Its basic parameters are shown in Table 1.

<table>
<thead>
<tr>
<th>Basic parameters</th>
<th>22 kVA/17.6 kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power standby</td>
<td>20 kVA/16 kW</td>
</tr>
<tr>
<td>Dimensions</td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>1,946 mm</td>
</tr>
<tr>
<td>Width</td>
<td>917 mm</td>
</tr>
<tr>
<td>Height</td>
<td>1,196 mm</td>
</tr>
<tr>
<td>Weight (including all liquids and equipment)</td>
<td>1300 kg</td>
</tr>
<tr>
<td>Voltage</td>
<td>400/230V</td>
</tr>
<tr>
<td>Fuel capacity</td>
<td>25 hours at 100% load</td>
</tr>
<tr>
<td>Operating temperature</td>
<td>-32°C to 49°C</td>
</tr>
</tbody>
</table>
The output power can be adjusted from 2 kW up to 50kW. Design can be modified according to customer request as well.

4.2. Mobile Container Power Station

Independent power station (Figs. 4 and 5) integrated into ISO 1C container utilizing solar and wind energy. Ideal for deployment in remote locations without power grid [3]. System is capable for permanent power supply.

Key features:
- photovoltaic panels with output 7.75 kW (Fig. 6) [5].
- wind turbines with max. rated power 2 x 2.4 kW;
- batteries energy storage up to 1600 Ah;
- backup diesel generator set with 5 kW output and additional fuel tank.

Fig. 4 Mobile container power station

Fig. 5 Container power station

Fig. 6 Photovoltaic panels for a power station

5. Wastewater Treatment Plant in an ISO Container

Wastewater treatment plant is designed as a mobile solution of water purification (Fig. 7). The treatment plant use aerobic treatment technology together with membrane separation of activated sludge from cleaned water. The water cleaned in this way can be further reused as service water.

5.1. Process Description of the Technology

Wastewater is pumped into the mechanical pre-treatment compartment (A), where floating and sedimentable solids of diameters larger than 1 mm are removed. From the mechanical pre-treatment compartment, the wastewater stream flows through the overflow to the balancing reservoir and from there it is pumped into the activation tank. In the activation tank (B), impurities are removed under oxic conditions. Thus, if needed, this space can be used alternately under oxic and anoxic conditions or it can be used as an accumulation tank, as necessary. From the activation tank, the water stream is pumped with a submerged pump (E) into the filtration tank (C), which accommodates membrane modules (D). At the same time, the filtration tank is used for biological treatment of wastewater and ultrafiltration through the membranes. The treatment plant is provided with an aeration system, which is used for wastewater aeration and, (in the filtration tank), also for cleaning of the membrane modules.
6. Conclusions

Universal standard container ISO 1C guarantees requirements for standard lift and transport for optimum possible movement. It can accommodate workroom, medical facility, lab, office, kitchen, water treatment facility, storage, repair room, therefore the requirements for all containers are the same and they fully operate as a part or as a whole system with a common energy supplying system and a water treatment system. Such hub is independent and autonomous far from public mains. Even in humanitarian operations such container set is an only source of aid for an affected population. It is also suitable for use in the most adverse field conditions [4].

Acknowledgment

This publication was created in the frame of the project „Research of a technological base to propose applications in using renewable sources of energy in practice“, ITMS 26220220083.

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Distribution of Residual Stresses of Railway Steel Components after the Cold Rolling

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Abstract

Numerous research works and service observations show that from practical point of view, the most dangerous proves to be the maximum tensile stress which may accelerate the development of cracking process and cause permanent deformation of the steel components. It is believed that the fatigue crack growth in railway rails is greatly influenced by the residual stress states. The main sources of residual stresses in rails are: the manufacturing process, the rolling wheels of railroad cars and the transverse bending used in cold forming of switch blades and wing rail. The paper presents experimental and a simulation of the process of cold rolling leading to non uniform plastic strains, and as a final effect – residual stresses.

KEY WORDS: rails, FEM, residual stress, ultrasonic measurements

1. Introduction

The production process of rails and turnout profiles is the reason for the formation in this elements of residual stresses. Cold forming of rails and turnout parts (straightening, bending, rolling) causes the creation of residual stresses which are the trace that the technology of their production leaves in the material. The rails and the needle sections after the rolling and cooling phase of the rail do not meet the requirements for their straightness the straightening process is therefore necessary. Straightening of rails made with roller straighteners introduces elastic - plastic deformation of the rail in the band cooperating with rollers. The effect of straightening is influenced by the number of rolls and their diameters and spacing. Optimization of rail straightening due to the creation of residual stresses requires the impact on the rail with the lowest possible forces, adjusting the diameter of the rollers to the curvature of the running surface of the rail, as well as the selection of roller spacing.

The residual stresses that can reach half of the tensile strength limit on the bottom surface of the rail foot are important for the operational properties, and in particular the resistance of the rails to cracking. They can damage the rails before their fatigue strength is exceeded.

2. Experimental Studies of Residual Stresses

The tests of own stresses in rails and needle shapes were made by the author of the article. The ultrasonic stress meter DEBRO was used here with a multi-sensor head for subsurface longitudinal waves. The DEBRO technique uses the elastoacoustic phenomenon, ie the dependence of the stress on the propagation speed or the time of ultrasonic wave transition over a specified road section. In the measurement of own stresses special arrangements of heads recording longitudinal and transverse subsurface waves are used. These systems take into account the influence of temperature changes on the velocity of propagation of the ultrasonic wave.

Fig. 1 presents a diagram of the rolling process with marked measurement cross-sections.
The measurement places on of 60E1 and I60 rails are shown in Fig. 2.

After selection of measurement places the residual stress measurement was performed only on the surface of the rail flange and on the top surface of the rail head. Residual stresses were measured in distances of 0, 150 mm, 300 mm and 450 mm from both sides of the shores action (point of force application). The stresses on the working surface of a head were measured 5, 10 and 20 mm to the left and right from the centre. In turn, the stresses on a food (rail flange) were measured starting from 10 mm from the centre and next with 10 mm interval see (Figs. 3 and 4).

The diagrams (Fig. 5) show example of residual stress changes of rail and switch blades after rolling and straightening process. A axis (X) represents a distance from the centre of a head surface rail, and axis (Y) represents of a residual stress.

On the basis of the graphs shown, the average values of the own stresses on the running surface do not exceed 250 MPa for the UIC 60 (60E1) and in the case of the I60 needle bar were smaller than 170 MPa. However, it should be noted that individual measurements (not averaged from several measurements) have occurred values of tensile stresses exceeding 250-300 MPa.
3. FEM Simulation Studies

Tests of residual stresses in the steel components of track superstructure are expensive and time-consuming, even when using non-destructive testing methods. If possible, measurements shall be limited to the most essential while the simulation methods and numerical calculations shall be used instead. Such calculations allow to define the influence of dimensional and material parameters on the stress distribution. The subject of the numerical calculation in this article is simulation of rolling and straightening process of the section samples of 60E1 rail and I60 switch point. The analysis concerns strains and stresses generated of rolling.

3.1. The Material of the Model

The dependence curves of stress $\sigma$ to strain $\varepsilon$ relation were defined for simulation purposes, as a result of steel tensile test (Fig. 6). Young’s modulus $E = 210$ GPa and Poisson ratio $\nu = 0.3$ were used for simulations. As it is shown in Fig. 6, nonlinear material model was used, with elastic – plastic material behavior taken into consideration. Table 1 shows material ductility (relation $\sigma - \varepsilon$, for axial tension of steel) results obtained in the course of empirical tests. Values shown in table 1 were defined using a software.

<table>
<thead>
<tr>
<th>Stress $\sigma$ [MPa]</th>
<th>Plastic strain $\varepsilon$ [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>629.7</td>
<td>0.4</td>
</tr>
<tr>
<td>900.0</td>
<td>2.6</td>
</tr>
<tr>
<td>1066.0</td>
<td>6.0</td>
</tr>
<tr>
<td>1069.0</td>
<td>15.0</td>
</tr>
</tbody>
</table>

Fig. 6 Experimental material curve and its approximation

a. Load and boundary conditions

For the purpose of simulation calculations, contact points between the cylinder and the rail and needle profiles were determined. Fig. 7 show FEM models of 60E1 and I60 rail with boundary conditions and loading. The rails was supported by two adjacent rollers at specific centers. Between rail and wheel prepared special interface (Fig. 7, b).

Fig. 7 of 60E1 and I60 rail with boundary conditions and loading—the rolling process (a), and rail / wheel interface (b) [2]

b. Results of numerical simulation

The results of numerical simulation for 60E1 rail and I60 switch point models are shown in Fig. 8, presenting outline of residual stresses after the relief and.
Fig. 8 Results of residual stress of rail 60E1 and 160 after simulation [2, 3]

Fig. 9 presents a comparison of the simulation results with the results of ultrasonic measurements for comparable conditions and measuring places.

Fig. 9 The comparison of results of residual stress after rolling process from the numerical analysis and measurements of ultrasonic method for 60E1 (a) and 160 rail (b)

Numerical simulation results shown in Figs. 8 and 9. A location of maximum of residual stresses around the periphery of analyzed rails may be determined based on the results obtained.

Comparison of measurement results with the results of numerical calculations indicates their qualitative compatibility (Fig. 9). Quantitative discrepancy between measurements and simulation calculations may result from too idealized and simplified boundary conditions in the numerical model. The second reason may be information about the exact process of rolling and straightening the profiles used in the research. The maximum tensile stresses for the rail profile do not exceed 350 MPa, and compressing -300 MPa for the analyzed cross-sections. In the case of a needle section, the level of internal stress is ± 100 MPa.

4. Conclusions

Research on damage processes and development of defects in rails and railway turnout elements indicate the need to know the real state of stresses, both from external loads as well as from residual stresses. The selected results of ultrasonic tests and computer simulations presented in the article are the introduction to subsequent analyzes and simulations. The article does not exhaust the whole problem of optimization of the rolling process and it is expedient to straighten out studies and simulations with a greater degree of difficulty. The next task to be solved by the author may be the optimization of the rolling and straightening process with the use of a larger number of rollers with different spacing and clamping forces. Some result discrepancies presented in the article may result from overly simplified boundary conditions adopted by the author at work. An important factor in the distribution of residual stresses can also be the material used for the roll surface as well as the exact adjustment of the pressure of the straightener rolls. These elements were not included in the work, it will be the subject of other considerations and research.

References
Research of Efficiency of Trolleybuses Used in Urban Public Transport

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Abstract

Air pollution in cities and possibilities to reduce it is a relevant topic. One of the efficient ways to reduce air pollution in cities is the use of electric vehicles, including public transport. Trolleybuses are successfully used in some cities. Trolleybuses are powered by electricity, therefore they emit no exhaust gases and expenses for electrical energy are less compared to fuel for buses with internal combustion engines. In the research the energy consumption of trolleybuses used as public transport in Kaunas city was estimated and their operational efficiency was evaluated.

KEY WORDS: trolleybus, public transport, overhead wires, electrical energy

1. Introduction

Air pollution in cities and possibilities to reduce it is one of the most important problems nowadays. The main source of pollution in cities is vehicles, therefore in large European cities the traffic is limited by different means – traffic is forbidden, vehicles which meet high ecological standards can enter city centre or vehicles are charged. If private vehicles may be abandoned in the cities, public transport is vital to city and it is impossible to abandon it. Underground and trams powered by electricity are used in big cities. In smaller cities the installation of underground and trams is not economically profitable. Thus buses, minibuses and trolleybuses are used in all cities including small ones. To reduce air pollution, hybrid or electrical public transport is used. Trolleybus is an electrical vehicle that consumes energy from a contact network. In the late 1880s a number of small transit systems were put into operation using electric power supplied by the system of Leo Daft, of the United States, which used two overhead wires; electrical power was gathered by a small carriage, or troller, running on the wires. The troller was carried on the vehicle by a bent piece called a bow or by a collapsible and adjustable frame called a pantograph. The word trolley came from the little troller of Daft’s system. Trolleybuses had the advantages of electric propulsion (more quiet operation, avoidance of fumes, and faster acceleration) and could load passengers at the curb, but they were less flexible than the motor bus [1]. Two wires and poles are required to complete the electrical circuit. Power is most commonly supplied as 600-volt direct current. The installation of contact network is expensive and complicated, but there are cities where trolleybus park is widely developed and successfully used. The noise level is also relevant for city inhabitants; trolleybuses do not emit almost any sound as they do not have internal combustion engines like buses or do not make noise on rails like trams. Currently, around 300 trolleybus systems are in operation, in cities and towns in 43 countries [2].

Trolleybuses are successfully used for passenger transportation in Kaunas city. The first trolleybuses began to run on Kaunas streets in 1960s and a large part of passengers are transported nowadays. The exploitation of trolleybuses is cheaper; the expenses for fuel/electricity are less. New generation trolleybuses are equipped with regenerative braking systems, they are efficient while braking because they can produce and return part of the consumed electrical energy to the contact network [3].

The aim of the work is to estimate the electricity consumption of “Skoda TR-14” and “Solaris Trollino” trolleybuses and to evaluate economic efficiency of trolleybus use as a public transport in city.

2. Kaunas Public Transport

According the data of JSC “Kauno autobusai” at present 267 buses and 155 trolleybuses are exploited in the company, on average the vehicles drive 21 million kilometers per year, the total length of bus and trolleybus routes is 1854 km. Currently there are 43 bus and 14 trolleybus routes in Kaunas city, each year 80 million passengers are transported on these routes; the passengers use 880 public transport stops on the routes.

In Kaunas buses drive along the longest and the shortest routes; the duration of the longest bus route No 3 is 3 hours, the shortest route No 49 travels just 30 minutes. The longest bus registered in Lithuania also drives in Kaunas, it is “Van Hool AGG” with length of 25 m [4].

The length of trolleybus contact network is 124 km, it is held by nearly 4000 pillars [5]. The contact network is constantly maintained, worn parts are replaced and defects are eliminated. In Kaunas city the contact network is powered by 10 substations. For traction substations, electricity from high-voltage substation cables is supplied with a voltage of 10 kV, which is transformed into traction substations to 600 V and the alternating current is changed to a direct current. The contact network is divided into sections, each section has its power feeder. In the contact network, a
short-term voltage rise of up to 700 V or a decrease of up to 400 V is possible. From substation cables go to every feeder (i.e. power supply). Feeder is a 300 to 500 m range of contact network with separate power supply. The contact network requires 5.7 ± 0.1 m height above the street. The contact network cable with positive polarity voltage is always closer to the center of the driveway, and with a negative polarity voltage - closer to the sidewalk.

At present three trolleybus models are exploited in Kaunas: “Skoda Tr-14” (97 pcs.), “Berghof Premier A” (16 pcs.) and “Solaris Trollino” (42 pcs.) [6].

3. Research Methodology

Experiments have been carried out to determine the amount of energy used during the operation of the trolleybus and the amount of energy regenerated to the network during braking. “Skoda Tr-14” and “Solaris Trollino” trolleybuses were used for experiments. An oscilloscope “Picoscope 3423” was used to measure the voltage generated from the contact network when the trolleybus rides and regenerated voltage to the contact network when the trolleybus brakes; hook-on meters were used to measure direct current [7].

The installation of hook-on meters in trolleybuses is shown in Fig. 1.

![Fig. 1 Installation of hook-on meters in trolleybuses: a – “Skoda Tr-14”; b – “Solaris Trollino”](image)

Experimental measurements were carried out at JSC “Kauno autobusai” site, address Islandijos road 209, Kaunas (Fig. 2). During the experiments, the temperature of the air reached 23-25° C, the south-east wind, the wind speed of 3m/s [8].

![Fig. 2 Experiment location and route](image)

While calculating the amount of electrical energy consumed, it was estimated that the work done over time is equal to the energy consumption. The work performed by the current was calculated by the expression:

$$ P = \int_{t_0}^{t_f} I(t) \cdot U(t) dt $$

where $t$ - time before the current work is calculated, $s$; $I(t)$ – instantaneous value of current strength in time, $A$; $U(t)$ – instantaneous value of voltage in time, $V$.

Since a large amount of data during the measurements was received, it was processed by the Matlab program. In order to calculate the amount of consumed electrical energy, first the work performed by the electric current in a unit of time was calculated. The instantaneous power of the trolleybus is calculated by expression 2.
\[ P_{\text{Instantaneous}} = I_{\text{Instantaneous}} \cdot U, \] (2)

where \( I_{\text{Instantaneous}} \) - instantaneous value of current strength in time, A; \( U \) - instantaneous value of voltage, V.

As the direct current supplied by the trolleybus contact network is equal to 600 V, then \( U = 600 \text{ V} = \text{const.} \). Multiplying the voltage value \( U = 600 \text{ V} \) by instantaneous value of current strength in time, instantaneous power \( W \) is calculated.

The amount of instantaneous power consumed Wh is calculated by the expression 3.

\[ P_{\text{Instantaneous}} = \frac{(t_{ni} - t_i)}{3600}. \] (3)

Total amount of energy consumed over time is calculated by the expression 4.

\[ P_{\text{Consumed}} = \int_{t_0}^{t_n} P_{\text{Instantaneous}}(t) dt. \] (4)

While analysing the measurement results, the electrical energy regenerated to the network is identified according to the negative (-) flow of electric current direction. The amount of regenerated power is calculated by the expression 5.

\[ |P_{\text{Regenerated}}| = \sum_{n=1}^{n} P_i, P_i < 0. \] (5)

To obtain the results of experiments as accurate as possible, three experiments with each type of trolleybus were carried out. When the experiments were carried out, the data was processed, the calculations were performed, and it was estimated that the trolleybus “Skoda Tr-14” consumes 1.3 kWh to drive one kilometer, and the trolleybus “Solaris Trollino” drives the same distance consuming just 1.06 kWh, i.e. it consumes 18.46% less electrical energy.

During the experiments, the trolleybuses were without passengers, so the energy consumption on the real route will be higher. When the total amount of electrical energy consumed by a trolleybus park, the amount of trolleybuses used and their distance travelled are known, the actual electrical energy costs of different types of trolleybuses can be predicted.

According to calculations it is estimated that “Skoda Tr-14” consumes 1.73 kWh per one kilometer and “Solaris Trollino” consumes 1.44 kWh in real life situation.

In Kaunas city passengers are also transported by buses that are driven by diesel fuel or CNG. Below a comparison of fuel/electrical energy costs is presented (Table 1). “Solaris Urbino 2” (diesel fuel), “Solaris Urbino 12 CNG” (CNG fuel) and trolleybus “Solaris Trollino 12 AC” (electricity) of similar size are compared.

Table 1

<table>
<thead>
<tr>
<th>Bus/trolleybus model</th>
<th>Solaris Urbino 12</th>
<th>Solaris Urbino 12 CNG</th>
<th>Solaris Trollino 12 AC</th>
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</thead>
<tbody>
<tr>
<td>Year</td>
<td>2011</td>
<td>2013</td>
<td>2007</td>
</tr>
<tr>
<td>Engine power, kW</td>
<td>188</td>
<td>238</td>
<td>175</td>
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<td>Length, mm</td>
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<tr>
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<tr>
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<td>8880</td>
<td>-</td>
</tr>
<tr>
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<td>Diesel fuel</td>
<td>Natural gas</td>
<td>Electrical energy</td>
</tr>
<tr>
<td>Fuel consumption, l/100 km</td>
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<td>55*</td>
<td>144**</td>
</tr>
<tr>
<td>Fuel price Eur/l</td>
<td>1.050</td>
<td>0.6002*</td>
<td>0.08354**</td>
</tr>
<tr>
<td>Price for 100 km, Eur</td>
<td>43.05</td>
<td>33.011</td>
<td>12.029</td>
</tr>
</tbody>
</table>

*-m³, **-kWh

The bus “Solaris Urbino 12” consumes 41.04 liters of diesel fuel to drive 100 km; one liter of diesel fuel costs 1.05 Eur, therefore the total price for this bus to drive 100 km is 43.05 Eur. The bus “Solaris Urbino 12 CNG” driven by LPG consumes 55 m³ of LPG to drive 100 km, therefore its fuel consumption is just 33.011 Eur to drive 100 km. The trolleybus “Solaris Trollino” consumes 144 kWh of electric power to drive 100 km, therefore its cost for electrical energy is 12.029 Eur for 100 km.
4. Conclusions

Experiments were carried out to determine the electricity consumption of “Solaris Trollino” and “Skoda Tr-14” trolleybuses, which measured the amount of electricity consumed and regenerated to contact network.

On the basis of the experiment data obtained it was found that “Solaris Trollino” consumed 1.0425 kWh to drive one kilometer, and “Skoda Tr14” consumed 1.300 kWh.

Having evaluated the results of the experiments, the number of exploited trolleybuses, their range and total cost of electricity, energy consumption of trolleybuses in real terms was estimated – “Skoda Tr-14” consumes 1.73 kWh, o “Solaris Trollino” – 1.44 kWh to drive one kilometer.

It was calculated that electrical energy consumption of trolleybus “Solaris Trollino” is about 20% less compared to “Skoda Tr-14”. Performing the comparison of electrical energy consumption and bus fuel consumption it was found that the distance of 1 km travelled by trolleybus “Solaris Trollino” is cheaper up to 72% compared to bus “Solaris Urbino”.

References

5. Trolleybus contact network. [online cit.: 2018-08-26]. Available from: http://www.troleibusas.lt/?tag=kontaktinis-tinklas
LNG Supply Chain on Danube

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Abstract

Liquified natural gas (LNG) is natural gas converted to liquid form for easier and more safe storage, transport and distribution. As far as the European continental LNG transport is still not resolved on a sufficient level, an international consortium LNG Masterplan has been established for the most important inland waterway Rhine-Main-Danube. The masterplan of this consortium promotes the introduction of LNG as a fuel and cargo for inland shipping that enables economical and ecological transport of LNG from the seaports to the energy consumers in major industrial areas along the inland waterways. This document provides insight into the development process related to the subactivities of the project covered by company Danube LNG.

KEY WORDS: LNG, supply chain, fleet of vessels, sea-river tanker, floating terminal, dual fuel

1. Introduction

The development task arising from our subactivities was to design an appropriate fleet of vessels for Danube (Fig. 1); the project has been ordered by Danube LNG representing the European Economic Interest Group (EEIG). The group has been established with the main business purpose of research and development aimed at comprehensive technical and economic aspects of the logistics chain for the supply of LNG. EEIG is the beneficiary of support from the European Union under the European Commission Decision of dated 16th October 2013 (2012-EU-18067-S).

Fig. 1 LNG transportation route on the Middle and Lower Danube

The development process was fully coordinated by Danube LNG, the design and engineering work was performed by a group of experts under the leadership of company MULTI engineering services (former POLARIS project experts).

In the project kick-off phase the coordinator extended the requirements on the supply chain to eliminate transporting LNG with large sea-carriers and avoid bunkering to the river tankers at seaports. The aim was to develop a “door-to-door” LNG transport line with an ability of navigation on the waterways from the Caspian Sea, through the Volga-Don Canal over the Black Sea and the Danube from river km 0 to river km 2120 (Abwinden) [19]. Therefore, the basic requirement for the sea-river tanker ship as the most important part of the supply chain have been set up at the following level:

- Ability of navigation on the waterways of the Caspian Sea, the Volga-Don Canal and the Black Sea;
- Duration of voyage on the navigation route: 20-30 days;
- Combined diesel (LNG)-electric propulsion system powered by dual fuel generator sets;
- Total capacity of LNG cargo tanks 2500 m³ or more;
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- Minimal demand for cooling needs of the LNG cargo;
- Minimum 50% transport capacity in the restricted navigation areas with maximum draught of 1.6 meters;
- Maximum air draught allowing safe navigation along the entire route;
- Capability of assembling to a pushed convoy together with two Danube type (DE II) barges.

Technical parameters of all the other components of the chain had to be adjusted with the sea-river carrier to achieve the optimal collaboration and performance. The LNG fleet contains the following 5 transporting, bunkering and storage vessel types:
- Sea-river LNG carrier
- LNG tanker barge I
- LNG tanker barge II
- LNG floating pier
- Floating LNG terminal

2. Development and Design

During the entire development process an iterative approach was applied, so typical for the teams designing ships. All the essential technical and naval architectural calculations have been performed on computer models for several different variants of the vessels. Taking into the consideration the economical, ecological, legislative, but also other aspects the optimal solution has been chosen for providing the basic design package, artistic impressions and PR materials [20].

For all the vessels at least a general arrangement plan, a main frame drawing, a draft technical specification and a preliminary weight and centre of gravity calculation were worked out and delivered. Preliminary hydrostatic, intact and damage stability calculations (Fig. 2) were performed using the naval architectural software package DelftShip v.7.14.

Fig. 2 DelftShip, typical output from damage stability calculation
The design and construction of the sea-river tanker comply with the DNV GL rules for classification of ships [14] as much as the relevant TSCI [11-13] regulations were taken into consideration. Following the TSCI classes the “SM 3,5” class notation was targeted which prescribes the maximum allowable wave height of 3.5 metres in sea conditions. [15] This category allows a restricted navigation on the waterways of the Black Sea and the Caspian Sea within a 20 miles distance from the coastline. The overall hull girder strength was calculated for 3.5 metres high waves by means of the strength assessment software of DNV GL - Poseidon v.15.0.1 (Fig. 3). The initial speed-power prediction for sea and river conditions was made by the resistance module of software package Maxsurf v.20.04 [18].

The design and construction of the tanker barges, the floating pier and the floating terminal comply with the relevant TSCI [11, 12] rules for the inland navigation ships. The overall hull girder strength of the steel hulls was calculated by the FEA module of the DNV GA software Poseidon v.15.0.1 (former GL Frame). In order to check the strength of the reinforced concrete modules of the terminal a rule-based “scantling” calculation was performed according to TSCI.

![Fig. 3 Poseidon FEA, typical output from strength calculation](image)

Requirements of other international agreements and regulations [1-6] were also implemented, especially the ADN 2013 (UN 1972) / ADN D [7]. The draft ADN 2015 [9] was taken into account partially (was issued just before the deadline of the project).

The delivered documents are on a technical concept level, reviewed and commented by the class authorities.

3. Fleet of LNG Vessels

The main component of the LNG supply chain study is a proposal of a complex transport and storage system consisting of 10 floating LNG terminals moored to the river bank along the concerned Danube waterway, 4 sea-river LNG carriers with 1 or 2 attached LNG tanker barges and 20 coupled floating piers moored nearby the LNG terminals. Ultimately a fleet of numerous cargo ships and pushers powered by LNG and navigating the waterway belong to the supply system as well.

As a result of the development process a set of innovative vessel types (Fig. 4) were designed, their short
technical descriptions are given in the following sections.

**Sea-river LNG Carrier**

The purpose of the project was to develop and provide technical conceptual design of self-propelled river-sea tanker ship (Fig. 5) carrying LNG on the waterway between the Caspian Sea and the Middle Danube area.

The result of the development process is a progressive ship design which not only fulfills the requirements, but also exceeds them in certain aspects. As required the tanker ship is able to navigate the both, the rivers with restricted water depth and air draught and the seas under more severe weather conditions. The high freeboard and the longitudinal strength of the hull girder allow the sailing on sea waterways where the wave height exceeds 3.5 metres.

The three converted diesel-electric generators able to run on LNG produce sufficient electric power for the tanker ship navigating at sea as much as for the river conditions when the vessel works as a convoy pusher. This concept enables energy efficient operation because the employment of the main generators and thruster units can be optimized for the actual electrical load and the necessary thrust. The expected fuel consumption of the dual fuel engines is around 232 g/kWh [16].

![Fig. 4 LNG carrier and bunkering vessels](image)

![Fig. 5 Sea-river LNG tanker ship](image)

The vessel is designed with three separated engine rooms for the main generator sets and propulsion units, an auxiliary engine room, an LNG machinery room and storage and accommodation spaces. The living quarters can accommodate 8 crew members, the retractable wheelhouse can be lowered to pass under bridges. In the cargo area 10 independent C-type LNG cargo tanks of capacity 348.5 m³ are installed which are bounded by double-hull space. All the tanks are auto-refrigerating and equipped with technology for charging/discharging and isolated by means a so-called “Super-insulation”.

Main technical parameters of the sea-river LNG carrier:

- $L_{pp}$ (length between perpendiculars) 129.50 m
- $L_{OA}$ (length over all) 130.45 m
- $B$ (breadth moulded) 16.55 m
- $B_{OA}$ (breadth over all) 16.60 m
- $H$ (depth) 5.60 m
- $T_{MAX}$ (maximum draught at sea) 3.00 m
- $H_{FIX}$ (air draught) 6.20 m
- $D$ (displacement) 4858 t
- $DWT$ (deadweight) 2328 t
- $P_G$ (power output main generators) 3 x 1080 kWe
- $P_T$ (power consumption main thrusters) 3 x 800 kW
- $v$ (cruising speed at sea) 12 kn
- $V_{LNG}$ (LNG cargo capacity) 10 x 348.5 m³
- $V_{DO}$ (diesel oil capacity) 91.0 m³
- $V_{WB}$ (ballast water capacity) 1664.0 m³
- $V_{FW}$ (fresh water capacity) 34.0 m³

**LNG Tanker Barge I**

The purpose of the project was to develop and provide a technical conceptual design of Danube-Europe II type pushed barge (Fig. 6) able to carry LNG cargo. Reusing and conversion of existing DE II barges was also an option.

The vessel has to meet the requirement to cruise in a two-unit pushed convoy assembled with the sea-river carrier on the Danube waterway, between the river kilometres 0 and 2120. When it is necessary to reduce the draught of the pushing LNG tanker, approximately 50% of the LNG can be pumped over to the tanks of the coupled barges. Their
maximum draught in these conditions is 1.6 m [17].

In the cargo hold of a DE II pushed barge are installed 3 C-type cylindrical LNG tanks of capacity 348.5 m³ fully equipped with bunkering technology and insulated by means of the “Super-insulation”. The system is auto-refrigerating so there is no need for cooling down even in the most adverse seasonal conditions on Danube. The technical facilities of the barge enable transferring LNG from and to the floating bunkering pier as much as the sea-river LNG carrier within a pushed convoy.

![Fig. 6 Coupled LNG tanker barges DE II](image)

Main technical parameters of the LNG tanker barge I:

- \(L_{pp}\) (length between perpendiculars) = 71.50 m
- \(L_{OA}\) (length over all) = 76.55 m
- \(B\) (breadth moulded) = 11.40 m
- \(B_{OA}\) (breadth over all) = 11.44 m
- \(H\) (depth) = 3.20 m
- \(T_D\) (design draught) = 1.60 m
- \(T_S\) (scantling draught) = 2.50 m
- \(H_{FIX}\) (air draught) = 6.15 m
- \(D\) (displacement) = 1286 t
- \(DWT\) (deadweight) = 437 t
- \(V_{LNG}\) (LNG cargo capacity) = 3 x 348.5 m³
- \(V_{DO}\) (diesel oil capacity) = 4.0 m³
- \(V_{WB}\) (ballast water capacity) = 494.0 m³

**LNG Tanker Barge II**

The purpose of the project was to develop and provide an alternative solution for the Danube-Europe II type pushed barge. A completely new vessel type (Fig. 7) was designed on technical concept level to avoid the hydrodynamic and other disadvantages of a coupled DE II barge convoy.

In the cargo hold of the pushed barge are installed 6 C-type cylindrical LNG tanks of capacity 348.5 m³ fully equipped with bunkering technology and insulated by means of the “Super-insulation”. The system is auto-refrigerating so there is no need for cooling down even in the most adverse seasonal conditions on Danube. The technical facilities of the barge enable transferring LNG from and to the floating bunkering pier as much as the sea-river LNG carrier within a pushed convoy [17].

![Fig. 7 Non-propelled LNG tanker barge](image)

Main technical parameters of the LNG tanker barge II:

- \(L_{pp}\) (length between perpendiculars) = 97.80 m
- \(L_{OA}\) (length over all) = 99.55 m
- \(B\) (breadth moulded) = 16.60 m
- \(B_{OA}\) (breadth over all) = 16.64 m
- \(H\) (depth) = 3.20 m
- \(T_D\) (design draught) = 1.60 m
- \(T_S\) (scantling draught) = 1.70 m
- \(H_{FIX}\) (air draught) = 6.28 m
- \(D\) (displacement) = 2512 t
- \(DWT\) (deadweight) = 948 t
- \(V_{LNG}\) (LNG cargo capacity) = 6 x 348.5 m³
- \(V_{DO}\) (diesel oil capacity) = 4.0 m³
- \(V_{WB}\) (ballast water capacity) = 593.0 m³

**LNG Floating Pier**

The purpose of the project was to design and provide a technical conceptual design of a bunkering floating pier (pontoon, Fig. 8) fulfilling the requirements for charging and discharging LNG to and from the vessels of the LNG supply chain, but also for filling vessels propelled by LNG, vessels with combined propulsion as well as vessels with conventional diesel propulsion. The possibility of mooring the floating pier at LNG terminals of the Main and Rhine waterway area is an option.
The floating pier is equipped for secure mooring of the sea-river LNG carrier, as well as the commonly used vessels on the Danube-Main-Rhine waterway. Its technical systems have sufficient cryogenic distribution network for discharging approximately 3000 m$^3$ of LNG from the tanker ship. This operation takes maximum 8 hours of continuous pumping. The LNG storage tank capacity is large enough to take over the role of the port terminal in case of minor pumping failures during the repairing. One C-type cylindrical LNG tank of capacity 348.5 m$^3$ is installed, fully equipped with bunkering technology and insulated by means of the “Super-insulation”. The storage LNG tank is capable to receive safely LNG at the hourly pumping capacity of 400-600 m$^3$. The floating pier is capable to receive safely the evaporated LNG in case of exceeding the allowable pressure in tanks. The diesel fuel capacity is sufficient for the needs of filling up three commonly used pusher tugs having combined Diesel/LNG propulsion.

![Fig. 8 LNG floating bunkering piers](image)

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<td>$VF_{W}$</td>
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</table>

**Floating LNG Terminal**

The purpose of the project was to design and provide a technical conceptual design of a floating LNG terminal for Danube (Fig. 9) fulfilling the requirements for LNG storage and for charging and discharging LNG to and from the vessels of the LNG supply chain.

The storage area of the vessel is composed from 7 identical 2 compartment precast concrete modules which accommodate 12 C-type cylindrical LNG tanks of capacity 348.5 m$^3$ fully equipped with storage technology and insulated by means of the “Super-insulation”. For the fore and aft collision spaces 2 special concrete modules are designed. The double side construction of the monolithic modules gives sufficient protection against possible lateral collisions. For the modules a watertight reinforced lightweight concrete material was specified. All the superstructures are of light construction manufactured from standard shipbuilding steel.

In addition to the storage and collision spaces the vessel has an engine room, a tank room, accommodation spaces and a control room. The terminal is equipped with all the cryogenic systems necessary for safe storage of LNG, with two generator sets for producing electricity, with a flare system and an emergency vaporizer unit.

![Fig. 9 Floating LNG terminal for inland waterways](image)

<table>
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<td>$T_D$</td>
<td>2.30 m</td>
</tr>
<tr>
<td>$H_{FIX}$</td>
<td>10.65 m</td>
</tr>
<tr>
<td>$D$</td>
<td>6828 t</td>
</tr>
<tr>
<td>$D_WT$</td>
<td>1878 t</td>
</tr>
</tbody>
</table>
4. Conclusions

The elaborated project addresses efficiently the transport, distribution and storage of liquefied natural gas (LNG) in the region of the Middle and Lower Danube. The innovative design of the sea-river tanker enables a door-to-door LNG transport between the terminals along the entire combined waterway what can significantly reduce the duration of voyage and the delivery time. This way the boil-off losses in LNG can be minimized and the overall efficiency of the supply system is increasing. Hopefully, our idea of the Danube LNG fleet integrated with other necessary components and the ground infrastructure will be transformed into an efficient LNG supply chain soon.

Since the project was supported by EU the delivered documentation is public and accessible on the official website of LNG Masterplan.

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Bio-Corrosion Damage to Steel of Gas Main under Combined Effect of Sulfate-Reducing Bacteria and Thionic Bacteria

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Abstract

The microbiologically influenced corrosion of underground main gas pipeline was identified. Samples obtained from natural gas pipelines were inoculated into bacterium medium that simulated a natural gas pipeline environment. The effect of SRB cells of the genus Desulfovibrio sp. strain Kyiv-10 and Thiobacillus sp. strain PAS-7 in case of their combined action in a nutrient mixture of Postgate B medium and Beyerink medium on the corrosion rate of pipe steels 17G1S-U and 20 was investigated.

KEY WORDS: microbiologically influenced corrosion, underground pipelines, corrosion rate

1. Introduction

After a long-term operation, underground pipelines can be corroded by soil microorganisms (MO). Among the association of soil microorganisms, sulfate-reducing (SRB) and thionic (TB) bacteria are the most corrosive and aggressive to pipe steels in the underground environment [1-6]. Under the action of soil microorganisms, both aerobic and anaerobic, there occurs degradation of the protective insulating coating followed by its cracking and detachment. As a result, there is corrosion under the insulating coating, resulting in ulcers on the surface of the metal pipe.

One of the most reliable ways to protect gas mains against damage caused by biocorrosion is changing the adhesive properties of the steel surface, which is achieved by modifying the chemical composition of steels, and the use of inhibitors. To-date, some works are known that describe the regularities in the influence of SRB and TB bacteria on the corrosion of individual pipe steels in Postgate’s B medium and Beyerink medium [1, 7]. However, their combined effect in a mixture of nutrient media on the kinetics of biocorrosion processes and structural changes in the metal is not yet investigated.

The purpose of this research is to evaluate the effect of SRB cells of the genus Desulfovibrio sp. strain Kyiv-10 and Thiobacillus sp. strain PAS-7 in case of their combined action in a nutrient mixture of Postgate B medium and Beyerink medium on the corrosion rate of pipe steels 17G1S-U and 20.

2. In-Service Defects of the Gas Main

In the zone of laying the gas main “Pasichna-Tysmenytsia”, probing was performed. Visual analysis was conducted of the surface of the gas main commissioned in 1968 and its insulating coating, which consists of a bituminous rubber mastic and a bituminous paper wrapper. The sites of local biocorrosion damage were found, Fig. 1a and b.

In administrative terms, the object of reconstruction is located in the Ivano-Frankivsk region. This part of the Carpathian region is characterized by increased rainfall and, consequently, high humidity. Here, forest-like landscapes are formed. The number of days with precipitation is 130-188 days a year. The average July temperature is +18.3°C, the average January temperature is -4.3°C. Summer precipitation has a storm-like character, which promotes an intense surface runoff, soil erosion, and the development of erosion processes. For the Carpathian region, such conditions are typical, they cause surface overflow, which promotes the enhanced activity of SRB and TB bacteria.

At first glance, it may seem that the coating is closely adjacent to the insulation, Fig. 1a, however, under the insulation there is moisture across the pipe, which is extremely undesirable, since in cathode polarization, this leads to the separation of the insulation coating and the intensification of the local corrosion processes of the pipe metal.

In our opinion, corrosion of the pipe metal, Fig. 1, b, can be associated with the activity of bacteria of the sulfur cycle, such as sulfate-reducing bacteria (SRB) of the genus Desulfovibrio and Desulfotomaculum, and thionic bacteria (TB) of the genus Thiobacillus, capable of oxidizing sulfur and its compounds to sulfate acid, sharply reducing the pH of the medium.
3. Materials and Methods of Research

The objects of research were specimens from pipe steel 17G1S-U and steel 20 with the size of 10 × 30 × 1.0 mm cut from the non-operated pipe. SRB cells of the genus Desulfovibrio sp. strains Kiev-10 were grown on a liquid Postgate B medium in a thermostat at a temperature of 28° C for 14 days. Pure colonies of sulfate reducers were obtained on a semi-liquid Postgate B medium by seeding a ten-fold dilution. Thiobacillus sp. strains PAS-7 were isolated from gold-bearing ore deposits from South Africa. To cultivate thionic bacteria, the Beyerink medium of the following composition (g/l) was used: Na₂S₂O₃ ∙5H₂O – 5.0; NaHCO₃ – 1.0; Na₂HPO₄ ∙2H₂O – 0.2; NH₄Cl – 0.1; MgCl₂·6H₂O – 0.1; water distilled - 1.0 liter [8]. The control medium was a mixture of sterile Postgate B medium and Beyerink medium in a 1:1 volume ratio. For research, inhibitors based on the derivatives of dioxodecahydroacridine (inhibitor 1) and quaternary ammonium salts (inhibitor 2) were selected. Upon completion of the research, the metal specimens were subjected to mechanical and chemical treatment to remove corrosion products from their surface.

The corrosion rate of metallic specimens was determined by the gravimetric index of the corrosion rate (Kgr.):

\[ K_{gr} = \frac{m - m_0}{S \tau} \text{ (mg/dm}^2\text{∙day),} \]  

where \( m \) is the final mass of the specimen, mg; \( m_0 \) is the specimen mass before corrosion, mg; \( S \) is the surface area of the specimen, dm²; \( \tau \) is the exposure period, day.

The bactericidal properties of the inhibitors studied were determined according to the DSTU 3999-2000 [9-10]. The concentration of inhibitors was 0.5% and 1.0%. The effectiveness of the inhibitors studied was characterized by the degree of protective action of inhibitors (Z), calculated by the formula:

\[ Z = \frac{K_{gr} - K_{gr1}}{K_{gr1}} \times 100\% , \]  

where \( K_{gr} \) is the corrosion rate in the uninhibited medium, mg/dm²∙day; \( K_{gr1} \) is the corrosion rate in the presence of inhibitors, mg/dm²∙day.

4. Results and Discussion

Fig. 2 shows the corrosion rate of the 17G1S-U steel in a mixture of Postgate B medium and Beyerink medium under the influence of SRB bacteria, TB bacteria and their joint action.

It was established that in the mixture of sterile Postgate B medium and Beyerink medium in volume ratio 1:1, inoculated with SRB and TB cells, the corrosion rate of a metal increases by more than 2 (2.33) times, compared with the influence of SRB, and by 6 (6.22) times, compared with the influence of TB bacteria. The obtained data indicate that, with the combined action of SRB and TB bacteria during the corrosion damage to the metal, SRB bacteria have a dominant influence. This is probably due to the fact that aerobic TB bacteria, while consuming oxygen, create favorable anaerobic conditions for the development of SRB. The visual inspection of the steel specimen after exposure showed that there are both SRB and TB bacteria on the steel specimen, although the growth of SRB predominates, as evidenced by the wider dark strip. TB cells are present on the walls of test tubes, SRB develop at the bottom of the medium. In comparative conditions of experiments, steel 20 in a mixture of media, inoculated with SRB and TB cells of bacteria, corrodes at a rate, which is 4 (4.3) times slower than that of the 17G1S-U steel (Fig. 3).
Fig. 2 Corrosion rate of 17G1S-U steel under the influence of SRB bacteria, TB bacteria and their joint action

Such a significant reduction in the rate of biocorrosion processes in the transition from one steel grade to another is due, probably, to the influence of the chemical composition of the steel. The visual inspection of the medium showed the growth of the SRB. The metal specimen was corroded.

5. Impact of Inhibitors

Steel 17G1S-U

The analysis of the dependencies shown in Fig. 2 proves that when inhibitor 1 at a concentration of 0.5% was added to a mixture of media inoculated with SRB and TB cells, the rate of corrosion decreased by almost 27 (26.79)% , which indicates the inadequate effect of the inhibitor. In this case, a biofilm from SRB cells was observed on a steel specimen, TB cells were observed on the walls of the test tube, and traces of the biogenic ferment sulfide were observed at the bottom of the test tube. Increasing the concentration of inhibitor to 1.0% did not lead to further suppression of biocorrosive processes, indicating its inefficiency.

A high efficiency of blocking biocorrosion processes (94.6%) was manifested by inhibitor 2 at a concentration of 0.5%, indicating the absence of corrosion on the steel specimen and the presence of the growth of microorganism cultures. It was established that within the concentration variation range of inhibitor 2 (0.5-1.0%), the efficiency of blocking biocorrosive processes remains unchanged.

Steel 20

When adding inhibitor 1 at a concentration of 0.5% in a mixture of media inoculated with SRB and TB cells, the rate of corrosion increases by almost 4 (3.92) times. The results obtained indicate that this inhibitor, having lost its inhibitory function, initiates the development of biocorrosion processes and, as a consequence, causes the growth of SRB. With a further increase in the concentration of the inhibitor to 1.0%, there was no increase in the rate of corrosion, and, conversely, inhibition of the development of biocorrosion processes by 34 (34.2)% , compared with a concentration of 0.5%. The steel specimen is covered with a biofilm from SRB cells in the TB medium, as evidenced by their colonies of yellowish color. With the combined action of SRB and TB, inhibitor 2 at concentrations of 0.5% and 1.0% blocks the development of biocorrosion by 61.5 and 53.8%, respectively.

The research results proved that the highest degree of metal protection from biocorrosion (94.6%), caused by the combined effect of SRB and TB bacteria, was manifested by inhibitor 2 at a concentration of 0.5% for the 17G1S-U steel (Table 1).
Table 1

<table>
<thead>
<tr>
<th>Steel grade</th>
<th>Inhibitor</th>
<th>Inhibitor concentration, %</th>
<th>MO</th>
<th>Degree of protection, Z, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>17G1S-U</td>
<td>-</td>
<td>-</td>
<td>absent</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>0.5</td>
<td>TB</td>
<td>absent</td>
<td>50.0</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>SRB</td>
<td>26.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>TB</td>
<td>absent</td>
<td>26.8</td>
</tr>
<tr>
<td>2</td>
<td>0.5</td>
<td>TB</td>
<td>absent</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>SRB</td>
<td>70.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>TB</td>
<td>33.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>SRB</td>
<td>79.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>SRB+TB</td>
<td>94.6</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>-</td>
<td>-</td>
<td>absent</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>0.5</td>
<td>TB</td>
<td>absent</td>
<td>30.0</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>SRB</td>
<td>88.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>TB</td>
<td>40.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>SRB</td>
<td>66.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>SRB+TB</td>
<td>53.8</td>
<td></td>
</tr>
</tbody>
</table>

6. Conclusions

It is established that in the mixture of sterile Postgate B medium and Beyerink medium in volume ratio 1:1, inoculated with SRB and TB cells, the rate of corrosion is higher compared to the influence of monocultures of SRB and TB. In comparative conditions of research, steel 20 in a mixture of media with a combined effect of SRB and TB bacteria, corrodes at a rate, which is 4 (4.3) times slower than that of the 17G1S-U steel, which is probably due to the influence of the component composition of the steel.

The highest degree of metal protection from biocorrosion (94.6%), caused by the combined effect of SRB and TB bacteria, was manifested by inhibitor 2 at a concentration of 0.5% for the 17G1S-U steel. For steel 20 under similar conditions, this figure was 53.8%.

References

Selection of Means of Internal Transport as Exemplified by Transport Trucks

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Abstract

The problem of selection of means of internal transport, due to its importance for the companies where this type of transport is crucial for their operation, is both interesting and demanding in terms of rational decision-making. The authors of this article decided to investigate this problem due to its importance. Incorrectly selected means of internal transport can disrupt company operation and generate unnecessary costs. In this article, its authors attempted to analyze the process of selection of means of internal transport based on empirical data of the investigated company. The article identifies shortcomings in the area of selection of means of internal transport directly affecting the organization of transport within the company. With regard to the identified problems related to the area of selection of means of internal transport, the authors of this article calculated relevant coefficients and assessed the degree of utilization of these means.

KEY WORDS: means of transport, internal transport, transport trucks, selection, assessment

1. Introduction

Selection of means of internal transport is of paramount importance at the stage of designing a given company, its modernization or in the event it becomes necessary to assess the degree of utilization of company means of transport. For the purpose of such a selection, the following data is required: type of transported load, form of the unit load or form of the load unit, mass of the load unit, total mass to be transported within 24 hours, shift work, the distance to be covered, parameters of the transport route, etc. In some cases, much more data is available, it all depends on the type of company for which the assessment is being carried out. Appropriate selection of means of internal transport should be based on an in-depth analysis of the fulfillment of the criteria applicable to a given case [1-7]. The said criteria can be divided into three main groups:

a) Technical criteria – including the following parameters: speed, carrying capacity, range, work time, ease of load handling, capacity, dimensions, the possibility of using additional equipment, ease of maneuverability and many other parameters.

b) Ergonomic criteria – including the following: ease of maneuverability for the operator, ease of operation, low level of inconvenience of operation, low level of inconvenience in terms of generated noise, vibrations, fumes emission, etc.

c) Economic criteria – purchase cost, operation cost, ease of purchase, life, payback period, reliability, replaceability in the case of failure, availability and cost of spare parts, etc.

The investigated company has 13 transport trucks classified according to 4 groups (each group corresponds to a given model). The company performs the role of a warehouse, it is fully automated and furnished with high quality warehousing equipment. Due to the nature of the performed functions, there are no significant inventory movements. Therefore, the purpose of this article was to verify, whether the used transport trucks are suitable for the needs of the investigated company. The authors of this article chose to analyze the problem in question in order to find the answer to the following question: does the investigated company have appropriate means of internal transport as exemplified by transport trucks. Based on the analysis of available documents, observation of internal transport processes as well as interviews with managers responsible for in-house transport, the authors were able to formulate the question being the subject of the analysis: does the investigated company utilize the currently owned transport trucks to a sufficient degree? The following assumption represents the hypothesis: the transport trucks used by the company are not suitable for its profile. This assumption was made based on the interviews with the managers as well as the information on the frequency of use of the transport trucks. The following research methods were applied: documentation analysis, observation, interviews with the personnel as well as mathematical methods.

Modeling the system for the assessment of selection of means of internal transport on a selected set

There is no ideal mean of transport. Therefore, one should carry out an in-depth assessment and choose, form the available set, those which are as close to the ideal model as possible. Thus, a scoring method with the following steps may be applied:

- identification of a group of means of transport (at least 2 pieces);
- selection of criteria from all three groups: technical, ergonomic and economic;
- assigning an appropriate scoring scale for meeting the applicable requirements to each criterion according to the set pattern;
- assessment of each mean of transport according to the previously identified criteria and assigning a score for meeting the applicable requirements. For the continuous work time criterion – less than 10 hours – 0 points, from 10 to 14 hours – 1 point, from 14 to 18 hours – 2 points, from 18 to 22 hours – 3 points, from 22 to 26 hours – 4 points, more than 26 hours – 5 points. Such an assessment method eliminates particular means from the further analysis;
- adding up the points awarded in the scoring procedure, selecting from the available set not more than ¼ of the whole;
- in the next step, the best of the best should be selected.

Depending on the requirements, needs and possibilities, more weight can be attributed to particular criteria to facilitate the selection of appropriate means of transport and elimination of those, which fail to meet the applicable criteria. Table 1 presents the selection of means of transport for the investigated case; it demonstrates that group 4 transport trucks have the highest score. Table 1 was prepared based on interviews with experts of the investigated company. The criteria relevant for the organization of internal transport and those, which were identified by the warehouse personnel and experts as the most important ones from the perspective of company operation, were taken into consideration. The assessments are subjective and yet very important, as they reflect the actual needs of the company. The investigated objects represent a group of pallet trucks of a single model; they are most frequently used by the warehouse personnel and thus selection of this set seemed most reasonable. For the purpose of further discussion, a single representative set was selected.

### Table 1

<table>
<thead>
<tr>
<th>Criterion/mean</th>
<th>Scoring scale</th>
<th>Group 1 trucks</th>
<th>Group 2 trucks</th>
<th>Group 3 trucks</th>
<th>Group 4 trucks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical</td>
<td>X</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>suitability for the load</td>
<td>0-5</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>carrying capacity</td>
<td>0-5</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>speed</td>
<td>2-5</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>reliability</td>
<td>1-5</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>ease of loading</td>
<td>2-5</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>ease of repair</td>
<td>0-5</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Ergonomic</td>
<td>X</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>X</td>
</tr>
<tr>
<td>noise level</td>
<td>2-5</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>pollution level</td>
<td>0-10</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>ease of operation</td>
<td>1-5</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>inconvenience of operation</td>
<td>1-5</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Economic</td>
<td>X</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>X</td>
</tr>
<tr>
<td>purchase cost</td>
<td>2-5</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>repair cost</td>
<td>1-5</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>cost of spare parts</td>
<td>1-5</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>70</td>
<td>40</td>
<td>47</td>
<td>49</td>
<td>51</td>
</tr>
</tbody>
</table>

Having analyzed the data presented in Table 1, one can notice that group 1 was awarded the lowest score, which differs significantly from that awarded to the other groups. Group 2 and group 3 trucks were awarded a very similar score, while the score for group 4 is significantly higher than the score for group 1. This means that group 4 trucks are the leading means of transport in terms of the identified criteria and thus they can be the basis for further analyses and research.

2. Calculating the Number of Means of Transport

Following the analysis presented in Table 1, carried out according to the previously identified criteria, the number of needed means of transport should be calculated. Taking into consideration the scores presented in Table 1, group 4 will be the representative set. For the purpose of the calculations, the following data must be collected:

a) Number of shifts covered by the mean of transport \( z = 1 \);
b) Time necessary for the performance of transport work \( T = 598 \) h/year;
c) Effective time fund for means of transport \( F_e = 190 \) h/year per shift;
d) Standard load rate for the mean in time \( w_1 = 0.6 \).

Subsequently, the required number of means of transport is calculated in line with the following formula:

\[
i_e = \frac{T}{F_e} \cdot w_1 \text{ [pc.]}
\]
where

\[ T = \frac{d_t \cdot t_0}{60} \text{ [h/year]}, \]

where \( d_t \) - number of transport operations per year; \( t_0 \) - transport operation time for a given mean [min].

\[ d_t = j_t \cdot d_l \text{ [transp. op./year]}, \]

where \( j_t \) - number of transport units; \( d_l \) - number of movements in the process.

\[ t_0 = t_j + t_z + t_w \text{ [min]}, \]

where \( t_j \) - movement specific time; \( t_z \) - loading time [min]; \( t_w \) - unloading time [min].

\[ t_j = \frac{L \cdot 2 \cdot 60}{V \cdot 100} \text{ [min]}, \]

where \( L \) - length of the transport route covered with the load [in m]; \( V \) - speed of the mean of transport [km/h]; 2 - the coefficient allowing for the return route of the mean of transport, provided the speed in both directions is identical.

Therefore, for the investigated case, the required number of means of transport is:

\[ i_{tr} = \frac{598}{190} \times 0.6 = 5.24 = 6 \text{ pcs.} \]

Based on the made calculations (partial calculations were not presented in the article for the sake of its clarity, but their results were the basis for the calculation of the main index, i.e. the required number of transport trucks), the investigated company, at this point, needs a maximum of 6 transport trucks. From the company data as well as the observations, it becomes evident that at this point the company has as many as 13 transport trucks, which is over 50% more than actually needed. Such excess may generate unnecessary costs resulting from maintenance and operation of the trucks. During the interviews with the personnel, the authors of this article obtained information on the degree of utilization of the trucks owned by the company. Many of those trucks are not used as frequently as they should be, which means they remain idle for most of the time. Maintaining this situation over a long period of time causes frequent battery issues, as batteries become flat if the trucks are not used; this is problematic if a given truck, with a flat battery, is needed for ongoing operations. What is more, two trucks from the fleet have never been used. Throughout their warranty periods, all trucks were serviced on regular basis. In spite of this, two trucks needed repair, as prolonged downtime significantly affected their usability and they were not fit for use. Therefore, it is vital to have an adequate number of means of internal transport. Having too many means of transport is not economically justified, as it generates unnecessary costs.

3. Assessment of the Degree of Utilization of Means of Transport

Having selected the right type of means of transport, one should assess the degree of its utilization it terms of its load, the distance covered with the load and work time utilization. All these calculations are made in order to make sure the mean of transport is utilized correctly. The best and the most common approach is to make these calculations in the course of the analysis of active transport used within the company. This does not eliminate the need to identify the times, when the means of transport are used to a lesser degree - in an intermittent system. The assessment may cover intensive use, i.e. encompassing carrying capacity and mileage of the transport trucks, as well as extensive use, encompassing such parameters as travel time or loading time of the investigated objects. Fig. 1 illustrates the parameters in question.
Due to the highly diversified nature of the stock kept by the company, recording and registering the weight of transported loads does not seem feasible. Often, the transported loads differ significantly in terms of their weight and for this reason, the company does not keep data on their weight. Allowing for the capacity of the transport trucks used in the warehouse, the operators choose the loads in such a manner as to make sure the carrying capacity of the trucks is not exceeded. What can be assessed though, is the travel time; for this purpose, the following formula was applied (the mean carries out various operations):

\[ w_c = \frac{\sum_{i=1}^{d} t_{ji} + t_{zi}}{F_c}, \]

where \( t_{ji} \) - travel time within the operation \( i \) \([\text{h}]; t_{zi} \) - loading and unloading time within the operation \( i \) \([\text{h}]; F_c \) - effective time fund of the mean of transport.

In line with the information provided by the company, the time devoted to loading and unloading operations differs significantly, this results from the diversity of the kept stock. In some cases, the loading/unloading time is 9 minutes, while in other cases the operation may be very complex and may take approximately 13 minutes. The average time for such operations is 11 minutes for each one, thus there is a very diverse. In the event the transported load is large and heavy, the maximum travel time, including maneuvering, is 24 minutes. In the event the transported load is lighter and smaller, the travel time is reduced, significantly, to 10 minutes, therefore \( t_{ji} = 17 \) minutes. By using the above-mentioned data with the formula, the following result is obtained:

\[ w_c = \frac{21 + 17}{190} = 0.2. \]

Having analyzed the obtained results, one can notice that the value of coefficient we varies significantly from the desired value. In line with the previously adopted coefficient \( w_1 \), which equals 0.6. Coefficient we should be as close to that value as possible. This indicates that the degree of utilization of travel time and carrying capacity of the transport trucks is very low. As a result, there are forced downtimes of the transport trucks, which is an adverse and undesired phenomenon in any company.

4. Conclusions

Based on the analysis of the investigated case, the conclusion is that the company has too many transport trucks for its needs. Inventory movements are relatively small and thus the demand for means of internal transport should be adjusted to the needs of the company. In line with the presented calculations, the company needs 6 transport trucks, while at this point it has as many as 13. More than twice as many as needed. Additional calculations aiming at determining the degree of utilization of the means of transport indicate that the degree in question is low. This means that the transport trucks, for most of the time, are idle, which negatively affects their usability. As a consequence, this generates extra costs resulting from, inter alia, the need to carry out regular and paid (after the warranty period has expired) inspections or aging of particular elements, such as wheels. Therefore, it is of paramount importance to carry out, prior to the purchase decision, an in-depth analysis of the needs and warehouse operation model, while allowing for a number of factors, such as: frequency of inventory movements, size of the warehouse, type of stock as well as operation and purchase costs. Having too few trucks is a negative phenomenon, just as having too many. In both cases, the company incurs economically unjustified losses. The company should re-assess its needs and undertake measures aiming at mitigating the existing problem consisting in growing costs generated by unused equipment. At this stage, resale of the redundant trucks or their lease to other companies could be a good solution. If the company has other branches, it should be possible to transfer the trucks to other facilities, where they would be used on regular basis. There is a number of possibilities to avoid the situation presented in this article, one of them being leasing transport trucks as required. This option allows the company to increase or decrease the number of trucks according to its current needs as provided for in the relevant lease agreement. It appears that the company should undertake measures in order to reduce the number of transport trucks.

References

Consideration of Gender and Diversity Aspects in the Design of Interiors of Rail Vehicles

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Abstract

It is the aim of transport policy to transfer a very high proportion of road transport to sustainable public transport. To generate sufficient demand for public transport, it is essential to increase its attractiveness in all areas. Increasing the attractiveness on the one hand leads to a strong use of the system, while also to all those who are already users of public transport it leads to significant increases in comfort and thus in sustainable satisfaction.

In public transport, particularly in rail, there are a number of factors that have influence on the comfort for the passengers, for example acoustics, visuals or odour in the vehicle. Otherwise requirements while sitting or standing in the vehicle, separation from other travelers, sense of security, temperature sensitivity and many more. One of the most important factor is the stay in the vehicle. Therefore the aim must be to develop vehicles where as many passengers as possible feel comfortable.

With regard to the above factors, there are particular gender differences that are manifested mainly in different perceptions between women and men. In order to develop vehicles that provide a noticeable gain in comfort for all travelers the differentiated perception must be addressed which was intensively done in a research project. In applied scenarios the gender differences were translated so that both gender can be optimally addressed. The comfort criteria, the expectations and the current problem areas from the gender perspective were deeply analyzed. Based on that measures were developed on the different requirements from the perspective of women's and men's needs. The aim of the project was to develop a set of requirements for future vehicles which promise a gain in comfort for women and men. The paper will demonstrate the results and the main findings of the project and will show concrete suggestions for the design of the interior of rail vehicles in public transport.

KEY WORDS: Rail vehicles, Interior Design, Gender & Diversity

1. Introduction

The interior design is the main customer touchpoint in railway operations. First, it is thus important to focus on its design when taking the needs of customers into account. Second, breaking down all customers into specific groups allows for naming specific needs that might otherwise be ignored. This article focuses on the comfort factors relevant to the interior design of the passenger compartment of regional and urban rail transport vehicles.

2. Comfort Factors

The following comfort factors were chosen to be analyzed in terms of their relation to the interior design of the passenger compartment:

- Perceived Personal Safety;
- Personal Space/Individual Distance;
- Temperature Sensitivity;
- Acoustic Perception;
- Color;
- Olfactory Perception.

First of all, it is analyzed whether these factors differ with regard to their perception through various groups, specifically with regard to sex and gender. When citing differences, however, it is important to stress that actual behavior and neuroscience are not to be confused, especially with regard to gender differences. There is a “very long leap from neurons to actual behavior and the way experiences alter the brain.” [1]. In addition to that, Halpern, regarding cognitive abilities, states that “differences among average females and males tend to be much smaller than differences found among females and males with low and high abilities”.

Furthermore, differences derive not solely from sex, but from the interaction between biology and the environment, therefore the societal nature of gender cannot be overlooked when analyzing gender differences.
2.1. Perceived Personal Safety

With objective safety being the actual and quantifiable risk or the number of accidents or injuries, subjective safety or perceived personal safety is the individual feeling or perception of safety. This is either equated with fear of crime i.e. being the victim of a crime in person or, beyond that, captures concerns of indirect impairment as well, such as concerns about mass petty crime or violations of law or disturbances without legal consequences, in short, concerns of violations that do not imply direct involvement [2].

Linking landscape architecture with human evolution in his conception of habitat theory, Appleton [3] initially proposed the prospect-refuge theory. As an ecologically based theory for analyzing human behavior, it then became a framework for several researches, “especially those involving safety from crime in public spaces, such as urban greenways” [4]. Studies show that prospect and refuge affect people’s perception of the degree of safety of the environment [5]. This paper proposes the following principles when designing urban greenways that are both ‘green’ and safe:

- visibility of others;
- visibility by others;
- choice and control;
- solitude without isolation, and
- environmental awareness and legibility.

Extensive research has been done in the US concerning fear of crime in settings of neighborhood, often referring to the defensible space theory by [6]. [7] found that three variables were the most significant ones in explaining fear of crime:

- the presence of adequate maintenance;
- the presence of signs of community investment, and
- gender.

With regard to the influence of gender on perceived personal safety in public places, studies show that “the personal fears women express hamper their mobility” [8].

2.2. Personal Space/Individual Distance

The poem “Prologue: The Birth of Architecture” by W.H. Auden famously deals with the topic of personal space [9]:

Some thirty inches from my nose
The frontier of my Person goes,
And all the untillied air between
Is private pagus or demesne.
Stranger, unless with bedroom eyes
I beckon you to fraternize,
Beware of rudely crossing it:
I have no gun, but I can spit.

W.H.Auden
Prologue: The Birth of Architecture

Interpersonal distance “helps to regulate intimacy by controlling sensory exposure”, which includes tactile, but also olfactory, visual, and auditory exposure [10]. [9] categorizes distances between humans in four categories (measurements derived from his remarks and according to [11] and [12]):

- intimate distance: 0 - 45 cm,
- personal distance: near personal distance 46 - 75 cm, far personal distance: 76 - 120 cm,
- social distance: 120 - 365 cm, and
- public distance: 365 - 762 cm

Personal distance “might be thought of as a small protective sphere or bubble that an organism maintains between itself and others” and represents the limit of physical domination at an “arm’s length”. It is the sphere associated with one’s own psychological claim of ownership. Conversely, the degree of vicinity one allows another person can be seen as an indicator for the quality of the relationship and is shaped by cultural norms and socialization. Interestingly, individual spacing that leads to personal space invasions “is a more salient environmental condition than density per se.” [13]. Evans’ & Werner’s experiment showed that with mass transit, immediate seating density provokes adverse reactions while density of the car itself was inconsequential.

Concerning gender differences, a Japanese study found that personal space is smaller with same-gender individuals than with opposite-gender individuals [14]. This is supported by other, US-american studies [11]. However, others have found no statistical significance regarding distance and the size of personal space (Fig. 1) [15].
2.3. Temperature Sensitivity

Thermoregulation and a body’s thermal response to heat cannot be dealt with considering merely sex. Thermal response to exogenous heat load depends on the ratio of body surface to body mass, subcutaneous fat content and exercise capacity [16]. “When these differences are eliminated in experimental studies, it appears that women’s sweating response to heat load is still smaller than that of men.” [16]. Women’s core body temperature, however, is on the same level as men’s because of greater evaporative efficiency of sweating.

A 1978 study looked at the paradigm that women are less heat tolerant than men and found that “[m]uch of the difference is related to women’s relatively low level of physical fitness and lack of heat acclimatization, which are in turn a result of their traditionally sedentary lifestyle.” More important determining factors than gender are body size, physical fitness, and state of acclimatization [17].

Regarding body temperature and age, the paradigm “older and colder” was found to be valid in studies [18, 19], although [20] found that this does not apply to all older adults and the factors ambient temperature and gender also account for temperature variation.

2.4. Acoustic Perception

In [21] it was found that “[f]or rising intensity, females perceived more loudness change than males, a finding consistent with a greater sense of warning. For falling intensity, males perceived more loudness change than females.” This means that women are more susceptible to an increase in loudness and men to a decrease.

Alongside with other studies, [22] found that women “are more sensitive to a given physical range of tones than are males”.

In an earlier work, [23] compared male and female gender based on their average maximum comfort level and found that women’s level “was consistently about 8 dB lower than that of men” [24]. Sax [24], though, points to the fact that each of the studies he cites “also documented substantial variation among males and among females.”

2.5. Color

The theorizing about psychological effect of colors has been a field of study since Goethe’s Theory of Colors [Zur Farbenlehre] in 1810. [25] has done a review of theoretical and empirical work on the psychological functioning of color. In his work, he cites empirical findings. Among those supported by a minimum of five independent laboratories, there are:

- “Red stimuli have been shown to receive an attentional advantage”;
- “Blue light has been shown to increase subjective alertness and performance on attention-based tasks”;
- “Viewing red prior to challenging cognitive tasks has been shown to undermine performance”;
- “Viewing red on self or other has been shown to increase appraisals of aggressiveness/dominance”;
- “Blue stores/logos have been shown to increase quality and trustworthiness appraisals”.

2.6. Olfactory Perception

Olfactory abilities refer to different aspects of olfactory perception, e.g. sensitivity, familiarity, and identification.

The majority of studies point to the superiority of women concerning detection and sensitivity in perception of many odors, although “some studies failed to find any significant differences between males and females” [26]. “Sex differences in olfaction are largely restricted to tasks that require higher cognitive processing such as odor identification and memory” [27-29].

Regarding the hedonic valency, i.e. the pleasant/unpleasant character of an odor, according to [26], there are only rare studies comparing the perception of men and women. The National Geographic Smell Survey [30] showed that men preferred amyl acetate (pear and banana like odors) and mercaptan (milk, cheese like odors) more than women and
women preferred eugenol (clove) and rose more than men. Concerning identification of particular odors with the correct name, various studies found that women consistently show better results than men, irrespective of their ethnic or cultural background [26]. Perception of odors relating to social significance is also higher in women meaning that women can recognize other people by their smell more often than men (see [26] for sources).

The superiority of women concerning olfactory perception cannot be merely explained by difference in experience since their superiority is also extended to ‘male’ odors [31].

In short, [26] comparing various studies on sexual dimorphism on olfactory perception found that “sex differences have been shown in sensitivity-detection and recognition-identification tasks, and the superiority of women is more evident in these instances when the odours are related to a human origin.”

3. Comfort Factors in Rail Vehicles

With regard to passenger comfort in rail vehicles, all of the above-mentioned comfort factors come in place and suggestions could be made based upon the findings with regard to them. Since perceived personal safety and individual distance are highly influential, these factors have been taken into account in the design of the interiors.

In particular, designs for trams and subways were carried out. These were created in a 2D view (Fig. 2), from which 3D renderings for visualization were created (Fig. 3). These drafts were discussed with representatives of transport companies and reviewed for feasibility. From this, recommendations for the future design of rail vehicle interiors were made, including a catalogue with general recommendations such as:

- sufficient personnel space;
- free view from the vehicle;
- holding possibilities;
- Storage facilities (backpack, bags);
- protected standing area.

![Fig. 2 Top view interior design tram [32]](image)

![Fig. 3 Rendering interior design tram [32]](image)

4. Conclusions

The comfort factors temperature sensitivity, acoustic perception, color and olfactory perception have in common that there are no clear differences between men and women. Some tendencies are discernible, but these are often very low. With regard to the design of the interiors of rail vehicles, these factors were therefore dealt with at a lower level in the project. The focus was on the factors perceived personal safety and personal space/individual distance. Designs of interiors for different user groups were created for this purpose. These have been prepared in accordance with the principles applicable to the criteria.

Acknowledgements

This paper is a result of the research project Multisensuelles Fahrzeug which is funded by the Austrian Ministry for Transport, Innovation and Technology within the program “Talente”.
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Parameters of the Reliability and Risk Level for Repair and Track Maintained Work Improving

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Abstract

The article is devoted to the planning of medium repairs of a railway track based on the indices of reliability and risk levels of the elements of the permanent way. The author describes the criteria for the choice of different variants, ultimate risk limit in evaluation of gauge and subgrade conditions.

KEY WORDS: railway track, traffic safety, technology of planning of track repairs, reliability index, risk level

1. Introduction

The existing system of railway track control allows the component failure in between regulated inspections, and part of the time the system will function with a faulty component. The primarily maintained sections are those where the failures of a higher level (according to the degree of danger) are recorded. If there is a partial damage, the sections with a lower permissible speed have a priority [1, 2].

Plan development of repair and engineering works should be carried out on the basis of a complete analysis of track evaluation, the forecast of track change with time due to reserves of track facilities and the results of track maintenance and carrying out of track repairs.

The planning of medium repair (MR) of a railway track must to base on the indices of reliability and risk levels of the elements of the permanent way [4-7].

2. The Selection of Sections for Medium Repairs

The main criterion for the selection of sections for Medium Repairs (MR) is considered to be ballast pollution. It determines the technical condition of the gauge to the fullest extent (up to 70%) - the formation of track depressions, track twists and deviations in the plan. The principal criterion for the necessity to clean the ballast should be its loss of the bearing capacity when it becomes impossible to eliminate the deterioration of gauge geometry with the use of full machine surfacing. The need to replace the ballast occurs where there is gravel of soft rock in the track; there is a necessity to replace asbestos or other types of the ballast with gravel one (Fig. 1). Cut ballast is not allowed to lay on the embankment slopes because it complicates water filtration out of the subgrade and its natural drainage.

Deep ballast shoulder cleaning during the repair works considerably increases the track stability; nevertheless, the degree of stability after the repairs remains insufficient especially if we take into account the amount of costs for the large and medium track repair. Alongside with the violations of the repair techniques and the presence of season deformations, the main reasons for such a situation are a little amount of gravel renewal during the cleaning process. As a result, around 30% of all repair works comprising gravel cleaning do not improve gauge geometry. To increase the track stability it is necessary to make the renewal of gravel during its deep cleaning not less than by 50% of its amount with the preservation of appropriate particle size distribution.

Due to the fact that the condition of the ballast shoulder in the period between repairs depends on the timely repair for improvement (cleaning or cutting out of the dirt), we can come to the conclusion that in this period not less than two medium repairs of the improvement of the ballast shoulder and intermediate cleaning of local areas should be carried out.
To evaluate the actual condition of the ballast shoulder, they use such means of monitoring as rail spotters of the model KVL-P, the train set for infrastructure diagnostics "ERA" equipped with the system of video monitoring and video control, the ground penetrating radar of the embankment and ballast shoulder layers, as well as the results of the spring and autumn inspections of the track. The evaluation of the ballast condition is carried out according to the following data: a graphic diagram of optional parameters of characteristics of sleepers, fastenings, the ballast layer, the subgrade and dimensions, the ballast condition sheet – to identify and register geometrical parameters of the ballast shoulder; georadar data which allow to fix the thickness of ballast; records of surveillance video with the help of which the areas of ballast liquefaction (pumping) are found. Additional criteria to choose sections for the medium repair are the percentage of unfit timber sleepers and fastenings (see Fig. 2). Discharge index limit of the elements of the permanent way for the appointment of the medium repair on the sections of the continuous welded and jointed tracks is based on the actual track condition at the time of inspection on interlocking 1 and 2. The results of calculations are given in Tables 1 – 4.

<table>
<thead>
<tr>
<th>Track class</th>
<th>Ultimate discharge index limit of fastenings per 1 km, %</th>
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<tbody>
<tr>
<td></td>
<td>Group A</td>
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<tr>
<td>1-3 jointed track</td>
<td>10</td>
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<tr>
<td>1-3 continuous welded track</td>
<td>10.0</td>
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Table 1

<table>
<thead>
<tr>
<th>Track class</th>
<th>Ultimate index limit of sleeper quantity with pumping per 1 km, %</th>
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<tbody>
<tr>
<td></td>
<td>Group A</td>
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<tr>
<td>jointed track</td>
<td>0.9</td>
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<tr>
<td>continuous welded track</td>
<td>1.3</td>
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Table 2

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<th>Track class</th>
<th>Passed tonnage, million tons gross</th>
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<td>1</td>
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Table 3

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<td>6</td>
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</table>

Table 4

Note to Table 1 is that criteria for the repair appointment according to Track Facility Operating System Regulation of JSC "RZD" 2015 [3]. It is possible to determine the unfitness of fastenings per one kilometer on a sample basis: on two joints of 25 m (on a continuous welded track with reinforced concrete sleepers – on two sections of the track with the length of 25). The control of the condition of the fastening elements can be carried out with rail spotters of the model KVL-P equipped with the system of video control of rail fastenings, the train set for infrastructure diagnostics "Era" and during track inspections. The analysis of the actual condition of fastening elements is carried out with the use of the following output forms: a sheet of joint gaps of more than a given value, a gap condition complete sheet, a sheet of failures required speed limit in train traffic due to the parameters of rail and joint condition, a joint gap regulation sheet, a totals sheet of evaluation of rail and joint condition, a sheet of gap characteristics of a continuous welded track, a sheet of welded rail displacements, a summary sheet of evaluation of main track condition.

Note to Table 2 is that criteria for the repair appointment according to Track Facility Operating System Regulation of JSC "RZD" too [3]. Gravel contamination and pumping quantity are evaluated in the year preceding the
time of track repair appointment, the pumping that have been eliminated during the year are also included in pumping quantity. To appoint the terms of medium repair of a track on the basis of stability index and risk levels, it is necessary to take into account the condition of timber sleepers on the jointed track structure. In Table 3 there are criteria to choose the sections due to the value of ultimate discharge index limit of timber sleepers per 1 km of a track.

The procedure of determination of ultimate discharge index limit of timber sleepers per 1 km of a track $\zeta_{slp}$ is the following. First it is defined coefficient of proportionality of ultimate discharge value limit of timber sleepers per 1 km of a track and passed standard tonnage for the given track structure on interlocking [1, 2, 4]

$$\zeta_{slp} = \alpha_{slp} \cdot T_{0} \cdot K_{t}$$

(1)

here $\alpha_{slp}$ - ultimate discharge value limit of timber sleepers per 1 km of a track; $K_{t}$ - parameter of time registration of sleeper operation, years (at $t \leq 6$ years, $K_{t} = 1$); $T_{0}$ - passed standard tonnage for the given track structure.

$$K_{t} = 1 + 0.01 \cdot (t - 6)^{2}$$

(2)

here $t$ - actual time in years (or defined as passed tonnage related to section tonnage).

Then, in accordance to Track Facility Operating System Regulation of JSC "RZD" [3], it is defined from column 2 (see Table 3) a limit quantity of unfit and defective sleepers per 1 km of a track depending on the track class (the percentage of unfit and defective sleepers per 1 km is converted into items).

After that the calculation $\zeta_{slp}$ on interlocking 1 is done. The final results of the calculation $\zeta_{slp}$ at different tonnage time are expressed in percents of ultimate quantity of unfit and defective sleepers per 1 km of a permanent way (see column 2, Table 3).

The terms of "an unfit sleeper" and "a defective sleeper" are divided when repairs are appointed that comes in contradiction of Sleeper Facility Operating Instruction. To unfit sleepers belong ones that provide the gauge stability, and to defective sleepers belong ones that are included into the catalog of defects.

To reduce the quantity of unfit sleepers, first of all it is necessary to do spacing of "couples of sleepers" on the curved track sections and then on the straight ones. According to the results of track inspections it is necessary to take into account joints with an excessive number of unfit sleepers which remain on the track after spacing of "couples of sleepers" and provide address control of sleeper facility operating.

Unfit sleepers are replaced on the joints where the traffic speed is reduced by ultimate quantity of unfit sleepers on the joint. Works should be done on the curved sections in the first turn. Defective sleepers liable to taking out of the track on a regular basis are replaced during scheduled works. The presence of unfit sleepers and "couples of sleepers" may effect on the occurrence of deviations of degree II and III.

Reinforced concrete sleepers used on the railways allow time of operating up to 800 million tons gross and more. The proportion of unfit fastenings is 2÷3% during the given period. Totally the proportion of the elements demanding the replacement will not exceed 15% when there are unfit sleepers with time of operating of tonnage 1 billion tons gross and more.

During spring and autumn inspections it is necessary to point out in details the type of a defect, damage of timber and reinforced concrete sleepers; as a result it is possible to trace the degree of defect development under which the sleepers are liable to repair and replacement on a regular basis or an urgent one.

The frequency of monitoring of sleeper condition take place once a quarter with the use of rail spotters of the model KVL-P or the train set for infrastructure diagnostics "ERA" and twice a year during spring and autumn commission inspections [5-7].

Deviations from the sleeper maintenance fixed by the software of rail spotters KVL-P and the train set for infrastructure diagnostics "Era" are converted into the following output forms: a summary sheet of condition of sleepers, fastenings, subgrade and dimensions, a sheet of speed restrictions due to condition parameters of sleepers, fastenings, subgrade and dimensions, a sheet of deviations of degree III due to condition parameters of sleepers, fastenings, subgrade and dimensions, a graphic diagram of condition characteristics of sleepers, fastenings, subgrade and dimensions, a summery sheet of sleeper and fastening condition.

3. Conclusions

The analysis of condition of sleepers on the basis of the above mentioned forms allow to appoint the list of works more precisely in order to carry out hard medium and medium repairs of a track. The control of sleeper condition is possible with the use of the results of video monitoring of the train set for infrastructure diagnostics.

The main type of the repair on the main tracks should be Medium Repair in different forms which are also applied in the period between repairs. Plan development of repair and engineering works should be carried out on the basis of a complete analysis of track evaluation, the forecast of track change with time due to reserves of track facilities and the results of track maintenance and carrying out of track repairs.

The existing system of railway track control allows the component failure in between regulated inspections, and part of the time the system will function with a faulty component. The primarily maintained sections are those where the failures of a higher level (according to the degree of danger) are recorded. If there is a partial damage, the sections
with a lower permissible speed have a priority.

The planning of medium repair (MR) of a railway track must to base on the indices of reliability and risk levels of the elements of the permanent way.

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The Quantitative Assessment of Passenger Transportation by Railways

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Abstract

The article deals with the quantitative assessment of passenger transportation by railways, presents competitiveness analysis from a theoretical point view. The article presents analysis of Quantitative Research Results, where are showed ways how can solve general problems of transportation of passengers by railways.

KEY WORDS: railways, passenger transportation, quantitative assessment

1. Introduction

Road transport dominance over other modes of transport is indisputable. However, in comparison with other modes of transport, rail transport is a viable and competitive activity that is important in solving the problems of the national transport system: increasing traffic volumes for road pavement construction and traffic intensity, environmental pollution, and increasing road traffic safety.

It is possible to distinguish at least three stages of economic development: economic growth, decline and stabilization by observing the last years when Lithuania's accession to the European Union. With regard to the state of Lithuania's economy, the passenger transport market responded to changes in different ways. By trying to adapt to the current situation, acting under the laws of economics and competitiveness, developed strategies for ongoing activities, tried to maintain the existing customer segment and attract new ones. During the economic downturn (in 2008 – 2010), competition has reached the highest level due to a shrinking market. A large part of the companies providing passenger services did not keep up and go bankrupt, part of their operations were loss making, hoping for better times. With the recovery of the economy, the total number of passengers carried was steadily increasing, but the number of passengers travelling by rail decreased.

2. Study of the Competitive Environment of Passenger Transportation by Railway

2.1. Competitiveness Analysis from a Theoretical Point of View

Competition is the environment of an organization's activity that consists of direct or indirect interaction of market players with an organization that has a beneficial or adverse effect on the organization's activities.

The competition is a struggle or an adversarial competition, while in the business world it is an adventure to conquer a consumer or business on the market [1, 2]. In summary, competition it can be say to be a struggle and a competition mechanism, and the consumer of goods or services is the winner. The most important benefit to him is the ability to choose from producer, quality and price [3].

However, it should be borne in mind that it is necessary to pay attention to product differentiation as a measure of competition and monopoly in the market [4]. Unlike Chamberlin, Robinson argues that large companies influence market parameters and regulate economic processes.

Schumpeter presented the theory of economics and highlighted the functional approach to the definition of competition. In the theory of economic development, he defines competition as an old competition with a new one. In this case, new concepts are introduce: effective competition and effective monopoly. According to J. Schumpeter, an effective monopoly is a positive factor for the dynamics of the economy [4].

According to P. Fisk, Z. Gineitiene, direct factors are those factors that are independent of the organization - they are the same for all organizations (customers, suppliers, competitors, etc.), and the by-factors are different for each branch of economy (economic, social, political - legal, technological, ecological factors), depending on the specifics of the organization's activities [5-7].

The balance of the organization's activities is primarily due to the environment, since the organization is an open system, therefore its success will largely depend on whether the organization will be able to correctly assess the direct and secondary factors of the competitive environment [8, 12].

2.2. The Analysis of Comparison of Transportation Passenger by Different Transport Modes

In the analysis of individual modes of transport, it can be distinguished that land transport consists of the main three transport groups: passenger cars; other land transport; rail transport. According to Eurostat data, in the European Union (EU) countries since 2004, The most popular vehicle among passengers was cars. The aforementioned vehicle in the EU countries accounts for an average of 83.3% of all land transport. Compared to the EU average, in Lithuania cars are still more popular than 91%. Other land transport includes such vehicles as interurban, city buses, trolleybuses, etc.
On average, this vehicle has about 10% of land transport. Meanwhile, in Lithuania, other land cover amounts to 8.6%. The EU countries that are leading this indicator are Bulgaria, Cyprus, Hungary, and Slovakia [9].

As in the rest of the EU, as in Lithuania, rarely passengers are choosing rail transport. On average, only 7.3% of passengers used this mode of transport in the EU. Austrian, Danish, Dutch, and French travel mainly on trains. Rail transport in Lithuania occupies only an average of 0.8% of the market.

In addition to land transport, the following are also of particular importance for water and air transport:

- **Water transport.** Water transport consists of two - maritime and inland waterway transport modes. With regard to this mode of transport, it can be argued that it is more related to the carriage of goods than with passengers. However, it also has a large number of people. In the analysis of statistics, it can be stated that the number of people traveling by sea since 2009 decreases. In Europe, this mode is mainly used in Italy, Greece and Denmark. In Lithuania, on average, 286 thousand are used for sea transport of passengers.

- **Air Transport.** Observing trends in air travel passengers in the EU countries shows that since 2010, more and more people are using this mode - an average of 833 million people annually. By comparing the analysis of available data, it can be concluded that in the case of new flights, passengers who had previously opted for maritime transport began to choose this mode of transport as a result of the decrease in fares. The United Kingdom, Germany, Spain and France are leading the airline. In Lithuania, this indicator is on average 2.8 million passengers.

Based on the efficiency of passenger transport processes, the different modes of transport aim to improve the overall efficiency of the transport system [10] and ensure the competitiveness of the service.

On the other hand, combining the advantages of transport modes can achieve a reasonable balance between transport costs and time. Providing transport services to customers makes it possible to better plan time, reduce costs, thereby increasing the competitiveness of certain modes of transportation [10].

All companies, irrespective of the mode of transport, provide a practically identical service - it transports passengers. Therefore, the quality of the services provided, the additional conditions or discounts granted by the carriers play an exclusive role in this business. Also, the cost of the transportation service, the travel time and infrastructure are also very important.

JSC “Lithuanian railways” was established on 4th of September in 1991. Today, she is strong, valued by colleagues and partners, profitable work, investing heavily, offering the most sought after services.

This company is currently the only company in Lithuania that carries out passenger and freight transportation by rail, which has monoply rights in the market, has a full disposition of all the assets attributed to rail transport, has the greatest potential to operate in the company's EU railway system. The main users of JSC “Lithuanian railways” on local traffic: passengers traveling to and from work; students and pupils, as well as those who have privileges. The main users of JSC “Lithuanian railways” in international traffic: passengers traveling to visit relatives; passengers traveling on business and commercial trips or holiday.

Regarding the competitive environment of Lithuanian railways, the main competitors are companies that carry passengers in road transport. These are companies offering buses, minibuses or taxis. A very important aspect is the use of personal vehicles, because it helps to save time, gives comfort to the movement, freedom and the opportunity to go from door to door. Therefore, in a sense, private transport becomes the biggest competitor of Lithuanian railways. In this regard, the study of customer satisfaction and services is an important factor.

### 3. Analysis of Quantitative Research Results

**Research methodology.** In order to analyze the impact of passengers on the services of JSC “Lithuanian railways”, a quantitative survey was selected. According to Gamova for the determination of the number of respondents in the quantitative survey (survey) and the reliability and representativeness of the study, a sample was selected which, at the time of the calculation, was an error of 5%, in order to obtain 95 percent reliability data.

The research sample was carried out according to the Paniott formula:

$$n = \frac{1}{(\Delta^2 + \frac{1}{N})}$$  \hspace{1cm} (1)

The size of the appropriate aggregate is \(N\)-120; Sample size \(n\) - 106; Likelihood of probability \(P\) - 0.95; Error \(\Delta\) - 0.05.

Questionnaires were distributed to users of JSC. 120 questionnaires were sent out, from which 106 correctly filled out questionnaires were received. Based on these data, it can be stated that 95% of the reliability of the test results is fully met [11].

**Results of quantitative survey of passengers using rail transport**

In the evaluation of quantitative survey results, the majority of respondents were female (62%), and more than one third of respondents were male (38%) [11].

Having evaluated the distribution of respondents by age group, it was determined that the majority of respondents belong to the age group over 65 (16%).

According to the distribution of respondents by social status, it was found that the majority of respondents traveling by rail are working (44%), less than a quarter of respondents traveling by rail are unemployed (18%), pensioners (16%), pupils (12%), and students (10%). Based on the results of the study, it can be noted that rail transport
is mostly used by workers who sometimes travel by rail to workplaces.

After evaluating the distribution of respondents according to their place of residence, the majority of respondents indicated that they live in Vilnius (32%), while less than a quarter of respondents indicated that they live in Kaunas (18%), Trakai (16%), Klaipėda (14%), and only a few respondents noted that they live in Alytus (8%), in Šiauliai (6%), and in Panevėžys (6 percent). The results of the survey showed that the majority of the railways were visited by city residents (Vilnius, Kaunas, Klaipėda), as well as a quarter of the respondents made up the people of Trakai, traveling to work in the big city (Vilnius).

After the distribution of respondents according to the choice of the vehicle for travel, the majority of respondents indicated that they prefer to travel by rail (78%), while less than a quarter of respondents indicated that they chose road transport (12%), and only a few respondents indicated that traveling in a hybrid (by several means) (6%), by air (4%). The results of the survey showed that rail travel is most often used for travels in recent times.

Based on the distribution of respondents for reasons not selected by rail, it was found that 68% of the respondents did not select rail transport due to poor traffic, and less than a quarter of respondents did not select rail transport due to poor service quality (18%), high ticket prices (14%). The data obtained during the survey showed that the greatest shortage of Lithuanian railways, due to which rail transport is not selected, is becoming poor communication with other cities and objects in their country.

Following the distribution of respondents according to the direction of travel, the majority of respondents indicated that they mostly travel by rail in Lithuania (64%), while more than one third of respondents choose rail travel abroad (36%). According to the results of the research, it was found that the majority of respondents travel by rail in Lithuania, and only one third of them choose rail transport for trips abroad. The result may have been due to the fact that Lithuania does not yet sufficiently popularize rail travel services abroad. However, it is foreseen that the construction of new railways in the future and the improvement of rail links with the EU and CIS countries will increase the popularity of rail travel and increase the number of rail travel to foreign countries [11].

Having estimated the distribution of respondents according to the time spent by JSC “Lithuanian railways”, the majority of respondents indicated that rail transport has been traveling for over 5 years (36%), while less than one third of respondents travel by rail from 3 to 5 years (28%), from 1 to 2 years (24%), up to 1 year (12%). The results of the survey showed that more than a third of respondents have traveled by rail for more than 5 years. It is planned that, in the future, improving the connection not only with Lithuanian cities but also with many foreign countries, the renewal of the railway fleet and the creation of a larger number of travel routes will increase the number of travelers every year.

After assessing the distribution of respondents according to the frequency of using the services of JSC, it was determined that the majority of respondents mostly use rail transport 2-3 times a month (34%), as more than a quarter of respondents travel on rail once a week (22%), less than a quarter of respondents travel by rail every year (18%), travel daily (16%), once a month (10%). The results of the survey showed that the majority of respondents by rail travel 2 to 3 times a month, and only a little less than a quarter of respondents travel by rail daily. These results showed that respondents mostly choose road vehicles, while rail transport is third in terms of car and bus transport.

After evaluating the distribution of respondents according to the purpose of the trip while traveling by rail, the majority of respondents indicated that they ride for rest (44%), while more than one third of respondents indicated that they were moving to the workplace by rail (34%), and more than a quarter respondents noted that they go to the educational institution by rail (22%). Based on the results, it was found that the majority of respondents choose rail transport while traveling to rest and go to work. In view of these answers, suggestions can be made for improving the convenience of travel by rail, while traveling for rest. Also, by expanding access to rail transport for people traveling to workplaces, improving the use of the Internet and developing new services that help prepare for work.

Regarding to Gamova V. when assessing the factors contributing to the competitiveness of rail transport, the majority of respondents noted that the competitiveness of railways was ensured by safety during the trip (36%), comfort (32%), while more than a quarter of respondents indicated that rail competitiveness was ensured by ticket prices (22%), travel speed (10%). The results of the research showed that rail transport is the most appreciated for this transport safety and convenience. These answers of respondents could have been caused by the fact that JSC renewed its fleet by purchasing innovative high-speed trains that are safe and comfortable.

After evaluating the distribution of respondents according to the method of purchasing railway tickets, the majority of respondents noted that tickets are usually purchased at the ticket office (70%), less than a quarter of respondents buy tickets online (16%), buy tickets on a train (14%). The results of the survey showed that most rail passengers usually purchase a ticket at the ticket office in the usual way, and few, with the help of online services, purchase a new ticket online or on the train. These results may have been due to the fact that uncommon travelers are often unaware of railways or are afraid to use them due to lack of information on how to purchase a ticket online. Rarely traveling by rail is often unaware of the fact that tickets are available on the train. In order to increase the use of rail tickets for rail travel and the Internet service, it is necessary to increase the awareness of the Lithuanian public about the availability of these services.

When assessing the quality of passenger transportation services provided by JSC “Lithuanian railways”, the majority of respondents noted that the quality of passenger transportation services provided was satisfactory (34%), while less than a third of respondents indicated that the quality of the provided passenger transport services was high (26%), less than a quarter of respondents indicated that the quality of passenger transportation services provided was very high (18%), low (12%), very low (10%). Based on the results of the study, it can be stated that a significant proportion of respondents consider rail transport to be satisfactory.
Having evaluated the distribution of respondents according to the fact that there is often a problem with transport by JSC, the majority of respondents indicated that they had never encountered problems with rail transport (44%), sometimes encountered problems with rail transport (42%), and less than a quarter of respondents often encounter problems when traveling by rail (14%).

When assessing the choice of rail transport that determines the main factors, the majority of respondents noted that the choice of rail transport and its competitiveness compared to other modes is determined by the safety of travel (32%); less than a third of respondents indicated that the choice of rail transport is due to the possibility to travel to (14%), ticket availability (14%), travel timetables (12%), staffing competence (10%), speed of service (10%), comfort of travel (8%).

Having evaluated the distribution of respondents in assessing the advantages of rail transport, which determines the competitiveness of JSC, compared to other modes of transport, less than a quarter of respondents indicated that rail transport provides access to regular tickets (14%), the possibility to purchase tickets online (12%), relatively low ticket prices (12%), high speed trains (12%), access to non-stop destination points (12%), preferential systems (10%), and only a few respondents noted that they were given the opportunity to purchase a ticket on the train (6%), rail transport is characterized by quality of service (4%), more space and space than other vehicles (4%), due to the convenient time of trains (4%), opportunities to relax and read (4%), the possibility to travel to larger groups of passengers (4%).

When assessing the deficiencies in the transport of JSC “Lithuanian railways”, the vast majority of respondents noted that one of the biggest drawbacks was the long travel time (18%), lack of service services (16%), low traffic speed (16%), poor the quality of vehicles (14%), the lack of security (12%), and only a few respondents noted that one of the major drawbacks was the poor coordination of rail and bus work (6%), expensive tickets (6%), inappropriate traffic timetables (4%), poor stations (4%), lack of comfort (4%).

Regarding to Gamova V. in assessing who the largest share of investments is to be made by JSC, in order to improve the competitiveness of its services, the majority of respondents noted that the improvement of the information system on provision of travel traffic (32%), less than a third of respondents indicated that the new wagons (26%), less than a quarter of respondents indicated that the most investments are necessary for the protection of passengers (16%), reconstruction of stations (14%), reconstruction of roads (12%). When assessing the possibility of increasing the competitiveness of railways services in comparison with other vehicles, the majority of respondents indicated that improving the compatibility of local bus traffic with existing trains (14%), creating optimal routes (14%), improving the quality of the premises and ensure their cleanliness (12%), increase parking space (12%), improve communication with other transport modes (12%), provide security at the railway station (10%), improve the electronic ticketing system (8%) and etc.

4. Conclusions

The Results of quantitative survey of passengers using rail transport showed that most of the respondents choose rail transport for work, training, and rest.

The research revealed that the choice of rail transport is determined by its safety, timetable comfort, punctuality, comfort and travel during travel.

Having regard to the competitiveness of rail transport in comparison with other modes of transport, it was found that this was affected by ticket prices and the availability of regular tickets, paid travel on the Internet or on a train, travel benefits, and the possibility of traveling in large groups.

Considering the major deficiencies in rail travel, it has been found necessary to invest in upgrading railway stations, protecting passengers during the journey, purchasing new wagons and rolling stock, improving travel information, improving the compatibility of train traffic with public transport, creating optimal routes and etc.

References

Models of Cost-Efficient Transportation of Unified Loads in the International Approach for the Purpose of Defense Logistics

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Abstract

Management decisions in relation to transport processes lead to the necessity of making multi-criteria choices in the scope of acquiring means of transport or choosing a carrier. Entities ordering transport services integrate on a voluntary basis, joining specific programs and initiatives. Therefore, they do not revise the potential use of specialized carriers who compete with each other in terms of transport capacity. One of many criteria for the financial evaluation of an enterprise is its profitability. The article is an attempt to adapt solutions based on profitability related to the selection of a carrier for the needs of logistics in the area of international security.

KEY WORDS: logistics, profitability, transportation system, decision support

1. Introduction

Decision makers responsible for transport are guided most often by the rule of the most favorable (optimal) variant of the choice of transport service, provided by a specific carrier [1, 2]. In global terms, individual countries integrate on a voluntary basis, joining specific programs and initiatives. Therefore, they do not revise the potential possibilities of using specialized carriers, who attempt to interest entities from the defense sector with their own offer of competitive transport capacity. However, public spending turns to be more and more transparent, which encourages public sector entities to be more clarity and rational spending. In this case, financial tools commonly used for years help become helpful.

One of many criteria for financial evaluation in the organization is its profitability. The article is an attempt to adapt solutions based on profitability for the needs of selecting a carrier in case of defense logistics.

2. The Essence of Profitability

Profitability, otherwise known as profitability is a parameter reflecting the effectiveness of capital held by an entrepreneur and the effectiveness of asset management [5]. Efficiency is an economic category used primarily as a criterion for business assessment both at the level of the entire enterprise and its individual areas. In the case of profitability assessment, efficiency is understood in economic terms. Profitability ratios are also known as rates of return. They measure economy expressed by the relation of effects to inputs [5].

The operating profit or net profit is a measure of effects in the case of profitability ratios. Thus, the generated profit determines the level of profitability (effectiveness) of the resources used. Profitability refers to the flow, while profitability to the status. The size of the achieved profitability should be compared with previous periods, with the plan, with other enterprises, direct competitors or industry indicators. Profitability is the quotient of profit and the financial size in which it is calculated and is most often expressed as a percentage.

Profitability ratios are one of the most important measures of assessing the financial condition of an enterprise. They are used to determine the direction and pace of changes in profitability. Thanks to the ratio of the indicator, it can be used to compare different companies. They are often used in strategic planning. For correct assessment of the profitability of the company, it is important to know individual profitability ratios and their appropriate selection to the specifics of the company.

The profitability analysis distinguishes: sales (trade) profitability, asset profitability (economic), profitability of capital employed (financial). The following are distinguished among the profitability types: sales profitability (ROS), return on assets (ROA), return on equity (ROE), profitability - return on investment (ROI).

When examining profitability in a comprehensive way, you can use the Du Pont model. Du Pont's analysis has had a huge impact on the views of economists and continues to occupy an important place in the arsenal of methods for assessing the financial condition of the company [6].
3. Model Description and Research Methodology

Du Pont's analysis (Du Pont's model, also called the Du Pont's pyramid) is a method of comprehensive profitability assessment based on a pyramidal system. It allows you to synthetically assess the financial situation of the company. It combines the results from the balance sheet and profit and loss account with financial analysis of indicators [6].

In the Du Ponta Pyramid, the main role in financial controlling plays three relationships (Fig. 1): Return on Equity (ROE), Return on Assets (ROA) and net profitability (Net Profit Margin).

![Fig. 1 ROE/ROA/NPM relations in the Du Ponta pyramid](image)

Thanks to these three indicators, it is possible to compare enterprises regardless of the type of activity. These comparisons make it easier to make strategic decisions regarding investment, production, capital allocation or services (including transport services).

The main objective of Du Pont's analysis is to identify key areas of the company's operations that currently affect the return on equity of the company and whose future changes may improve or worsen the company's financial situation. The information provided by the pyramid model is of key importance for both the management and other recipients (stakeholders) of economic information flowing from the enterprise [7].

The Du Pont model is based on selected items of the balance sheet and profit and loss account. It presents causal relationships between very general indicators (such as ROE or ROA) as well as indicators occurring at lower levels of the pyramid (net profitability - ROS or asset turnover - TAT). The layout of the pyramid allows analysis both in the system from the general to the detail (from the top of the pyramid to the bottom of the pyramid) and in the system from detail to the general (from "the base" to "the tip"). Thanks to such an in-depth analysis, it is possible to not only complete and comprehensive assessment of the current activity of the company, but also predict the further direction and pace of its development. The pyramid layout also allows for analysis in terms of time, retrospective and prognostic (ex post, ex ante) [11].

4. Application of Du Pont's Analysis in Transport

Many carriers maintain an open policy while revealing the financial results of their operations. As can be seen from the above analyzes, one of many criteria for the financial assessment of the carrier (service provider) is its profitability. In the case of the carrier, it is the profitability of sales of transport services, and the profitability ratio in this respect is the quotient of positive (CIF) and negative (COF) cash flows taking into account the cost of capital (r). In financial mathematics described as PI and written in the form of a quotient:

$$PI(x) = \frac{\sum_{i=0}^{n} CIF}{(1+r)^{i}} \frac{\sum_{i=0}^{n} COF}{(1+r)^{i}},$$

where:

$$\sum_{i=0}^{n} CIF \frac{1}{(1+r)^{i}}$$ - is the sum of the positive flows of the carrier x,

when:

$$\sum_{i=0}^{n} COF \frac{1}{(1+r)^{i}}$$ - is the sum of the negative flows of the carrier,

where $PI$ – Profitability Index$^1$; $r$ – oznacza koszt kapitału; $n$ – number of years.

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$^1$ When the profitability ratio $PI > 1$ is initially accepted, the project is to be implemented. The higher the value of the $PI$ index, the more profitable the investment seems to be. Profitability ratio is used to select the most effective among several investment projects.
In international transport, for the needs of defense logistics, where there is an urgent need to deliver supplies to the operation areas, transport means of various uses are used [8-10]. Decisions are determined by the technical capabilities of the means, in particular the load and range. Guided by such criteria, the means of transport (air) can be divided as in Table 1.

### Table 1

<table>
<thead>
<tr>
<th>criteria / division</th>
<th>tactical (level T)</th>
<th>strategic (level S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load</td>
<td>Low (≤ 20 t)</td>
<td>High (&gt; 20 t)</td>
</tr>
<tr>
<td>Range</td>
<td>Small (≤ 3000 km)</td>
<td>Great (&gt; 3000 km)</td>
</tr>
<tr>
<td>Cost</td>
<td>x ( \rightarrow ) min</td>
<td>y ( \rightarrow ) min</td>
</tr>
<tr>
<td>Accessibility</td>
<td>YES</td>
<td>NO</td>
</tr>
</tbody>
</table>

Analysis of data from the Ministry of Defense shows that using only own means of transport (level T) generates costs at the level of x, and using only one carrier (level S) costs at the level of y. The Ministry of Defense (the participating country) as a public finance entity is beneficiary of budgetary funds. Rational planning of the ministry's logistics policy (including transport issues) is therefore in the interest of taxpayers and should be subjected to specific research and analysis, and the conclusions from the research should be introduced as adjusted variables for logistic modeling in the future without the need to "cling" to the existing ones (not necessarily effective solutions). Further on, the concept of consolidation of transport processes and its impact on the profitability of carriers was presented. The methodology sums up the analysis of ROS and ROA analysis.

### 5. Consolidation of Transport Processes as a Factor of Cost Reduction

It is extremely important to react dynamically to changes occurring on global markets in the scope of carrier offers and if possible to diversify external bidders (until a common transport policy based on means of transport from own resources has been developed) ².

Responding to external threats requires from states of EU a coherent policy of managing logistic (including transport) resources as well as available (external) resources. The policy of consolidation of transport processes is at the current stage of European integration the only possible and economically justified solution ensuring the effectiveness of solutions at the assumed level of costs. The implementation of intercontinental traffic to the destination of operational areas based on long-term contracts with a specific carrier (eg Volga - Dniepr Gmbh) is currently a costly doubtful solution, and additionally more and more difficult due to political considerations. Consideration should be given to entrusting some or all transport orders to competing companies of the air transport sector, which from year to year expand their offer, adapting their business profile to the requirements of the defense sector of EU countries.

![Fig. 2 The impact of integrated transport processes on the carrier's profitability](image)

Panalpina (Governmental & Defense Business) research (Fig. 3) shows a general relationship between the level of profitability \( (r_1 - r_3) \) and the consolidation of transport processes \( (k_1 - k_3) \). This is due to the high level of profitability of sales of transport services, which is directly impacted by the PI coefficient taking into account or decreasing as a result of consolidation of transport processes - the cost of capital \( (r) \). The measure of cost calculation is: the cost of transporting 1 kg of actual or 1 kg of volume, whichever is greater. It may be a situation that a product with given dimensions weighs 50 kg but it is deleted as a commodity with a weight of e.g. 75 kg, because it is overall large. Carriers on the transport services market set their prices, which calculates, depending on the size (capacity) of available units, routes of transport and load of a given direction [3, 4]. The profitability of the aircraft itself is determined depending on its maintenance costs. The price always consists of 3 elements: the cost of transporting 1kg or 1Vkg (volume of a kilogram), fuel supplement of 1kg and so-called. security (safety factor) from

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² For example, in the years preceding the introduction of the A400M into operation.
every kilogram. Most often the total transport cost is calculated according to the formula\(^3\):

\[
K_c = K_p + K_{ast} + K_{rio} + K_{inne},
\]

where \(K_c\) – total cost of transport; \(K_p\) – cost of fuel; \(K_{ast}\) – depreciation cost of an asset (aircraft); \(K_{rio}\) – cost of repair and maintenance; \(K_{inne}\) – other cost.

However, the specificity of transported cargo requires a special product orientation (eg hazardous materials), and thus the costs related to the loss or damage of the cargo. By modifying the above, the transport cost should be presented as:

\[
K_t = K_p (1\text{kg}/1\text{Vkg}) + K_{dp} (1\text{kg}/1\text{Vkg}) + K_{us} (1\text{kg}/1\text{Vkg}) + K_{ud} (0.15 X),
\]

where \(K_p (1\text{kg}/1\text{Vkg})\) – transport cost depending on 1kg or volumekilogram (Vkg) \(K_{dp} (1\text{kg}/1\text{Vkg})\) – cost of additional fuel; \(K_{us} (1\text{kg}/1\text{Vkg})\) – cost of standard insurance; \(K_{ud} (0.15 X)\) – cost of additional insurance; \(X\) – value of cargo; \(K_{ast}\) – depreciation cost of asset (aircraft); \(K_{rio}\) – cost of repair and maintenance.

The carrier is normally insured against formal and legal activities and thus has insured planes (military planes are not insured). However, it does not mean that in case of a disaster or loss of goods, 100% of the value of the parcel is paid. It is in fact, about 5-20% of its value. Therefore, always the sending unit can insure the goods at 100% of its value at the carrier. The cost of insurance is about 0.15% of the value of the shipment.

Therefore, the actual cost of 1 hour of the flight of a commercial airplane flying on different routes and to different airports with different quantities of goods is difficult to determine. You can not specify a precise price, but you can be tempted for an average value based on specific assumptions. This is what makes commercial companies more competitive than a model based on fixed international framework agreements, based on which the cost of 1 hour of flight regardless of the goods, route and airports is calculated at the highest possible level.

![Fig. 3 Transportation cost of the chosen carriers](image)

In commercial companies, you pay for a specific shipment which goes much cheaper for the recipient. Figure 3 compares the cost of transport of selected carriers (in €/h)\(^4\). Currently, carriers aim to reduce operating costs by introducing modern, cheaper aircraft (for example, the use of the newest B-747 saves about 15% of fuel). Many carriers also change engines to more economical ones.

6. Conclusion

The dynamic environment, constant changes in regulations and the need to adapt to them, as well as the development of competition, significantly impede the functioning of enterprises on the market. Operating in such an environment, frequent index analysis of the company is necessary and constant monitoring of the assets and financial situation of the company in order to be able to properly direct the subsequent strategic actions taken.

The analyzed material mainly focuses on the most popular method of determining profitability, using net profit. There were presented tools for mathematical analysis of profitability using the Du Pont model on the base on own research and data from Panalpina transport company. It should be remembered that profitability analysis may also use other values from the profit and loss account, such as, for example, gross profit on sales or operating profit.

It is worth emphasizing that it is not possible to indicate a specific profitability indicator that would be appropriate or expected by carriers. Its value depends to a large extent not only on the size of the entity, but also on the industry in which it operates. In practice, the best solution is to compare the profitability of one company to the profitability of another company - but of similar size and operate in the same industry or compare the rate of return on sales in relation to 2 years.

In sum, the financial result may be positive - then it is called profit and the enterprise is described as profitable. In the case of a negative financial result, we talk about loss, and we call it such a deficit. The loss does not mean that the

\(^3\) Calculation used by Panalpina Polska

\(^4\) SALIS – an international transport program for NATO countries
company develops incorrectly. Before formulating such conclusion, it is necessary to carefully examine what has become the reason for such a result. For example, it may happen that the company generated a loss as a result of accounting operations. On the other hand, net profit may be derived from higher financial revenues, while the profitability of core operations decreases.

References

Self-Organized Learning Algorithm for Immune Neuro-Fuzzy Anti-collision System of Autonomous Unmanned Aerial Vehicles’ Team

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Abstract

In this research authors propose the improved algorithm for collision prevention based on the combination of immune neural network and fuzzy logic for the team of autonomous unmanned electrical aerial vehicles (UAVs) cooperatively reaching the common goal. The mathematical model for cooperative and safe task performance of the UAVs is developed, target function for self-organized learning of the immune neuro-fuzzy control system is defined. Information, decisions and corresponding actions of each team participant are distributed between UAVs, so each autonomous device should make and optimal decision between safety and performance criteria, i.e. for safe maneuver leading towards the team goal achievement. UAVs’ team members share the data from each other and learn to make better decisions by unsupervised learning immune neuro-fuzzy algorithm. The experimental proofs of mathematical and computer modelling, as well as practical experiments of the multi-rotor helicopter prototype are provided.

KEY WORDS: Unmanned aerial vehicle; anti-collision system; aerial vehicle’s team; electric drive; immune neuro-fuzzy logic

1. Introduction

The use of aerial vehicles for industrial purposes began relatively recently. In Australia drones are equipped with artificial intelligence powered software that can distinguish sharks from dolphins, wales, boats, and other marine life in real-time with 90% accuracy. Drones could help detect potential terrorists in public spaces, merely by measuring anomalies in their heart rates, according to Chahl, a Professor of Sensor Systems in UniSA’s School of Engineering. All these possibilities of use aerial vehicles prove the relevance of the topic.

All over the world, companies are trying to embed artificial intellect (AI) in the vehicles and to provide the autonomous drive, and unmanned aerial vehicles, such as drones or quadcopters, not an exception. In 2016 S.Roelofsen, A.Martini and D.Gillet proposed a collision avoidance algorithm for unmanned aerial vehicles with limited field of view constraints [1]. Authors presented a safe collision avoidance algorithm based on potential fields for fixed-wing unmanned aerial vehicles (UAVs) with constrained field of view sensors such as cameras. They demonstrated the effectiveness of the proposed method with several simulations, including one with randomized trajectories covering a large set of possible configurations. In difference with a mentioned research, this paper deals with a collision avoidance of rotorcraft vehicles.

In [2] conflict resolution was achieved with obstacle trajectory data taken from a simulated camera and range-finder in the presence of their respective measurement uncertainties. M.Hehn and R.D’Andrea proposed an algorithm for the real-time trajectory generation for quadcopters [3]. The ability to plan trajectories from non-rest conditions was used in conjunction with way points in order to guide vehicles around obstacles without stopping.

In this study, the main focus is still on the UAV speed changing of the multiply UAV collision prevention between themselves. In 2014 anti-collision system for navigation inside an UAV using fuzzy controllers and range sensors [4] was proposed. In that research authors were working to provide a system that will help to prevent UAV collisions with obstacles, but nothing about collisions with other UAVs was said. In 2013 a comparative study of collision avoidance techniques for unmanned aerial vehicles was presents and published by A. Alexopoulos and others [5]. The first collision avoidance method in that study was based on a geometric approach which computes a direction of avoidance from the flight direction and simple geometric equations. The second technique used virtual repulsive force fields causing the UAV to be repelled by obstacles. The last method was a grid-based online path re-planning algorithm with A* search that finds a collision free path during flight. Various flight scenarios were defined including static and dynamic obstacles. In difference of that research, we provide a system, were dynamic obstacles are UAVs, and all these dynamic obstacles are communicating with each other, providing a team work. In [6] authors propose a control algorithm of multiple unmanned electrical aerial vehicles for their collision prevention.

2. Problem Formulation

The algorithm described in this paper prevents collisions between UAVs’ team members in tasks of several UAVs working in one area.

In general, there are several ways to avoid the collision between UAVs of the same team:
This research allows significantly improve the previously developed algorithm of UAV anti-collision system that allowed to avoid collisions by appropriate altitude selection.

The goal of the current research is to develop the algorithm for autonomous UAV, that will give possibility for UAVs to train themselves without a teacher to avoid the collisions in the most effective way by changing the UAVs speed and without human intervention, i.e. the system should be self-organized.

For that purpose authors have developed a use of immune neuro-fuzzy logic method to minimize collision probability.

3. Anti-Collision System Structure

The proposed anti-collision system is not centralized and is distributed among the UAVs of the team. All calculations and decision making are made by the immune neuro-fuzzy anti-collision system embedded in each UAV separately. Fig. 1 shows the structure of the proposed system.

There are communication components ensuring data transmission, such as satellite positioning system – GNSS (such as GALILEO, GPS etc.) and radio frequency modules – RF.

Each UAV of the team has embedded electronic device DTR – control components to obtain the position, to calculate the motion parameters, to communicate with other devices and to control the electric drive of UAV.

![Fig.1 Structure of the anti-collision system of UAVs](image)

DTR device of the UAV receives the information about UAV location by GNSS and information about other UAVs location, speed and movement direction by RF.

INN performs the collision prevention function by the following steps:

Step 1. Fuzzy logic (FL) makes a risk assessment. If the collision probability is high enough, than Step 2 is made and INN calculates necessary speed changes, otherwise no further calculations and changes are needed.

Step 2. The affinity algorithm (AA) compares the similarity of the current situation with all situations that stored in the immune memory (IM) and finds the situation with the lowest discrepancy.

Step 3. INN specialized neurons use stored weights of the found similar situation and calculate speed change $\Delta v$ for UAV and other vehicles.

Step 4. Target function (TF) calculates the collision probability $P$ of UAV taking in account changed speed.

Step 5. Decision making algorithm (DM) evaluates the found solution by multiple criteria optimization minimizing of collision probability $P$ and UAV’s speed change $\Delta v$.

Step 6. If the criteria are satisfied ($P$ is close to zero and $\Delta v$ is as small as possible), data about the situation and INN weights are saved in the IM and necessary speed changes $\Delta v$ are sent to the DTR device.

Step 7. DTR controls the UAVs electric drive (power electronics elements PE and electric motor M) to change the speed and transmits the information about the suggested speed change to other vehicles.

4. Mathematical Model of Anti-Collision Immune Neural Network and Fuzzy Logic

In this paper, immune neuro-fuzzy control proposed to be taken as intelligent control method. While fuzzy logic provides an inference mechanism under cognitive uncertainty in reactions to the UAV situation danger level, computational immune neural networks offer exciting advantages, such as learning, adaptation, fault tolerance, parallelism and generalization.[7].

The mathematical model of the UAVs’ team represents the set of autonomous unmanned aerial vehicles whose actions agree with certain rules and with only common interests.

The set of UAVs is given:
\begin{equation}
UAVS = (UAV_1, ..., UAV_n). \tag{1}
\end{equation}

The utility function as a common interest function is:
\begin{equation}
U = w(x, a_1, a_2, ..., a_n) \rightarrow opt, \tag{2}
\end{equation}
where \( u \) – utility function – common interest function; \( x \) – state of the environment; \( a_i \) – action of the \( i \)-th UAV.

The information of each UAV depends on the state of environment:
\begin{equation}
y_i = \alpha_i(x), \tag{3}
\end{equation}
where \( y_i \) – information of \( i \)-th UAV.

The decision rule of \( i \)-th UAV results an action of \( i \)-th quadcopter and depends on the information:
\begin{equation}
a_i = \beta_i \leq (y_i), \tag{4}
\end{equation}
where \( \beta_i \) – decision rule of \( i \)-th UAV.

Interaction between \( i \)-th and \( j \)-th UAV:
\begin{equation}
q_{ij} = \frac{\partial w}{\partial a_i \partial a_j}. \tag{5}
\end{equation}

A set of decision rules is optimal if:
\begin{equation}
E(S) = E\left[w\left(x, \{\beta_i(y_i) \mid i = 1, ..., n\}\right)\right] \rightarrow \text{max for a given probability distribution on } x
\end{equation}

For anticollision task the set of possible points of potential collisions is defined:
\begin{equation}
P = (p_1, p_2, ..., p_n). \tag{6}
\end{equation}

The location \( L_{UAV} \) of UAVs is represented by three subsets \(< \chi^c_{UAV}, \psi^c_{UAV}, \eta^c_{UAV} >, \tag{7}
\end{equation}
that are latitude \( \chi \), longitude \( \psi \) and altitude \( \eta \):
\begin{equation}
\chi^c_{UAV} = \{\chi^c_1, \chi^c_2, ..., \chi^c_n\}, \psi^c_{UAV} = \{\psi^c_1, \psi^c_2, ..., \psi^c_n\}, \eta^c_{UAV} = \{\eta^c_1, \eta^c_2, ..., \eta^c_n\}, \tag{7}
\end{equation}
where \( \chi^c \) – latitude of the current point; \( \psi^c \) – longitude of the current point; \( \eta^c \) – altitude of the current point.

The common goal defined in this paper is to reach and successfully pass all points of potential collision of UAVs are defined by these sets of geographical coordinates:
\begin{equation}
\chi^p_i = \{\chi^p_{i1}, \chi^p_{i2}, ..., \chi^p_{in}\}, \psi^p_i = \{\psi^p_{i1}, \psi^p_{i2}, ..., \psi^p_{in}\}, \eta^p_i = \{\eta^p_{i1}, \eta^p_{i2}, ..., \eta^p_{in}\}; \tag{8}
\end{equation}
\begin{equation}
\chi^e_i = \{\chi^e_{i1}, \chi^e_{i2}, ..., \chi^e_{in}\}, \psi^e_i = \{\psi^e_{i1}, \psi^e_{i2}, ..., \psi^e_{in}\}, \eta^e_i = \{\eta^e_{i1}, \eta^e_{i2}, ..., \eta^e_{in}\}, \tag{9}
\end{equation}
where \( \chi^p_i \) – latitude of the beginning point of potential collision; \( \psi^p_i \) – longitude of the beginning point of potential collision; \( \eta^p_i \) – altitude of the beginning point of potential collision; \( \chi^e_i \) – latitude of the ending point of potential collision; \( \psi^e_i \) – longitude of the ending point of potential collision; \( \eta^e_i \) – altitude of the ending point of potential collision; \( c \) – number of trajectories point of potential collision.

The safety criterion defined in the previous paper is still actual:
\begin{equation}
D = \|UAV_{UAV}\| = \sqrt{(\chi^c_i - \chi^c_j)^2 + (\psi^c_i - \psi^c_j)^2 + (\eta^c_i - \eta^c_j)^2} > S, \tag{10}
\end{equation}
where \( S \) is safety distance limit for each pair of \(< \text{UAV}_i, \text{UAV}_j >, \text{, } i = 1, ..., n, \text{, } j = 1, ..., n, \text{, } i \neq j \).

It is obvious that in case if \( \chi^c_{UAV_i} = \chi^c_{UAV_j} = \chi_{tp} \text{ AND } \psi^c_{UAV_i} = \psi^c_{UAV_j} = \psi_{tp} \text{ AND } \eta^c_{UAV_i} = \eta^c_{UAV_j} = \eta_{tp} \) the
safety criteria can not be satisfied, because \( D = 0 \).

So, the common target function with anticollision criteria is following:

\[
\begin{align*}
\max P_{\text{max}} (\Delta v) & = \max \{ P_{ij} \} \to \min \\
\Delta v_x (\Delta v) & = \sum_{i=1}^{n} \Delta v_i \to \min \\
D & = |UAV_i, UAV_j| > S \\
& \quad i = 1..n \\
& \quad j = 1..n \\
& \quad i \neq j
\end{align*}
\]

(11)

where \( P_{\text{max}} \) - the maximum collision probability; \( P_{ij} = (P(<UAV_1, UAV_2>),...,P(<UAV_i, UAV_j>),...,P(<UAV_n-1, UAV_n>)) \)

- set of probabilities of collision for all pairs of UAVs \(<UAV_i, UAV_j>\), \( i \neq j, \ 1 \leq i,j \leq n \)

The proposed INN can be used as one of the tools to assess and improve the situation on a point of potential collision and UAV traffic optimization. The structure of INN is presented in Fig. 2.

![Fig. 2 Immune neural network structure](image)

The prosed INN for UAV consists of one input, one layer with specialized neurons \( \mu \) and one output layer. Input data \( V_i \) (unmanned aerial vehicle’s speed) and \( d_i \) (distance from unmanned aerial vehicle till the possible collision point with another aerial vehicles) enters the input layer. From the input layer these data are sent to the AA (affinity algorithm) and \( \mu \) layer, which is made of \( \mu \) neurons. AA checks all the similar situations, stored in the database in the IM (immune memory) and calculates the discrepancies. Situation with a smallest discrepancy is chosen and it’s number \( \alpha \) is sent to the \( \mu \) neurons. Each \( \mu \) neuron has an immune memory. Here situations’ numbers are stored together with weights \( w_\alpha \), which were used while solving the exact problem i.e. processing the similar input data. After \( \mu \) neuron received from the AA number of the situation \( \alpha \), the coefficient \( \beta = w_\alpha \) is selected from the immune memory of the \( \mu \) neuron and training is started with found weights application. The activation function of each traditional neuron generates an output for speed change \( \Delta v_i \) for each unmanned aerial vehicle. Collision probability \( P_{\text{max}} \) is also calculated by using fitness function \( F \). If the collision probability is bigger than specified then weights of \( \mu \) neurons are changed by the training algorithm \( \beta = TA(\beta) \) and new values of weights are sent to the \( \mu \) layer and training is repeated. If the collision probability \( P_{\text{max}} \) is less or equal to specified, than the information about the number of the situation and weights \( w_\alpha \), which were used to solve the optimization task, are saved into the immune memory of \( \mu \) neurons, number of the situation and input data are saved into the immune memory database and decision about necessary speed change of the UAV is transmitted to the vehicle’s embedded electronic device DTR.

Input layer contains the antigen, defined by a set of following input tuples:

\[
X = (d, V) = \left( d_1^1, v_1^1, d_2^1, v_2^1, ..., d_k^1, v_k^1, d_1^2, v_1^2, ..., d_k^2, v_k^2, ..., d_n^m, v_n^m \right)
= \left( x_{11}, x_{12}, ..., x_{21}, x_{22}, ..., x_{k1}, x_{k2} \right),
\]

(12)

where \( k \) – number of points of potential collision for all controlled UAV in the area of visibility of anti-collision system; \( d_{ij}^a \) - distance (m) of each UAV \( u \in U \) moving towards the \( j \)-th point of potential collision; \( v_{ij}^a \) - actual speed (m/s) of UAV vehicle \( u \in U \) moving towards the \( j \)-th point of potential collision; additionally each UAV transmits the following data to the control system of the UAV with INN.

The output layer of INN contains the set of neurons generating antibodies for the task solution to minimize multiple
criteria target function. In this task the antibody is represented by the set of speed changes for each UAV unit: 

\[ \Delta V = (\Delta v_1, \Delta v_2, \ldots, \Delta v_n) \]

The assessment of antibody-antigen fitness is performed using two criteria target function, which in general form is following:

\[
F(\Delta V) = \begin{cases} 
P_{\text{max}} = \max(P_{ij}) \rightarrow \min \\
\Delta V = \sum \alpha_i \Delta v_i \rightarrow \min 
\end{cases}
\]

(13)

General fuzzy logic structure, shown in the Fig. 3, consists of input as a risk level of recognized objects, membership functions for risk assessment, rule database for selection of actions and defuzzification functions for the level of the activity. In these models, relations among variables are described by means of if–then rules with fuzzy predicates. Fuzzy sets are defined through their membership functions (denoted by \(\mu\)) which map the elements of the considered universe to the unit interval [0, 1]. The extreme values 1 and 0 denote complete membership and non-membership, respectively, while a degree between 0 and 1 means partial membership in the fuzzy set. A particular domain element can simultaneously belong to several sets (with different degrees of membership) [8]. In Fig. 3, for instance, 45% of risk belongs to the set of high risk with membership 0.2 and to the set of medium risk with membership 0.8. We can suppose which action must be chosen for the crash prevention after defining the level of the risk in percentages. This gradual transition from membership to non-membership facilitates a smooth outcome of the reasoning (deduction) with fuzzy if–then rules, in fact a kind of interpolation [8].

![Fig. 3 Partitioning of the risk domain into four fuzzy sets](image)

5. Immune Neural Network Data Processing Algorithm

The algorithm of INN consists of the following steps.

Step 0. Initializing input parameters for the algorithm, the technical details of embedded device should be taken in account such as CPU clock rate, RAM size, non-volatile data storage size etc. Initialized parameters are: \(T_{\text{max}}\) - maximal number of INN training iterations; \(\epsilon_{\text{lim}}\) - maximal match error, responsible for creation new record in IM or replacing the existing; \(P_{\text{safe}}\) - maximal acceptable (safe) value of collision probability; \(r\) - coefficient for speed reduction to avoid the collision if solution is not found \(0 < r \leq 1\).

Step 1. Input data \(X = (x_{11}, x_{12}, x_{21}, x_{22}, \ldots, x_{n1}, x_{n2})\), where \(x_{ij} = d_{ij}, x_{i2} = v_i\) received about \(n\) objects approaching point of potential collision.

Step 2. The affinity algorithm AA (X, S) checks all \(m\) situations stored in data base \(S = \{s_1, s_2, \ldots, s_m\}\), calculates the discrepancies:

\[
E = (e_1, \ldots, e_n), \text{ where } e_j = \sum_{i=0}^{n} \sum_{k=0}^{2} \left( \frac{x_{ik} - x_{jk}}{x_{ik}} \right)^2,
\]

(14)

and finds the closest match \(\alpha\), where \(e_{\alpha} = \min(E)\).

All the data in IM is stored in clusters for easier and faster match finding process [9]. For example, if three UAVs are participating in the possible collision situation, there is no need to find the similar situation in the group of situations with two participants. Therefore, method of clustering is used for data storage in IM and faster affinity algorithm work.

Step 3. The value \(\alpha\) is one of activating input of each \(\mu\) (special neurons). When \(\alpha\) is received, the coefficient \(\beta = w_{\alpha}\) is selected from the immune memory of the \(\mu\) neuron. Iteration counter \(t = 0\).

Step 4. Neuron is activated only if \(\alpha\) is received or if new \(\beta\) are received from the training algorithm TA to feedforward the gained input value \(x = \beta\) and increase iteration counter \(t = t + 1\).

Step 5. The activation function of each traditional neuron generates an output for speed change \(\Delta v_i\) for each object.

Step 6. The fitness function \(F\) calculates the probability of collision \(P_{\text{max}}\).

Step 7. If \(P_{\text{max}} > P_{\text{safe}}\) then coefficients of \(\mu\) neurons are changed by the training algorithm \(\beta = TA(\beta)\) and if \(t < T_{\text{max}}\) repeat from Step 4.

Step 8. If \(P_{\text{max}} < P_{\text{safe}}\) then the activating signal \(\gamma\) is transmitted to both situations database and each M neurons.

Step 9. If \(t > T_{\text{max}}\) then situation can not be solved in the defined time, so the safe solution is necessary. In this
paper such solution is speed reduction $\Delta v_i = -r \cdot v$ and END algorithm else go to Step 10

**Step 10.** When $\gamma$ is active and

if $\varepsilon_\gamma > \varepsilon_{lim}$, then each M neuron saves the existing coefficient as $w_m+1 = \beta$, the IM saves the situation $X$ as $s_m+1 = X$ and $m = m + 1$

else if $\varepsilon_\gamma \leq \varepsilon_{lim}$, then $w_m = \beta$, the record $\alpha$ in the IM is updated. $s_n = X$,

**Step 11.** END of the algorithm.

6. Computer Models and Experiment

Any maneuvers of the quadcopter requires to know the exact rotation speed of the propeller engines and necessary Euler angles.

For this purpose a Simulink model for the quadcopter UAV for angles calculations was developed (Fig. 4).

A computer experiment of the developed program of implemented algorithm was made (Fig. 5).

The conditions for experiment are following: four routes are selected; UAV are selected in pairs in opposite direction; one cross point is defined; 40 km/h is defined as nominal UAV speed, speed is allowed to increase up to 60 km/h to avoid collision. Collision probability changes from 0 to 1, maximal value of target function is set as 0.04, motion speed criteria is defined as following - nominal speed minus speed difference, divided by nominal speed.

![Fig. 4 Simulink model for the quadcopter UAV](image1)

![Fig. 5 Point of potential collision computer model](image2)
For each UAV the inputs for Artificial Neural Network (ANN) are motion speed of all UAV’s and their distance to point of potential collision, including own. According to this data, each UAV own INN to get speed change satisfying the target function. The decision to accelerate or brake is adjustable by specific collision sensitivity index. At beginning of self-training algorithm, the first set of weights appropriate to target function is taken to memory pool. The number of iterations is limited to 200, to find the optimal speed change decision. If no result, speed is decreased in double. All UAV collision contacts are recorded in array.

The INN calculate the necessary speed change, however each UAV has acceleration and deceleration rate, that does not allow to change the speed immediately.

Three simulations with the same experimental conditions were made to prove the efficiency of the developed algorithm.

Experiment Nr.1 – no any motion control is used. For 30 minutes simulation 110 collisions are detected.

Experiment Nr.2 – usual neural network (NN) is used for motion control. Immune memory is not applicable. Each UAV uses random weights for the target function minimization. For 30 minutes simulation 19 collisions are detected.

Experiment Nr.3 – proposed Immune Neural Network (INN) with Immune memory is used for motion control. For 30 minutes simulation no collisions is detected.

The comparison of the amount of collisions in different experiments is shown in Fig. 6.

Another parameter to compare ordinary neural network NN and immune neural network INN is a number of iterations for self-training to obtain target function satisfying decision.

The comparison of number of iterations for the one vehicle is shown at Fig. 7. At the beginning of experiment the number of iterations for both structures are approximately the same, because at the beginning of simulation INN is untrained and no much data of the best solutions are in the immune memory. When training is done and immune memory is full enough with good examples, INN find out better solutions and update the immune memory.

At the end of experiment the results show, that NN need more iterations as INN to solve the same task, this significantly increases processing time and leads to a bigger amount of collisions. This explains the amount of fixed accidents by using NN in the Fig. 6.

7. Conclusions

The developed self-organized learning algorithm for immune neuro-fuzzy anti-collision system of autonomous unmanned aerial vehicles’ team is working correctly.

Experiment shows, that all unmanned aerial vehicles reached their target point without any collisions by changing only one target parameter – speed of the flight.
As the proposed devices are embedded into the UAVs there is no necessity to involve infrastructure and devices can work regardless of location, also in forest or over reservoirs.

Developed devices with INN can be used in transport collision prevention control systems.

Developed unsupervised learning method is successfully used for INN.

INN helps to minimize time for processing and decision making.

Proposed additional layer, immune memory and developed affinity algorithm of INN allow increasing performance compared to traditional ANN.

INN is able to significantly reduce the collision probability.

As computer experiment proves, it is not necessary to assign the master or slave roles for UAVs. All vehicles are using self-learning INN and created algorithm can control safe motion on the routes by themselves.

Application of artificial neural network is justified by ability to use stochastic self-learning algorithm for neuron network training with random numbers selection, thus weight changes according uniform distribution principle, therefore the possibility to allocate the same weight for different UAV is excluded. This hypothesis is proved by computer experiment.

It is necessary to develop prediction algorithms for the location and velocity to continue the calculation, if the data receiving is delayed.

Further step of improvements is a collision avoidance between UAVs by trajectory change and integration of all methods in a safety control system of UAV.

References


Vehicle deformation includes traces of location of the most significant objective data. It has to be known for precise collision reconstruct. The less control variables are available, the more important is the importance of the available data. Because of the increase in driver assistance systems in modern vehicles, fewer and fewer "mechanical" traces (such as braking, drift, skid marks or even end positions, if the vehicles are post-collision-automated) are expected after traffic accidents. In this paper, the possibilities and limitations are presented by the most common methods of Energy Equivalent Speed (EES) value determination. Each of the investigated methods has a primary area of application, along with advantages and model-specific limitations. The authors developed the EES value determination procedure (with an integrated EES database) in the paper. Such procedure is designed for the use in accident reconstruction practice. Experience shows that the conditions for determining EES values are often not ideal. The validated EES value determination procedure is intended for use where such suboptimal conditions prevail. This procedure combines at least two EES value determination methods suitable for the case of application. By combining and weighting the results of several methods with different approaches, the disadvantages of one method can be compensated for by the advantages of the other methods and outliers revealed. This approach increases the validity of the result and ensures better reproducibility in EES value determination. Systematic errors caused by the relevant model and the user’s own error are largely compensated by the combination of several methods. Combining a visual (highly illustrative) method with the estimated (empirical) values of an expert panel and mathematical (scientifically justifiable) models ensures the possibility, as required by expert opinions in practice, of traceability for the technical layman and of verifiability for the expert.

**KEY WORDS:** traffic accident, safety, analysis, EES – Energy Equivalent Speed

1. Introduction

Except the tracks at the scene of the accident the deformation of the vehicle to the most important objective data, which must be known, in order to accurately reconstruct the impact velocity. The less control units available, the more important is the importance of known data. In relation to deformation energy, that its determination in the form of an EES value (equivalent energy speed) is particularly important in such cases, in which only a small amount of objective data is available. In view of the increase in deployment of modern vehicle assistance systems it is possible to expect in the future, in the case of traffic accidents, there will be less and less "mechanical" tracks available (such as brake, drift, shear, or even end positions, if the vehicles are automatically controlled after an accident). If, despite high-end systems, there is a collision, the damage, can be evaluated with respect to deformation energy. Even with good collisions the EES is an important control unit for the possibility of higher collision calculation validity, as well as its documentation in an expert report.

In the expert practice, no independent, scientifically recognized standardized and scalable method of complex EES determination. In practice, the most commonly used methods are the estimation of an expert, the use of simple calculation formulas, estimate in a circle of multiple experts based on their experience, visual comparison with impact test results and simulation results from a mathematical model based on the Crash3 method. Calculation options using MKP they are not in the normal analysis of traffic accidents, due to their financial and time-consuming demands. Each method has the advantage of being able to use it, but also negatives, which may be highlighted in its isolated application. From the previous experience of the work processor, that the use of formulas, as well as an EES value estimate by experienced experts can lead to acceptable results. According to Becke et al. [1] is the EES value determined by experts based generally only on their experiences. Estimates, however, that their isolated use cannot be done their test of accuracy, and also do not provide a tangible result, based on the procedure, which could be understood by laymen. Due to the lack of evidence of EES estimation it is not possible to examine the result of their estimation without, so that some of the exact EES determination methods are not used. In the absence of transparency, transparency is lacking and the possibility of
unambiguous scrutiny. In the case of transparency requirements when elaborating it is stated by the Institute of experiment: "Expert judgment is an expert judgment given or the real state of things that is understandable for laity and researched by experts. All the results and conclusions obtained must be justified and scrutiny." [12]. Burg pointed out in that regard, that "the expert's report must be clear, which was used in its processing. The key points and methods of analysis used are to be explained in detail." [2]

From the expert practice, in the isolated use of current most commonly used methods at an equivalent energy rate (EES) there may be an undetectable deficit. By combining and weighing each with methods used based on other principles may be narrowed to the specific boundaries of that method by taking advantage of other methods. This methodical process leads to ensure better accuracy of the result and reduces a systematic error, which could be caused by choosing an incorrect method.

2. Estimate by Experts

Results of the method "Estimate by experts" show that its use without using specific examples of impact tests or real cases can be marked as dangerous. Here, for example, Johannsen [13] that the tolerance band of highly experienced experts normally lies within ± 5 km / h. Especially at low speeds this flat-rate error of EES estimation as an important starting point for the analysis of traffic accidents to a large percentage of energy differences and resulting in a high instability of the result obtained about the impact velocity. With sufficient experience from experts, it is possible in principle to achieve good results. The results of the research, however, that the estimates of experienced experts may significantly deviate from the actual EES value. Even if the EES estimation method is deployed, expert forum is recommended and create a mean and a standard deviation from each estimate. It is also advisable to filter clearly incorrectly and error estimates.

Research has shown that, that they have the greatest error rate at an impact speed of less than 10 km / h (Fig. 1) as well as vehicles weighing less than 700 kg (eg motorcycles) and more than 3,000 kg (eg, trucks - see Fig. 1). In addition, that at a large difference in weight of two vehicles was the deformation energy of the heavier vehicle in six out of seven cases estimated to be too high.

![Fig. 1 Percentage difference between EES - mean value](image]

From the EES, the value exceeds 60 km / h only a very small amount of data is available for the analysis, so for this area of speed it is not possible to establish a valid result with technical correctness. An EES-pillar impact assessment of about 70 km / that most of the experts evaluated it too low (Fig. 2). This may be due to lack of experience in determining higher EES values and resulting in the resulting uncertainty. To get more accurate estimation of EES determination at higher speeds it is necessary to do more number of high-speed impact tests.

![Fig. 2 EES Estimation Result in Column Impact Test](image]

It is basically recommended to use "Estimate by experts" as the initial grading of the EES value or to ensure the result by combining from several methods based on other principles.
3. Visual Comparison

Becke et al. [1] states: "Various tests with experts have shown, that estimating the EES value without the help of comparative impact tests leads to a wide range of individual estimates." This is confirmed by the results of the research, carried out by the processor of this work. Under the comparative impact tests described above, crash tests, for which EES is known. Lorenz [15] that well documented and accurately assessed real-world accidents can be used as the basis for EES validation. How Humegan [11], that these can be used as an expanded experiment. Attempts showed that in the method "Visual comparison" it is necessary to set out clearly the boundary conditions with respect to the vehicle being compared, with comparability, in particular: year of production, mass and impact zone. [18, 19]. Due to continuous development and claims the passive safety of the vehicles changed their structural stiffness as well as the reference depth of deformations (Figs. 3 and 4).

Fig. 3 Deformations depending on weight and year of vehicle production: evaluation impact tests to the wall at a speed of 56 km/h [10, 14, 16]

Fig. 4 Structural stiffness, depending on the weight and the year of vehicle production: Impact test on the wall at a speed of 56 km/h [10, 14, 16]

Fig. 5 Visual comparison of different vehicles with a similar year of production [8]
Due to the deformation behavior of the vehicles, a division was made for the purpose of this work vehicles until the year 2000 and vehicles after the year 2000. This deformation behavior is related also with the introduction of various new test methods for impact tests (Fig. 5). With modern vehicles is the influence of weight on different vehicle models, respectively their classes in terms of structural stiffness and the deformation behavior visually less perceptible, but, as a result of the new destruction testing procedures, it may change again.

Variation of vehicle weight otherwise, identical impact conditions have an impact on deformation behavior, so the actual weight of the vehicle must be taken into account as a boundary condition to assess comparability. Important is, in order to ensure comparability, must be the area of damage and the direction of impact as likely as possible. Highest match when comparing vehicle for visual comparison is obtained in type and constructively identical vehicles of the same design, weight, year of manufacture, identical impact zone, and damage intensity. [4, 6, 17]

4. Mathematical Methods

This section examines the areas of use and the specific boundaries of the Crash 3 method called "3D EES model for vehicles based on accident data ". Attempts and investigations have shown that the use of the method Crash 3, which is the next development stage of the energy raster method requires accurate tracking of the vehicle being examined. Reconstruction of the deformation line based on the outgoing basis of photographic material may lead to errors (Fig. 6).

Fig. 6 Problems of defining the deformation line: various deformation lines more experts [9]

For structural stiffness data, it must be available data from vehicle impact tests, which are comparable in relation to the vehicle type, vehicle weight and year of manufacture. With modern vehicles (since 2000) are due to non-linear, as well as the jump patterns of structural stiffness (Fig. 7) necessary impact tests at relevant speed ranges [4, 17, 18].

Fig. 7 Runway Runways - Time from FEM simulation of different vehicles; a test speed of 60 km / h [9]

Two-dimensional mathematical models can not sufficiently take into account deformations at different levels with respect to the elevation axis. The 3D EES model for vehicles based on accident data is not universally available, so only theoretical conclusions were possible.
5. MKP Simulation

Burg [3] as an alternative to impact tests, it is possible to use MKP simulation to determine the EES. To use MKP calculations for the purpose of the analysis of traffic accidents, they are necessary knowledge of the specific boundaries of this method. To assess, what are the exact simulation models, available in the PC-Crash expert program were processors

The emphasis of research lies on practical use MKP simulations for the needs of traffic accident analysis and the detection of specific boundaries of this method. Attempts by the processor indicate, that the simulation model of Geo Metro from the PC-Crash program in the investigated impact configuration (Fig. 8) and in the speed range from 40 km / h to 60 km / h exhibits the best match with the LS-DYNA type model simulation model. In the higher, respectively lower test speeds deviations from deformation occurred and structural-rigid course. According to the results the maximum structural stiffness difference between models can reach up to 500 kN / m [7, 17].

The Chevrolet C2500 simulation model is best compared with the LS-DYNA simulation model at a full-coverage wall at a speed of about 60 km / h. Above and below 60 km / h deviations were observed during deformation and structural stiffness (structural stiffness difference between models up to 1,000 kN / m). The Toyota RAV4 simulation model shows when impacting a full-coverage wall when investigated speed range up to 60 km / h comparable deformation and the structural-like course as LS-DYNA. Similar results have also been obtained from a backlash with full coverage. When examining a side-pole impact (side impact on the column) there were negligible differences (about 13 mm) at the deformation depth. Applicability of FEM simulation results to a real vehicle is possible by visual comparison (Fig. 9) as well as displacement of the measurement points (Fig. 9).

When examining the transfer capability and the use of simulation results for vehicles of the same class it can be stated, that simulation model geo metro is sufficiently comparable with the results of the impact tests of Fiat Punto (Fig. 10) and Ford Escort (Fig. 11). Using simulation results for Geo Metro for Fiat Punto and Ford Escort is therefore in the investigated impact configurations and test speeds possible.

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Research results with simulation model Toyota RAV4 vehicles show that this MKP the simulation model provides for a test speed of 50 km/h good match with the real impact of the impact test for Jeep Cherokee (Fig. 12). The comparison used Kia Sportage shows in the event of an impact on the wall with full coverage of 0.32 m shorter deformation, which can be attributed almost double structural stiffness of 3,893 kN/m of the test vehicle compared to the vehicle from the simulation model (approximately 1,350 kN/m).

With ODB (Offset-Deformable Barrier) crash test with partial overlapping the results of FEM simulation are taken into account mass ratios are comparable with an attempt at the KIA Sportage (Figure 12). It is clear from the research, that the use of simulation results for vehicles of the same class is principally possible, but may not always be generally applicable. For these purposes, each vehicle must be individually assessed depending on the impact configuration and collision rate and compared with available simulations using the FEM method. Appropriate attempts are required for these purposes. From the results of these experiments then it is possible to compile tabulated insights, or some MKP model to a specific vehicle and a specific impact parameter is available [17, 18].

6. Conclusion

It turned out, that each of the methods examined has its typical area of application, as well as their specific borders. In order to compensate for the advantages and disadvantages of different methods, the combined use of several methods with different methodologies is used. FEM simulation models, which are currently in the calculation program PC Crash can be partially compared with vehicles of other classes. Research with selected vehicles, however, that deviations may occur. For this reason, further research is needed for the purpose of this method, to gain insight into which vehicle, with which differences to which impact configuration and impact velocity is comparable to simulation models. In addition, it
is also appropriate to further develop and improve the PCM Crash module. To simplify the determination of the deformation energy of the vehicle after vehicle-vehicle collisions using FEM simulation, it is appropriate to display deformations in isolation and analyze them.

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Activity Based Costing in the Optimization of Logistic Processes

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Abstract

Analyzing the problem of costs in logistics, more and more often used to identify and analyze specific activities taking place in the functional divisions of the organization. As a result, the consumption of economic resources and external services as well as the time of human work are expressed in terms of value. This approach has resulted in abstracting in recent years the methodology of activity based costing – ABC. The article is an attempt to implement solutions resulting from the application of the above method in business operations to optimize processes in the field of broadly understood logistics.

KEY WORDS: logistic, cost, optimization, management

1. From ABB to ABC

Process management of enterprise logistics requires the application of not only modern models of cost accounting (Activity Based Costing), but also innovative methods of budgeting and cost control (Activity Based Budgeting). An enterprise can get the full benefits of using a cost-based cost management model only if it adjusts the supply of its resources (including services) to the demand generated by products and customers [5].

Logging is an important role in logistics management. This is the process of developing budgets, and the budget itself is a quantitative resource management plan designed to ensure the achievement of the company's objectives. These goals should be measurable, eg achieving a specific growth rate of the company (sales, assets), maintaining the level of liquidity, profitability, market share, value creation, etc. Thus, the budget is simply a quantitative and valuable plan of the company's operation.

Fig. 1 Budgeting costs ('planning loop') under operating costs [6]

The budgeting of activity costs (Activity-Based Budgeting - ABB) allows the company to forecast changes in the supply of resources resulting from the planned process improvements and changes in the size of demand and the assortment structure. The sequence of steps in the process of budgeting the costs of activities is as follows [2].

- estimation of the expected production and sales volume for individual products and customers;
- forecasting the demand for activities;
- calculation of the demand for resources necessary to carry out activities;
- determining the supply of types of resources according to the forecasted demand.

The next steps in the budgeting process are included in the so-called "Planning loop" illustrated in Fig. 1.

Traditional solutions in the area of budgeting costs do not lead to optimal allocation of resources to processes occurring in the enterprise. This is due to the failure to take into account the functional dependency between the consumption of resources and the level of activity occurring in various processes of the enterprise. From years, methods and ways of identifying areas that are cost-generating, ie places to which valuable resource consumption or services
expressed in live work are sought (so-called cost centers). An attempt to identify the costs of actions by Kaplan, Cooper and Johnson from Harvard University in the USA led to the presentation in 1987 of ABC - Activity Based Costing.

1.1. Activity Based Costing in Logistics

The approach to logistics results from the "school", ie the trend and scientific achievements of a given field. In the literature on the subject, the most common approaches to issues related to the flow of matter and information (knowledge) include systemic, process or (less commonly) approaches to specific phenomena.

2. Idea of ABC

Considering the problem of costs in logistics, the approach is increasingly used to identify and analyze specific activities taking place in the functional divisions of the organization. As a result, the consumption of economic resources and external services as well as the time of human work, expressed in terms of value (for reporting and analytical and accounting purposes most often in a given time interval) are ascribed to such identified activities. This approach resulted in abstracting the methodology of activity-based costing – ABC.

When considering the (traditional) approach to cost accounting, one should consider whether it is optimal from the point of view of the functioning of the organization and what shortages is burdened from the point of view of logistics? The key question in this respect is: How can costs be attributed to processes to make better decisions? The company's activities, such as processing orders, storing goods, completing deliveries or transporting to customers, create costs that can be attributed to individual orders (recipients, clients) or company resources using cost carriers. Cost drivers are the basic factors affecting the amount of costs of a given activity and creating operating costs [3].

The essence and problem at the same time in the use of the ABC concept is the identification of "cost-generating" processes (areas). Often this is done intuitively using the "blank sheet" method. That is why it is so important when applying this concept a benchmarking approach in relation to all processes taking place in organizations with a similar profile of activity [7].

"ABC is not replacement for the traditional general ledger accounting. Rather it is „translator” or „overlay” as in the Figure 2, that lies between the cost accumulators or the expenditure account balances in the general ledger and the end-users who apply cost data in decision making. So ABC converts inert cost data into relevant information, so that the users can take the action”[Cokins 1996: introduction]

An example of a carrier for transport can be the number of deliveries to a given contractor, while the storage area can be a carrier of resources of action consisting in storage of materials necessary to manufacture products (fig 3).

There are as many ways to classify costs and settle an enterprise's logistics cost account as there are many enterprises operating on the market. The use of activity-based costing is increasingly common in enterprises that provide comprehensive logistics services. It is a good solution for companies wishing to increase their awareness of cost centers, customer profitability research and the profitability of products or services in terms of logistics. Of course, there are other variations and ways to create an account of the company's logistics costs. The exact one was selected and described in order to illustrate exactly where the logistics costs of enterprises are located.

What are the costs of logistics? Logistics studies show a common statement that logistics costs are the sum of the costs of servicing the entire supply chain. In order to assess the efficiency and effectiveness of the logistics chain, it is necessary to analyze the costs arising in the logistics processes and their share in the total costs of the enterprise. Therefore, the method, scope and methods of calculating them are an important tool in managing the flow of materials and products. It is not a simple task, because such analysis should be adapted to the national accounting rules and cost calculation and financial results. These do not provide for separating logistic costs from the company's cost records. In addition, logistics costs are also created in those departments that seemingly have little in common with logistics. It is advisable to develop in the company for the proper use appropriate registration sections and cost accounts, which will help to identify the most important components of logistics costs.
Some costs are impossible to identify, because they can not be found, eg lost potential revenues resulting from the inefficiency of logistics activities in the form of:
- lack of stocks of finished products for which demand existed at a given time;
- discounts and price discounts resulting from untimely deliveries, inadequate product quality or ill-chosen assortment;
- losses due to reduced quality of production processes resulting from faulty material flow;
- losses due to aging of excessive inventory in the form of total or partial loss of their value in use;
- losses due to loss of product quality resulting from defective selection of transport means, loading units, etc.

A full picture of logistics costs can be obtained by classifying them in groups. The basic assumption of the activity cost accounting is that the economic processes implemented in the enterprise consist of a number of separate activities that are necessary to manufacture and sell products. It is possible to specify the stages of the cost of activities, which in turn lead to the settlement of indirect costs for individual products or services. And so there is possible to extract:
- stage I - identification of significant activities occurring in the organization (collecting information on costs).
- stage II - determination of the costs of the identified activities (identification of the resource-action relationship).
- stage III - definition of the media for the costs of activities (identification of the action-product relationship).
- stage IV - settlement of indirect costs of individual actions on products (determination of unit cost).

3. Basic Definitions in the ABC / M Concept

Operation (activity) - is an activity (work) performed within the organization. Operation is what people / systems do in the organization. Organizational resources are consumed when performing actions. The activities are dynamic, they are carried out in time, so managers need to measure the use of organizational resources in their activities to know the costs of their activities. Examples of actions are: processing orders, retooling machines, visiting clients, completing deliveries, invoicing, etc [4].

Operating cost carrier - is a measure of the frequency and volume of demand for actions generated by cost objects. Each activity can be allocated to cost objects with another cost action medium. Cost object - these are customers, products, suppliers, distribution channels for which actions are implemented [4].

The resource (resource) - is defined as the economic component used or consumed during the implementation of activities. The resources are static, visible to the naked eye, hence most of them are easy to identify. Examples of resources are: employees, area, production lines, capital, IT system, means of transport, etc. [4].

Resource cost driver - it is the basis for assigning resources (costs) to actions and resources. It is a measure of the amount and intensity of resource consumption through actions and other resources. The purpose of determining the cost carriers of resources is to convert the functional approach to costs into a process intake [4].

4. Application of the Action Cost Account - ABC

The cost-of-activity account is of special significance in contemporary organizations due to its essence, referring directly to the flow of resource costs through activities to cost objects using asset cost carriers and action cost carriers. In the area of ABC account applications, there are:
- identification of significant activities occurring in the enterprise;
- determining the costs of separate activities;
- definition of the cost carriers of activities;
- settlement of indirect costs of individual actions for products.

The ABC account explains the impact of various product combinations on the unit cost of products determined by the effect of cost degressivity - the larger the batch of products, the lower the unit cost. Using the additional calculation to account for the costs of indirect processes for products according to a single add-in key, indirect costs are distributed proportionally to the products according to the adopted key and they do not show the influence of batch size or different
picking of products on the unit costs of products.

Cost degressivity and product completions are obtained using the principles of full cost accounting based on elementary processes due to the fact that the settlement of indirect costs of elementary processes allows to maintain cause-and-effect relations. The application of the calculation rules for the traditional full cost accounting in the conditions of complex production variants results in a breach of the cause and effect principle, in the settlement of indirect costs for products and the use of a single index key, which deforms information about unit costs of products.

In business units producing unitary production, serine and in the case of a massive variety, an additional calculation is used. It involves the use of clearing keys to add the remaining costs to direct costs. Every calculation of a given calculation is calculated. The individual cost of the selected object is calculated by the method of additive calculation.

5. The Essence of the Additional Calculation – Methodology of Personal Research

Additional calculation requires creating a cost structure according to the type and structure of costs by entities or cost centers. The basic structure of costs highlighted in the calculation of calculations consists of two items:

a) costs by nature - identified on the basis of source documents with products, series of products (orders);

b) indirect costs - costs of entities (common for products, series, orders).

The settlement keys should be the quantities expressing the proportional dependence between the manufactured products and the common costs of the entities incurred in the reporting period and specifying the contractual relationship between the basis for settlement and the costs to be settled. As billing keys, quantities expressed in quantity are used (Fig. 4).

![Fig. 4 General classification of settlement (billing) keys](image)

Number of man hours and machine hours or value: value of material consumption (or consumption of direct materials - for settlement of purchase costs); direct wages (or direct costs - to account for branch costs) and the technical production cost equal to the sum of direct costs of products and indirect departmental costs - to settle the costs of sales and costs of the board.

**Example**

For the presentation of the essence, the cost settlement in the classical system in Table 1 presents selected cost categories. During the month, the generating unit has booked the costs in the calculation system on synthetic and analytical accounts:

**Table 1**

<table>
<thead>
<tr>
<th>Account symbol</th>
<th>Account name and items of the calculation system</th>
<th>Together</th>
<th>Costs in PLN (ZL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>Basic activity costs</td>
<td>50 000</td>
<td>7000</td>
</tr>
<tr>
<td>-</td>
<td>Direct materials</td>
<td>30 000</td>
<td>5000</td>
</tr>
<tr>
<td>-</td>
<td>Direct wages</td>
<td>20 000</td>
<td>2000</td>
</tr>
<tr>
<td>121</td>
<td>Faculty costs</td>
<td>10 000</td>
<td></td>
</tr>
<tr>
<td>122</td>
<td>Purchase costs</td>
<td>3000</td>
<td></td>
</tr>
<tr>
<td>123</td>
<td>Selling costs</td>
<td>3780</td>
<td></td>
</tr>
<tr>
<td>150</td>
<td>Management costs</td>
<td>12 600</td>
<td></td>
</tr>
<tr>
<td><strong>Together</strong></td>
<td><strong>79 380</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

During the month, 10 units of “A” finished products and 100 finished products "B" were produced and sold At the end of the month, production did not occur. The calculation account was made using the additional calculation method. the following billing keys:

a) direct materials - for settlement of purchase costs;
b) direct wages - for settlement of faculty costs;
e) technical production cost - for settlement of management costs;
d) the total cost of finished products - to account for the cost of the sales.

**Solution:**

Calculation of % indicators for the settlement of indirect costs for individual products:

\[
\text{the sum of indirect costs in the period * } 100\% \quad \text{overhead\% of indirect costs} = \text{the total amount of costs underlying the settlement}
\]

\[
\frac{3000\text{zl}}{30000\text{zl}} \times 100\% = 10\%;
\]

\[
\frac{20000\text{zl}}{10000\text{zl}} \times 100\% = 200\%;
\]

\[
\frac{63000\text{zl}}{12600\text{zl}} \times 100\% = 20\%;
\]

\[
\frac{75600\text{zl}}{3780\text{zl}} \times 100\% = 5\%;
\]

The growing popularity of activity based costing (ABC) is due to the fact that the traditional method of allocating costs between products according to the direct remuneration key becomes less and less useful. While the direct wages were usually a significant part of production costs, today such a situation is rare. Therefore, the overheads of general administrative expenses which are five times higher than the value of direct remuneration are currently not unusual. As a result, slight fluctuations in direct wages result in significant changes in unit production costs.

The ABC method takes into account the fact that general administrative costs do not arise out of nowhere, but are generated by specific activities, such as storing products in the shop. Hence the need to break down the business into basic processes - such as production, storage and distribution - and these processes into activities. For example, distribution includes picking deliveries, loading, transporting and unloading. For each of these activities there must be some parameter determining its cost. In the case of storage, this may be the volume of the packaging, and in the case of transport, the weight of the load. After identifying this parameter, it should be determined how many of its units belong to the given activity and what is the cost of one unit. For example, the parameter determining the cost of transport may be the number of kilometers driven. Multiplying the number of kilometers driven by the cost of traveling one kilometer. We get the cost of the activity. After summing up the costs of all activities performed as part of a given process, we get its total cost.

**6. Application of the ABC Account - Case Study**

Press S.A. it produces three types of products: A, B and C. Product A is manufactured in the largest quantities and sold in large batches. The production volume of products B and C is the same or similar in particular periods. Product C is the most labor-intensive, and A requires the greatest amount of mechanical processing (table 2).

<table>
<thead>
<tr>
<th>Specification</th>
<th>A (10 000)</th>
<th>B (3 000)</th>
<th>C (1 000)</th>
<th>Together</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production volume in pcs</td>
<td>10 000</td>
<td>1 000</td>
<td>1 000</td>
<td>10 000</td>
</tr>
<tr>
<td>Costs of direct materials</td>
<td>336 000</td>
<td>34 000</td>
<td>20 000</td>
<td>390 000</td>
</tr>
<tr>
<td>The costs of direct wages</td>
<td>190 000</td>
<td>20 000</td>
<td>40 000</td>
<td>250 000</td>
</tr>
<tr>
<td>Indirect costs of production</td>
<td></td>
<td></td>
<td></td>
<td>250 000</td>
</tr>
<tr>
<td>Working hours direct (wh) per unit and total</td>
<td>2 20 000</td>
<td>1 1 000</td>
<td>3 3 000</td>
<td>24 000</td>
</tr>
<tr>
<td>Machine hours (mh) per unit and total</td>
<td>5 50 000</td>
<td>3 3 000</td>
<td>2 2 000</td>
<td>55 000</td>
</tr>
<tr>
<td>Number of series</td>
<td>180 200</td>
<td>140 140</td>
<td>210 210</td>
<td>550 550</td>
</tr>
<tr>
<td>Control time in hours</td>
<td>2 050</td>
<td>650</td>
<td>750</td>
<td>3 450</td>
</tr>
</tbody>
</table>

The indirect costs of production in the amount of 1 350 000 PLN consist of the following costs:

- supplies of materials: 200,500 PLN
- technical preparation of machines for production: 239,500 PLN
- maintenance of machinery and equipment in motion: 710,000 PLN
- quality control: 100,000 PLN
**Solution:**

Assigned addition calculation: (the key to indirect costs is the cost of direct wages)

Indirect cost overhead index \[= \frac{1250000}{25000} \times 100\% = 500\% \]

The fixed rates of costs of individual units of activity are used to calculate the costs of these activities attributable to the manufacture of products A, B and C and the unit (pcs) of each of these products (table 3).

### Table 3

Settlement of costs of operations for a product unit

<table>
<thead>
<tr>
<th>Activity</th>
<th>Centers Cost rate of the unit of activity</th>
<th>Product</th>
<th>Actual amount per products</th>
<th>Operating costs settled on total products</th>
<th>Operating costs per unit of product</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5) = (2) * (4)</td>
<td>(6)</td>
</tr>
<tr>
<td>Deliveries of materials</td>
<td>781,25</td>
<td>A</td>
<td>180</td>
<td>140 625,00</td>
<td>140 625,00 / 10 000 = 14,06</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>30</td>
<td>23 437,50</td>
<td>23 437,50 / 1 000 = 23,44</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C</td>
<td>46</td>
<td>35 937,50</td>
<td>35 937,50 / 1 000 = 35,94</td>
</tr>
<tr>
<td>Technical preparation of machines for production</td>
<td>436,364</td>
<td>A</td>
<td>200</td>
<td>87 272,80</td>
<td>87 272,80 / 10 000 = 87,27</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>140</td>
<td>61 090,96</td>
<td>61 090,96 / 1 000 = 61,10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C</td>
<td>210</td>
<td>91 636,44</td>
<td>91 636,44 / 1 000 = 91,64</td>
</tr>
<tr>
<td>Machine maintenance</td>
<td>12,91</td>
<td>A</td>
<td>50 000</td>
<td>645 500,00</td>
<td>645 500,00 / 10 000 = 64,55</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>3 000</td>
<td>38 730,00</td>
<td>38 730,00 / 1 000 = 38,73</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C</td>
<td>2 000</td>
<td>25 820,00</td>
<td>25 820,00 / 1 000 = 25,82</td>
</tr>
<tr>
<td>Technical preparation of machines for production</td>
<td>28,986</td>
<td>A</td>
<td>2 050</td>
<td>59 421,30</td>
<td>59 421,30 / 10 000 = 59,42</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>650</td>
<td>18 840,90</td>
<td>18 840,90 / 1 000 = 18,84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C</td>
<td>750</td>
<td>21 739,50</td>
<td>21 739,50 / 1 000 = 21,74</td>
</tr>
</tbody>
</table>

The costs of maintaining machinery and equipment in motion per unit, products A, B and C can also be calculated as follows (PLN/machine hours):

A: 12,91 PLN/mh * 5 mh = 64,55 PLN; B: 12,91 PLN/mh * 3 mh = 38,73 PLN; C: 12,91 PLN/mh * 2 mh = 25,82 PLN.

### Table 4

Unit cost of products at calculation by abc method (pln)

<table>
<thead>
<tr>
<th>Cost item</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct materials</td>
<td>336 000 / 10 000 = 33,60</td>
<td>34 000 / 1 000 = 34,00</td>
<td>20 000 / 1 000 = 20,00</td>
</tr>
<tr>
<td>Direct wages</td>
<td>190 000 / 10 000 = 19,00</td>
<td>20 000 / 1 000 = 20,00</td>
<td>40 000 / 1 000 = 40,00</td>
</tr>
<tr>
<td>Direct costs (total)</td>
<td>33,60 + 19,00 = 52,60</td>
<td>34,00 + 20,00 = 54,00</td>
<td>20,00 + 40,00 = 60,00</td>
</tr>
<tr>
<td>Deliveries of materials</td>
<td>14,06</td>
<td>23,44</td>
<td>35,94</td>
</tr>
<tr>
<td>Technical preparation of machines for production</td>
<td>87,27</td>
<td>61,10</td>
<td>91,64</td>
</tr>
<tr>
<td>Maintenance of machines and devices in motion</td>
<td>64,55</td>
<td>38,73</td>
<td>25,82</td>
</tr>
<tr>
<td>Quality control</td>
<td>59,42</td>
<td>18,84</td>
<td>21,74</td>
</tr>
<tr>
<td>Total indirect costs</td>
<td>225,30</td>
<td>142,11</td>
<td>175,14</td>
</tr>
</tbody>
</table>

7. Conclusions

Implementation of the cost of activities is not easy, because first requires recognition of the processes that make up a given activity, when the links between the functional divisions are not very clear. Then you need to identify the parameters determining the costs of individual activities, which requires looking at them from a different angle. For example, in the case of a forklift operator, it will be the number of transported pallets, and in the case of storage, the amount of inventory that must be stored in the warehouse in a given period. Additional problems arise when the costs of activities determine more than one parameter. We then face a similar question as in the allocation of general management costs: "How do you determine the weight of these parameters?"

The idea of the ABC model is not new. The principle of rational management results from a category of thinking that has a significant impact on promoting efficiency and / or cost reduction. This may be, for example, the use in production of existing, previously developed standard parts, instead of designing new parts or buying them from the
outside. In this case, the reduction of design costs is obvious.

According to K.H. Lattes, head of the Siemens AG Munich department producing about 200 models of electric motors, without ABC, the company's strategy would be doomed to failure.

In the ABC model the essence is its focus on control and decision-making values and management. Currently, the activity costs account is gaining immense popularity around the world. The ergonomic design of this account model accurately describes the business organization and motivates its implementation.

8. Summary

Cost management in contemporary organizations, many of which operate in a network environment in the era of globalization, requires a specific, almost holistic way of looking at financial flows in the global economy, and in particular the ability to analyze costs, budget resources and spend them rationally. Knowledge of the subject of costs, accounting and the basis for the functioning of public finances becomes a requirement for contemporary managers and decision-makers responsible for spending funds from the state budget and those responsible for managing the enterprise.

The article deals with the important issues of logistics and budgeting costs. However, the new, comprehensive approach reveals the extraordinary complexity of the issues, which common denominator are costs, costing and budgeting. The publication uses an innovative approach, characterized by a wide range of analyzes. The ABC analysis can be used both within the public finance sector, which, through the budget funds' managers, expends public funds and its business profile as a rule, non-profit character for the enterprise sector, dominated by business entities focused on optimizing the costs of their operations.

The author many times refers to the efficiency approach to the problem of logistics costs management, which he presents, for example, through the selection of case studies, especially those that refer directly to the calculation of costs of activities or task budgets.

Bibliography:

Comparison of Methods for Assessing the Changes in Railway Passenger Numbers

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Abstract

The result of measures to increase the passenger number in railway transport usually is an increase of the number of passengers in one or another section. The article examines the issue how to assess the change of railway passengers in one or other railway section comparing it with the change of passenger in the entire railway system, change of population of the country and change of gross domestic product. The article compares to methods of comprehensive assessment of these indicators developed by the author.

KEY WORDS: railway, passenger transport, indicators, passenger flow, change of passenger numbers, gross domestic product, population, methods

1. Introduction and Literature Analysis

The railway passenger transport is usually examined in two aspects: technical and organisational. The change of number of failures of rolling stock [12], the change of operating costs of rolling stock during their aging [13] and other technical issues are examined in technical aspect. In organisational aspect, the passenger transport in some countries of Europe is perceived as social obligation of the state to population and is financed from the state budget [1]. However, in any case, the railway must transport the reasonable number of passengers and receive the respective income. Therefore, the transport services are constantly improved, i.e. the attractiveness of passenger railway is increased [8]. The questionnaire surveys of passengers are carried out and it is determined why the need for passengers is increasing or decreasing, as well as various methods of scientific researches are applied [3-5]. The results of questionnaires show that the railway transport loses its attractiveness (if loses) due to insufficient speed and lack of comfort. As a result, the advantage of car transport is rapidly emerging compared to railway transport. It is necessary to improve the transport service in order to attract more passengers, e.g., increase the attractiveness of railway transport. The passenger needs, methods of assessment and improvement of transport quality are established for this purpose [8]. The questionnaire surveys of passengers are carried out and qualitative significances of indicators are determined [9], as well as knowledge potential assessment model adapted to transport sector is being offered [10]. The impact of Lithuania's accession to the EU on the national transport system and development of transport system are examined, railway passenger transport issues are identified [2], and other modern methods to assess and improve the passenger transport quality are sought. The questionnaires are widely applied in social researches and design of transport system collecting the necessary information. For instance, the questionnaire survey was carried out in the United States of America concerning the preservation of railway cargo and passenger corridor [11]. The researches of transport system help to make decisions for the best use of the transport network distributing the cargo and passenger transport as good as possible. The distribution of passenger number between sections and its change in section (during passenger boarding and leaving the train in stops) are examined. Discrete points describe the distribution of passenger flow in section; then it is possible to derive the regression equation through the points, in order to be able to solve various optimization problems in different methods later [6]. Moreover, it is purposeful to examine the regularities of passenger number change in section in detail. The best option is to assess the change of passenger number in section in respect of the change of entire railway system, change of gross domestic product of the country, and change of population. In their previous works, the authors offered one of the methods to solve these issues. It was offered to use the ratio of the change in the passenger number with changes of other economic and social indicators as criteria. The change indicators are obtained by subtracting the percentage change of the corresponding indicator from 100 [7]. The indicators have been assessed by multi-criteria optimisation methods. In the present article, the author offers to deal with the mentioned task in a slightly different way. The author offers to prepare one complex indicator of social and economic factors change and compare it to the indicator of passenger change. The author hopes that the simplicity of the comparison process will be an advantage of such methodology; it will be necessary to compare to indicators.

2. The Formation of Methods for Assessing the Changes in Railway Passenger Numbers

The authors offered to express the ratios of passenger number change mathematically with changes of other economic and social indicators in the following way:
where $K_g$, $K_p$, and $K_{GDP}$ – the indicator ratios of passenger number percentage change in $i$ section corresponding to the indicators of percentage change in the total number of passengers of the country, change of population and percentage change of gross domestic products; $\Delta P_i$ – the percentage change of passenger number in railway section; $\Delta P_g$ – the percentage change of passenger number in a country; $\Delta P_p$ – the percentage change of population in a country; $\Delta P_{GDP}$ – the percentage change of gross domestic product of a country.

After having calculated the indicators, their entirety can be assessed in various ways: as arithmetic mean or applying the methods of multi-criteria optimisation. However, the author states that it is not necessary to calculate three indicators each time for simplified researches. It is enough to compare the indicator of passenger number in a section to a complex indicator of the change of economic and social indicators. One formula could be used instead of three:

$$K_{\text{complex}} = \frac{100 + \Delta P_i}{100 + \Delta P_{\text{complex}}}$$

where $100 + \Delta P_{\text{complex}}$ – complex indicator of the change of economic and social indicators.

The easiest way to assess the change of economic and social indicators in percentage is to calculate the arithmetic mean:

$$\Delta P_{\text{complex}} = \frac{\Delta P_g + \Delta P_p + \Delta P_{GDP}}{3}$$

At first, the researcher must have the separate data of the respective indicators to calculate the arithmetic mean.

The annual percentage change of the total number of railway passengers in Lithuania in 2006–2016 is presented in Fig. 1.

![Fig. 1 Chart of annual percentage change of passenger number in Lithuanian railways in 2006–2016](attachment:chart.png)

The data of Fig. 1 shows that the largest decrease of passenger number was in 2007 (-17.24 percent), and the largest increase was in 2010 (7.32 percent). The data in Fig. 1 were collected by calculating according to formula (5). Other indicator – change of Lithuanian annual GDP is shown in Fig. 2.

![Fig. 2 Chart of Lithuanian annual GDP in 2006–2016](attachment:chart2.png)

Fig. 2 shows that the largest positive change of Lithuanian GDP was in 2007 (11.1 percent), the largest negative change was in 2009 (-14.8 percent). Gross domestic product is one of the main indicators of economy of any country, thus the comparison to this indicator is the direct comparison of development of any field to the general development of a country’s economy.
One of the social issues in Central Europe is a decrease of population. This percentage change in Lithuania is presented in Fig. 3.

![Fig. 3 Chart of annual percentage change of Lithuanian population in 2006–2016](image)

Fig. 3 shows that the change of population in Lithuania during the examined period is negative only. It is possible to make calculations according to the data provided in charts of pictures 1, 2 and 3. It is also possible to calculate according to methodology described in formulas (1, 2, 3) and methodology described in formulas (4, 5). The solution according to methodology described in formulas (1, 2, 3) is provided in literature [7]; the present article provides the results of solution only. These results are compared to the results of solution according to methodology described in formulas (4, 5). The sections of Lithuanian railways constituting the main passenger turnover were selected for the calculations. The distribution of passenger number in local routes is presented in Table 1.

### Table 1

<table>
<thead>
<tr>
<th>Route</th>
<th>Relevance of the section</th>
<th>Annual passenger number in a route, millions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vilnius-Kaunas</td>
<td>Connects the capital with the second city of country</td>
<td>1,14</td>
</tr>
<tr>
<td>Vilnius-Klaipėda</td>
<td>Connects the capital with the third city of country - port</td>
<td>0,44</td>
</tr>
<tr>
<td>Vilnius-Turmantas</td>
<td>Connects the capital with resort</td>
<td>0,44</td>
</tr>
<tr>
<td>Vilnius-Varėna-Marcinkonys</td>
<td>Connects the capital with rest areas</td>
<td>0,3</td>
</tr>
<tr>
<td>Other</td>
<td>-</td>
<td>1,19</td>
</tr>
</tbody>
</table>

After having examined the values of numbers, it is seen that the largest number of passengers travel by Vilnius-Kaunas route – 1,14 million passengers per annum. The graphic interpretation of Table 1 details is provided in Fig. 4.

![Fig. 4 Percentage distribution of passenger number in local routes](image)

Fig. 4 shows that 66 percent (32, 12,5, 12,5 and 9 percent) of the total number of all local routes passengers is made of the number of passengers of Vilnius–Turmantas, Vilnius–Varėna–Marcinkonys, Vilnius–Kaunas and Vilnius–Klaipėda routes (according to Table 1 - 2,32 mln. of passengers). The number of passengers in other local routes is 1,29 million of passengers (36 percent of all passenger number in local routes). It can be concluded that according to the methodology developed it is expedient to analyse these four main local routes. The arithmetic mean of criteria calculated according to methodology described in formulas (1, 2, 3) [7] is provided in Fig. 5 by sections.

The data of Fig. 5 shows that more positive (favourable) change of passenger number is seen in section Vilnius-Kaunas only comparing this change to the change of gross domestic product, change of population and change of total number of passengers in a country.

The complex annual change indicator of economic and social indicator $\Delta P$ is calculated according to formula (4) and presented in Fig. 6.

In order to use the methodology described in formula (4), it is necessary to know the percentage change of passenger number in sections. These data are provided in Table 2.

Based on the date in Fig. 6 and Table 2, it is possible to calculate the complex indicator $K_{\text{complex}}$ according to formula (4). The distribution of the present indicator values is presented in Fig. 7.
Fig. 5 The means of ratios of passenger number change in section with the changes of gross domestic product, population and total number of passengers in a country

Fig. 6 Complex annual change indicator of economic and social indicators $\Delta P_{\text{complex}}$

Table 2

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Vilnius-Kaunas</td>
<td>-10.77</td>
<td>-18.5</td>
<td>-9.29</td>
<td>-13.6</td>
<td>17.89</td>
<td>18.23</td>
<td>6.49</td>
<td>-0.63</td>
<td>3.28</td>
<td>-3.18</td>
<td>-4.67</td>
</tr>
<tr>
<td>Vilnius-Klaipeda</td>
<td>-1.14</td>
<td>-19.4</td>
<td>-5.63</td>
<td>-26.89</td>
<td>-25.06</td>
<td>11.02</td>
<td>4.13</td>
<td>6.84</td>
<td>-0.41</td>
<td>2.68</td>
<td>-3.1</td>
</tr>
<tr>
<td>Vilnius-Turmantas</td>
<td>-10.48</td>
<td>-25.36</td>
<td>-4.165</td>
<td>-12.1</td>
<td>-20.46</td>
<td>5.06</td>
<td>1.05</td>
<td>0.59</td>
<td>-5.34</td>
<td>-8.25</td>
<td>-8.65</td>
</tr>
<tr>
<td>Vilnius-Varėna-Marcinkonys</td>
<td>1.63</td>
<td>-23.9</td>
<td>-0.87</td>
<td>-9.59</td>
<td>-2.25</td>
<td>0.56</td>
<td>-5.19</td>
<td>1.08</td>
<td>-8.99</td>
<td>-13.15</td>
<td>-1.45</td>
</tr>
<tr>
<td>Other</td>
<td>1.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 7 Complex indicator assessing the ratio of passenger number change with the changes of other economic and social indicators
Small differences can be seen comparing the data of Pictures 7 and 5. At first, it shall be noticed that all relative indicators in Fig. 7 do not exceed 1, and the indicator of section Vilnius–Kaunas in Fig. 5 is 1.04. It is the largest indicator of presented in Picture 5. The size of indicator is determined by the fact that new double-decker trains in this section increased the attractiveness of transport. However, the new trains are also used in section Vilnius–Klaipėda. The result of this fact can be seen in Picture 7. The entirety of the facts makes the conclusion that it is impossible to answer unambiguously which measure was more effective (new trains in section Vilnius-Kaunas or section Vilnius–Klaipėda). The results are different using various methodologies.

3. Conclusions

In order to assess the change of passenger number in railway section, it is expedient to compare it with the change of passenger number in the entire railway system, change of gross domestic product of a country and change of population.

Two assessment methodologies of passenger number change in railway section were developed by the author and compared according to the example of Lithuanian railways. The point of the first methodology is the calculation and generalization of ratios of passenger number change with social and economic indicators. The point of the second methodology is that one generalised indicator assessing the social and economic indicators is calculated at first and the ratios of passenger number changes are calculated with this indicator.

It is impossible to answer unambiguously which measure was more effective (new trains in section Vilnius-Kaunas or section Vilnius–Klaipėda). The results are different using various methodologies.

Acknowledgement

This research was funded by a grant (No. S-LU-18-12) from the Research Council of Lithuania. This research was performed in cooperation with the Volodymyr Dahl East Ukrainian National University, Ukraine.

References

Optimization of Vehicle Suspension Neural Model

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Abstract

Vehicle suspension is a complex mechanical system - many interconnected parts, influencing one the other and vice versa. To create its mathematical model, is relatively difficult work. Damper itself, behave as nonlinear system (at higher frequencies), therefore is complicated to develop accurate suspension model. Analytical model [1-3] based on equations of motion is theoretical solution of this problem. This theoretical model can be marked as an ideal. In real suspension system there are forces that are not considered in the theoretical model – the mathematical description would be complicated. Increasing the accuracy of the model, leads to its big complexity. A way to cope with this contradiction, is to use unconventional methods.

KEY WORDS: vehicle suspension, vibrodiagnostic, NARX, neural network, MATLAB

1. Data Acquisition

Input \( u(t) \) is vertical displacement of wheel, which is generated by travelling over an obstacle. Output \( y(t) \) is response of vehicle suspension system (Fig. 1).

Response is measured as difference between vertical accelerations of wheel \( a_1(t) \) and vehicle body \( a_2(t) \).

\[
y(t) = a_2(t) - a_1(t). \tag{1}
\]

During experimental ride, data was recorded from two accelerometers placed on arm of wheel and body of car above the shock absorber. Experimental data was obtained by Brul & Kjaer PULSE 3560-C equipment (Fig. 2).
PULSE is a versatile, task-oriented system for noise and vibration analysis (Fig. 3). Type 3560-C is a portable data acquisition system, built for outdoor use (Fig. 4).

I tried to build suspension model based on real measured data. Because is not easy to create mathematical model from measured data (with accurate behavior as real car has), I had to choose method which is able to achieve this goal. Therefore, I used neural network.

2. Identification of Neural Model Based on Real Data

The base unit of neural network is McCulloch-Pitts artificial neuron. Neuron is processing unit which performs sum of inputs multiplied by weights. This sum is argument of activation function and that function determine output of neuron. Activation function $f$ can be in different forms – for example logistic sigmoid, hyperbolic tangent or linear functions. When are connected many neurons, result is one structure so called neural network.

Neural network [4] is a set of neurons organized into layered structure – input, hidden and output layers. Neuron connections are each to each between neurons of the neighbor layers. When network is without recurrent links, this network is known as feed-forward (Fig. 5). Signals are distributed only in one direction - from input network to the output.

Transfer function of hidden neurons is mostly logistic sigmoid or hyperbolic tangent function, in many applications output neurons work with linear transfer function.

3. NARX Model in Neural Network Form

Neural NARX model (ANN NARX) is identified according to the schema (Fig. 6).
Mathematical description of neural NARX model [5] represents the following equation.

\[ y(t) = ANN[u(t-1); u(t-2); u(t-3); y(t-1); y(t-2); y(t-3)] . \] (2)

3. Simulation Results

Measured data (response of right front wheel suspension system) was obtained from PULSE equipment – during crossing of the artificial obstacle (Fig. 7) by Skoda Fabia 1.2 HTP vehicle. Crossing velocity was 20 km/h.

For ANN NARX model was used feed-forward neural network (trained by Levenberg-Marquardt algorithm) with number neurons in hidden layer from 5 to 25 (Fig. 8).

Compare of measured (green curve) and simulated (red curve) data is shown in next Figs. 9-11.
4. Investigation of Neural Model Quality

Number of neurons in hidden layer has the crucial influence on quality of neural model. At first I had to define quality criterion. In this case it will be difference between network output and measured response in form of Error Surface (ErrS).

\[
\text{ErrS} = \int_0^t [y(t) - y'(t)] \, dt. \tag{3}
\]

Theoretical dependence of ErrS on number of hidden layer neurons (N in HL) is represented by the following graph (Fig. 12).

Real curve of this dependence was obtained by simulation experiments. There was trained 9 networks (each of them with different number of hidden neurons) and next was compared their answer with measured data (by using error surface integral criterion).

![Fig. 12 Theoretical dependence of ErrS on N in HL](image)

![Fig. 13 Real dependence of ErrS on N in HL](image)

5. Conclusion

By using this method was obtained the following result. The goal was - to determine \( N \), when ErrS will have a minimal value. The best match between simulated and measured data (minimal error surface) was achieved by network with 15 neurons in hidden layer – this network represents accurate suspension model, as is shown on Fig. 13.

References

Reduction of Thermal Signature of Military Vehicle Using Polymer Composite Plates

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Abstract

Goal of our work was to suppress heat signature of infantry fighting vehicle OT-90 hybrid. We selected three composite material for this task. At first, we discovered (by thermal camera) the most problematic parts of vehicle body (from side view) - exhaust pipe and right side area of body vehicle around the engine. We tried to reduce heat signature by covering these parts with polymer composite plates as material with low thermal conduction.

KEY WORDS: heat transfer, temperature profile, thermal camera, polymer composite

1. Infantry Fighting Vehicle OT-90 Hybrid

The OT-90 is based on the Russian designed BMP-1 infantry fighting vehicle (built under licence in Czechoslovakia) (Fig. 1).

OT-90 Hybrid (Fig. 2) was developed under cooperation of VOP Trenčín, a.s., DSSI a.s., STU Bratislava, AOS Liptovský Mikuláš. This vehicle is equipped with combination of diesel engine and electrical engine. This vehicle drive system offers less fuel consumption and less emissions. When vehicle is in light terrain or is empty, then is powered by electrical engine and when in hard terrain or is heavily loaded, then is powered by combustion engine. Also when power batteries require recharge, combustion engine is activated to recharge them. Combustion engine in this vehicle is Cummins ISBe 5,9I, electrical engine is Vacon TR 3226.
2. Thermal Analyses of OT-90 Hybrid

Thermograms of OT-90 Hybrid (Fig. 4) was obtained by infrared camera FLIR ThermaCAM P65 (Fig. 3).

Camera provides sensitivity of 0.08°C and high-resolution 16-bit thermal images in real time. Uncooled microbolometer detector has resolution 320 x 240 pixels.

**Basic technical parameters**
- Field of view 24° × 18°
- Thermal sensitivity 0.08°C at 30°C
- Spectral range 7.5 to 13 μm

Hottest parts are exhaust pipe and right side of vehicle - the place where is mounted combustion engine inside (Fig. 5).

Our effort was directed on finding material to cover of this critical parts. Goal was - durable and lightweight material [2, 6] with low thermal conductivity - with possible modification (improving) of conductivity. Our choice was polymer composite.
3. Polymer Composites

Under expression polymer composite we understand material created by connection of polymer matrix and fiber reinforcement [4, 5, 7]. Composite materials has matrix from epoxy resin and fiber reinforce. Others very useful features of polymer composites, are very high fatigue limit and absolute resistance to corrosion even in aggressive environment. Composite materials have excellent fire resistance.

Composites which we have selected for our experiment are composed from:
1. epoxy resin + glass fiber reinforcement (areal weight 163 g/m²);
2. epoxy resin + carbon fiber reinforcement (areal weight 160 g/m²);
3. epoxy resin + aramid fiber reinforcement (areal weight 173 g/m²).

All plates was made from 2 layers of fabric (Fig. 6).

4. Heat Transfer in Multilayer Composite Plate

We consider, that heat flux in multilayer composite plate is consisting from heat transfer by conduction, convection and radiation.

Heat transfer [1, 3] in multilayered wall is determine by formula

\[ \dot{q} = k \left( T_1 - T_2 \right), \]  

(1)

where

\[ k = \frac{1}{\frac{1}{\alpha_1} + \sum_{i=1}^{N} \frac{d_i}{\lambda_i} + \frac{1}{\alpha_2}}. \]  

(2)

5. Measuring Temperature Profiles of Polymer Composites

Polymer composite layered plates was exposed to defined heat source, and their change surface temperature was measured in time. For measuring was used thermal camera. This way we obtained temperature profiles for each composite plate (Fig. 7).

Fig. 6 Composite plates

Fig. 7 Measuring method
After exposing to heat flow, the lowest surface temperature had fiberglass composite, then carbon composite. Surface temperature of aramid composite plate was approximately equal to fiberglass – but with increasing heat source power, difference is increasing too.

We assume the use of fiberglass composite (has lower price then aramid) as base material for thermal shield for military vehicle (Figs. 11-12).
6. Conclusion

As was shown in previous chapter (measuring of temperature profile – Figs. 8-10), from three type of polymer composites (glass, carbon, aramid) the best result was obtained with glass fiber composite. This plate had the lowest surface temperature, after exposing to heat source (with different of power). Glass fiber composite is suitable base material for construction of cover thermal shield for covering problematic parts of vehicle body surface.

Shield (composite plate) is mounted (with the distance) above the vehicle body wall (Fig. 13) – as it show next figure.

Base composite material can be next modified - by additional material, to improve thermal properties. Our next work will be directed to this area.

References

Substantiation of Bernoulli Grippers Parameters at Non-Contact Transportation of Objects with a Displaced Center of Mass

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Abstract

The contactless transport of a flat object with a displaced center of mass by means of the Bernoulli gripper is considered. When shifting the center of mass of the object of manipulation relative to the axis of the Bernoulli gripping device, there is a deviation from the parallelism between their active surfaces in the static position. For this case, we propose formulas for calculating the distribution of air pressure in the radial gap between the active surfaces of the Bernoulli gripper and the object of manipulation. The results of calculations of the distribution of rarefaction on the surface of the object of manipulation show that the asymmetry of the distribution depends on the magnitude of the displacement of the object’s center of the mass. The method of calculating the force and torque associated with the action of the Bernoulli gripper on the object of manipulation is proposed.

KEY WORDS: non-contact transportation, Bernoulli gripper, nozzle, supersonic flow, shock wave

1. Introduction

The effectiveness of the use of industrial robots and the reliability of their loading operations depends on the design and performance characteristics of the gripping device [1]. The latter should ensure the safe capture and maintenance of objects of manipulation (OM), the stability of the base, the inadmissibility of damage or destruction OM, the ability to capture and base objects in a wide range of mass, size and shape, easy replacement, the ability to automatically regulate the retention effort.

Most of these requirements are met by contactless pneumatic gripping devices that use compressed air to create an aerodynamic effect of attracting flat OM. They are divided into the following types: Bernoulli grippers with a cylindrical nozzle; Bernoulli grippers with a ring nozzle (ejection); vortex; Bernoulli-vacuum grippers.

In articles [2-6] explores the characteristics and optimizes the parameters of Bernoulli gripper (BG) with a cylindrical nozzle.

In paper [2-4], the pressure distribution and suction force are measured experimentally. The theoretical calculation and experimental results reveal that the inertial effect causes a negative pressure distribution and resulting suction force, while the viscous effect and the total pressure of the central air supply give rise to positive distributions and a resulting repulsive force. It is found that the outer diameter of the gripper has a major impact on the suction force, and its design is closely related to the gap height and the supply mass flow rate. In paper [4] study experimentally and theoretically investigates the dynamic characteristics of the Bernoulli gripper.

In paper [5] describes the design and testing of a gripper developed for the handling of delicate sliced fruit and vegetable products commonly found in the food industry. The device operates on the Bernoulli principle whereby air flow over the surface of an object generates a lift. The purpose of paper [6] is the increase the flexibility of robots used for handling of 3D (food) objects handling by the development and evaluation of a novel 3D Bernoulli gripper. In article [7] proposes the use of contactless grippers instead of more traditional vacuum cups or fingered grippers. In particular, the main objective of this investigation is the measurement of the performance of different gripper configurations whose lifting force is generated by a high-speed air flow passing between the gripper and the leather ply.

In articles [8-14] explores the characteristics and optimizes the parameters of Bernoulli gripper with the ejection nozzle. In paper [8-9] Xavier F. Brun presents the modeling and prediction of the air flow, pressure, and lifting force produced by a noncontact Bernoulli gripper, which is essentially a radial air flow nozzle used to handle small and large rigid and nonrigid materials. Too the effect of substrate (thin silicon wafer) flexibility on the equilibrium wafer deformation, radial pressure distribution and lifting force is modeled and analyzed using a combination of computational fluid dynamics (CFD) modeling and finite element analysis.

In article [10] study, transporting speeds in the horizontal direction of the woven fabrics were investigated using a non-contact and effector. The author paper [11] investigate a numerical model on radial flow and pressure distribution showing regions of negative values which tend to levitate products is developed. The author’s purpose in paper [12] is to provide a technical review of a new Bernoulli gripper development using computed fluid dynamics (CFD) modeling, and also to outline an appropriate independent testing method for validating and evaluating process capability in terms
of automated thin wafer handling. In article [13], a soft acting non-contact gripper based on the distributed Bernoulli principle for ultra-thin wafer is developed and evaluated. The theoretical analysis and experimental studies of the designed gripper are carried out. In paper [14], present the working principles of Bernoulli and vortex grippers. Then, measured the curves of suction force, air consumption, and upstream pressure; furthermore, analyzed and compare the energy consumption from the viewpoint of the entire pneumatic system.

The study of the parameters of vortex grippers and their influence on the object of manipulation with a uniform gap between the active surfaces are devoted to the articles [15-20].

The dynamics of the air flow between interacting surfaces of Bernoulli–vacuum gripping device and object of manipulation is analyzed in article [21]. The methods of increasing lifting capacity in given devices are presented. The equation for defining pressure distribution in between interacting surfaces of gripping device and object of manipulation and equations for calculation of power characteristics is calculated.

Presented in these papers, the study of the power characteristics of Bernoulli grippers with a cylindrical nozzle was carried out for the case when the interacting surfaces of the gripper and the OM are parallel. However, the parallelism of these surfaces can be provided only in two cases: using base friction overlays (contact holding); with contactless OM holding when its center of mass coincides with the Bernoulli gripper (BGD) axis. For the case when the OM must be kept contactless, and its center of mass is shifted relative to the BGD axis, the radial gap between the active surfaces in a static position will have the shape of a wedge. Also, the wedge gap between the active surfaces of the gripper and the object of manipulation will be generated during a reorientation when the industrial robot of the loading and unloading operations is executed. In particular, the optimization of the orientation of the Bernoulli gripper is used when transporting objects along a straight line [22] or a screw trajectory [23], which minimizes energy transportation costs [24-25].

2. Methodology

The principle of BGD is as follows. The compressed air from the chamber 1 of the Bernoulli gripper (Fig. 1) through the nozzle 2 with radius \( r_n \) flows into the gap between its end surface and the surface OM 3.

![Fig. 1 Scheme for calculating BGD power characteristics](image)

At the same time, the radius \( r_n \), at \( h_c < r_n/2 \), undergoes the greatest constriction. In the place of the greatest narrowing, at excessive pressure of the gripper supply with compressed air of more than 30 kPa, the flow reaches a critical velocity equal to the speed of sound for these conditions. As a result of further increase in the area of the radial stream, its supersonic velocity increases, and the static pressure on the OM surface is reduced to a value less than atmospheric. At some distance from the center of the nozzle there is a sharp suppression of the supersonic flow, followed by its transition to subsonic, which is accompanied by the formation of a leap of pressure. As a result of further expansion, the velocity of the subsonic flow decreases, and the static pressure in the gap gradually increases to the magnitude of the atmospheric \( p_a \). The action of dilution on the OM surface leads to its levitation. The lateral displacement of OM prevents the emphasis 4.

When the center of mass of the object of manipulation relative to the BGD axis is displaced, the radial gap between their active surfaces in a static position has the shape of a wedge. The distance \( h_c \) and the angle \( \alpha \) depend on the weight \( G \) and the coordinate \( L \) of the center of the masses of the object of manipulation, as well as the nature of the
pressure distribution on its surface.

An analysis of the interaction of air jet with flat or cylindrical surfaces, presented in the papers [26-28], shows that the flow lines are practically radial, especially at flow rates close to the sound ones. In our case, we will assume that the flow lines are also radial.

To determine the air flow parameters in the gap between the interacting surfaces of the BGD and the OM, the following assumptions must be made: the flow of the jet after the exit from the nozzle occurs in the radial sectors without the flow of air from the sector to the sector; the air flow through each elementary sector $d\phi$ is proportional to the flow area at the nozzle cut $dS_n = d\phi r_n h_n$; the coefficient of air flow through the perimeter of the nozzle is accepted; The cross-sectional area of the pod chamber 1 is much larger than the cross-section of the nozzle $S_1 = 2\pi r_1 h_1$; the value of all parameters of the flow within the allocated elementary area $dS$ of the plane surface of the object are equal and correspond to the values of these parameters for the center point with the coordinates $r$ and $\phi$; the air flow enters the radial gap with the sound velocity; thermodynamic process of the supersonic flow – adiabatic; compressibility of air in the subsonic zone can be neglected; loss of energy when turning the air flow into the radial gap is small compared with frictional losses, so they can be neglected; the nature of the distribution of velocities in the radial interval is uniform.

The magnitude of the attraction force of the object by Bernoulli gripper is determined by the formula:

$$ F = F_f - F_n - F_r, $$

where $F_f$ is the force caused by the dilution in the supersonic and subsonic zones; $F_n$ – force is caused by the static pressure $p_0$ in the zone opposite the nozzle; $F_r$ – reactive force of the air jet, caused by its hit on the OM and turning at an angle of 90°.

At working values of the radial gap $h_c = 0.2...0.3$ mm, the reactive force $F_r$ can be neglected, with the static pressure in the zone opposite the nozzle, which is approximately equal to the absolute pressure $p_0$ of the BGD. Then

$$ F_n = \pi r_n^2 (p_0 - p_n). $$

The elementary force $dF_f$ caused by the action of static pressure on the elementary surface of the object $dS = drr\phi dp$: $dF_f = (p_\phi - p_0)dS = (p_\phi - p_0)drr\phi dp$, where $p_\phi$ is the absolute pressure of the air flow in the radial interval at the point with coordinates $r$ and $\phi$.

According to the calculation scheme (Fig. 1), the pressure distribution on the OM surface is symmetric with concerning the $x$ axis, then the general formula for determining the attraction force will look:

$$ F = 2 \int_0^{\pi/2} (p_\phi - p_0) r dr d\phi - \pi r_n^2 (p_0 - p_n). $$

(3)

The functions of pressure distribution in supersonic and subsonic zones respectively denote $p_\phi(1)$, $p_\phi(1)$ and will determine them taking into account assumptions.

To determine the pressure distribution $p_\phi(1)$ in the supersonic zone in the selected sector $d\phi$ of a radial flow will work out Bernoulli equation for sections coordinates $r_n$ and $r$:

$$ \frac{V^2}{2} + \frac{k}{k-1} \frac{p}{\rho^*} = \frac{V_\phi^2}{2} + \frac{k}{k-1} \frac{p_\phi(1)}{\rho_\phi(1)} + \zeta \frac{V_\phi^2}{2}, $$

(4)

where $V^*$, $p^*$, $\rho^*$ – under critical velocity, pressure and density of the air flow at its entrance a radial gap ($r = r_n$); $k$ – adiabatic index; $V_\phi$, $\rho_\phi$ – is the velocity and density of the air flow in the supersonic zone for the point with coordinates $r$ and $\phi$; $\zeta$ – coefficient of energy loss of the flow in the interval $r_n$ to $r$.

Using the method of [27-28] and taking into account the basic laws and equations of gas dynamics, we find equation for determining the pressure distribution $p_\phi(1)$ in the supersonic zone:

$$ 14.93 \left[ \left( \frac{p_\phi}{p_0} \right)^{1.7143} - \left( \frac{p_\phi}{p_0} \right)^{1.4286} \right] + \left[ r_n \left( \frac{h_c - \frac{r_n \delta}{r_0} \cos \phi}{r_0} \right) \right]^2 \left( 1 + \lambda_{1} \frac{r - L_c}{2h_c} \right) = 0, $$

(5)

where $\lambda_{1}$ is the mean value of the coefficient of viscous friction of the air flow in the supersonic zone, $\delta = r_0 \sin \alpha$ is the magnitude of the deviation of the OM from the horizontal position (Fig. 1).

To determine the pressure distribution $p_\phi(2)$ in the subsonic zone in the selected sector $d\phi$ of a radial flow will make Bernoulli equation for sections with coordinates $r$ and $r_g$:
\[ p_{r\phi} + \rho_s V_{r\phi}^2 / 2 = p_a + \rho_a V_{r\phi}^2 / 2 + \frac{E_2}{2}, \]

where \( V_{r\phi}, V_{r\phi} \) are the average velocity of the subsonic flow in the selected sector \( d\phi \) for the sections with coordinates \( r \) and \( r_g \); \( \rho_s \) - the density of the flow in the subsonic zone is approximately equal to the atmospheric air density; \( E_2 \) is the loss of the specific energy flux in the interval from \( r \) to \( r_g \).

Taking into account the basic laws, the equation of gas dynamics and the methodology of the article [27-28] find the pressure distribution in the subsonic zone in selected sector \( d\phi \) of radial flow:

\[
\begin{align*}
 p_{r\phi} &= p_a - \frac{0.2344 \mu^2 p_0^2}{RT_o \rho_a} \left( \frac{r_a^2}{r^2} \left( h_l - \frac{r \delta}{r_g} \cos \phi \right) \right)^2 - \frac{\lambda_2 r^2}{r_g^2} \left( h_l - \frac{r \delta}{r_g} \cos \phi \right) \int_{r}^{r_g} \frac{1}{r^2} \left( h_l - \frac{r \delta}{r_g} \cos \phi \right)^3 \, dr, \\
&\quad \text{if } Z_{r\phi} > 1; \\
&\quad \text{if } Z_{r\phi} \leq 1,
\end{align*}
\]

where \( \mu = 0.78...0.82 \) – coefficient of air flow costs [29-30]; \( R = 287.14 \text{ J/(kg} \cdot \text{K}) \) – gas constant for air; \( T_0 \) – absolute temperature of air in the chamber of the gripper, which is approximately equal to the temperature of the surrounding environment, \( \lambda_2 \) is the mean value of the coefficient of viscous friction of the air flow in the subsonic zone.

Use of formulas (5) and (7) for calculating the distribution of pressure on the OM surface corresponds to the condition

\[
Z_{r\phi} = \left( \frac{2}{k+1} \right)^{\frac{1}{k+1}} \left( \frac{h_l}{r_g^2} \frac{r \delta}{\cos \phi} \right) \frac{\mu \rho_0^2}{\rho_a^2 RT_o},
\]

3. Results and Discussion

Using the above methodology, a calculation of the pressure distribution on the OM surface for different values of the angle \( \phi \) (Fig. 2) was performed.

The calculations were made for BGD with the following design and operational parameters: \( r_a = 3 \text{ mm}; \) \( r_g = 30 \text{ mm}; \) \( h_l = 0.25 \text{ mm}; \) \( g = 0.075 \text{ mm}; \) \( \mu = 0.8; \) \( \lambda_1 = 0.03; \) \( \lambda_2 = 0.04; \) \( p_0 = 500 \text{ kPa}; \) \( T_0 = 290 \text{K}. \) Since the distribution of pressure on the OM surface is symmetric with respect to the \( x \)-axis, the graph for \( \phi = 3\pi/2 \) coincides with the graph for \( \phi = \pi/2 \). When the magnitude \( \delta \) (angle \( \alpha \)) increases, the asymmetry of the pressure distribution on the OM surface increases about the axis, and with the increase of the distance \( h_l \) between the BGD and the OM, the opposite decreases. The area corresponding to the value \( \pi/2 > \phi > \pi/2 \) is characterized by higher values of absolute pressure (lower values of dilution) compared with the zone \( \pi/2 < \phi < 3\pi/2 \).

For static equilibrium of OM with displaced about to the BGD axis the center of mass, here must be fulfilled such conditions: \( F-G = 0; M-GL = 0, \) where \( M \) is the torque caused by the asymmetric pressure distribution on the OM.
surface about the axis $y$; $G = mg$ – the weight of OM; $L$ is the distance from the BGD axis to the OM center of mass.

The elemental value of the torque caused by the action of dilution ($p_o - p_r$) on the elementary site $dS$ of the object, which is far from the axis $y$ at a distance $r_x = r \cos \phi$, is

$$dM = (p_o - p_r) r_x dS = (p_o - p_r) r^2 \cos \phi dr d\phi.$$  

(10)

Considering that the pressure distribution on the OM surface is symmetric to the $x$-axis, we obtain

$$M = -2 \int_0^\phi (p_o - p_r) r^2 \cos \phi dr d\phi. \quad \text{(10)}$$

In accordance with the system of equations (8), we can determine the displacement of the center of mass $L = M/F$, which corresponds to the parameters $h_c$ and $\delta$. The results of calculations using formulas (3) and (10) of the values $F$, $M$ and $L$ for different values of $h_c$ and $\delta$ (according to the above parameters of BGD) are presented in Fig. 3.

![Figure 3](image)

Fig. 3 The dependence of the lifting force $F$ and the displacement of the center of mass $L$ from the parameters $h_c$ and $\delta$

Charts in Fig. 3 help to determine the parameters $h_c$ and $\delta$, which characterize the equilibrium position of OM to BGD for different weights of the object and the coordinates $L$ of its center of mass. For example, in Fig. 3 the arrows show the interconnection between the parameters $L$, $h_c$ and $\delta$ for an OM with a weight of $G = 4N$. The analysis of data graphs confirms the correctness of simulation of physical processes, in particular, when reducing the weight of the retained OM can increase the displacement of their center of mass. If the weight OM $G \to F_{\max}$ then $L \to 0$, if $G \to 0$ then $L \to \infty$.

The presented researches prove that in order to increase the stability of the positioning and the reliability of holding objects in the process of manipulation, it is necessary that their center of mass is as close as possible to the BGD axis. If realization of this requirement is not possible, then it is necessary to increase the power characteristics of the BGD or to reduce the inertial loads during the acceleration (deceleration) of the final link of the PR. Increasing the positioning stability and reliability of holding objects with a displaced center of mass can also be achieved by means of combination of several grippers located on a shared frame [21], or by a special constructive execution of the active surface of the BGD.

4. Conclusions

The parameters of the flow of air flowing in the radial gap between the interacting surfaces of the contactless Bernoulli gripping device and the object of manipulation with the displaced center of mass are analyzed. The analytical dependences for calculating the air pressure distribution on a flat surface of the object of manipulation are proposed. It was established that the asymmetry of the distribution of the rarefaction on the surface of the object of manipulation depends on the magnitude of the displacement of the center of mass of the object. The formulas for calculating the force and torque associated with the action of the Bernoulli gripping device on the object of manipulation are proposed. Graphs of the dependence of parameters characterizing the static position of the object of manipulation to the Bernoulli gripping device are obtained.

5. Acknowledgment

Authors wish to acknowledge the financial support of State Fund For Fundamental Research (F83/78-2018) towards this project.

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Approach to Location of Air Cargo Terminals

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Abstract

Air transport is used for freight transport in cases where the higher speed of transport compared to road or rail is needed. The biggest volume of air transport belong to the transport of passengers, but in many cases there are flights, which are focused only on freight (cargo) transport. Compared to passenger air travel, the number of these flights is significantly lower. Even so, there are regular airlines for freight. When creating these lines, it is necessary to take into account the factors described in details in the first part of this article. The second part of the article is dedicated to the analysis of the airport infrastructure that is necessary for the transport of goods by aircrafts.

KEY WORDS: air cargo, cargo terminal, airport

1. Introduction

Air transport of goods represents only part of the transport chain. This mode of transport is not used for door-to-door transport, but is aimed at rapidly overcoming long distances. The goods must then be transported to the airport (to the cargo terminal), then loaded onto the aircraft, transported to the destination airport and then delivered to the recipient. For the first and last part of the journey, road transport is mainly used with respect to the volume of transported goods. Carriage of goods by aircraft may take place in two modes: either in the form of a pay-load (utilization of the remaining cargo space) in a passenger plane, or the goods may be transported by an aircraft designed solely for the carriage of cargo. The first mode can be called as belly-cargo. The choice of the mode depends mainly on whether the starting or destination airport is served by a regular freight line. Throughout the text, we think that the volume of transported goods from one shipper is considerably smaller than that of the entire cargo aircraft. If one customer uses the full capacity of the cargo aircraft, it is possible to carry out the transport directly on his/her order. However, this option will not deal with this article.

Due to the fact that air transport is particularly advantageous for longer distances, it is obvious that even the distance from the customer to the airport can be relatively large. As has already been mentioned, not every airport must be suitable for the transport of goods by aircraft. There are no regular freight lines at many smaller airports, and the availability or volume for belly-cargo may be limited. Similarly, it is also with destinations, which are served from smaller airports. There is not always a regular flight from a smaller airport to some large airports with regular cargo lines. This may lead to a situation where it is more convenient to transport a consignment by road to a more remote, larger airport, which is served by regular cargo lines or has a direct connection with another large airport. These facts lead to the customer having to carry out an analysis of the destination and destination aerodromes before shipping.

Airline companies have a different view of air cargo. For these, air cargo can be either a major source of revenue or an additional source in the form of a belly-cargo in personal aircrafts. It is not, however, the rule that each airline allows transportation of goods in their aircrafts. In the case of an airline operating air cargo, it is necessary to deal with the selection of destinations to be served by cargo aircraft. This selection affects many different factors that will be described below.

Last, no less important view of air freight transport is the airport infrastructure. In addition to a suitable system of runways and taxiways, suitable storage areas for the goods and, where appropriate, the provision of following logistics services must be available at the airport. From the point of view of the airport operator, it is therefore necessary to address the issue of the size and internal arrangement and equipment of the cargo terminal as well as its position with respect to the airport runway system and its location with respect to the passenger terminal. Factors that affect the location of the cargo terminal at the airport will also be described below.

2. Airport Selection for a Regular Freight Line

The first and very important prerequisite for establishing a regular freight line at an airport is the existence of a cargo terminal. Without the cargo terminal, it is not possible to provide further additional services, and transshipment between road and air transport is more complicated. In case the cargo terminal is built at the airport it is necessary to assess whether its capacity and throughput are sufficient for the anticipated volumes of transported goods. Capacity and throughput must also be assessed with respect to other cargo terminal users. In many cases, the cargo terminal is not owned by an airline but is operated either by the same operator as an airport or by another independent company. This cargo terminal can offer its services to many airlines. Its capacity is therefore shared. On the other hand, there are cargo
terminals owned or operated by air cargo companies. This type of terminals is not shared with other airlines and is therefore easier to plan for its required capacity.

However, only the existence of a cargo terminal at an airport is not a guarantee that one or more regular freight lines will fly to the airport. In order to involve the airport in the network of freight lines, it is important to assess what, for example, will be the annual demand for air transport. This depends primarily on the number of potential customers (manufacturing companies) in the defined area of the airport and on the nature of the products to be shipped. Even though a large number of industrial companies are located near the airport (e.g. within 100 km), their products may not be suitable for air transport or because of the price of air transport and the nature of the products it is unnecessary to consider the use of air transport. The choice of the mode of transport (in this case the use of air transport) for the given product mainly affects the following factors:

- Cost of transporting the material;
- Level of service commitment to the customer or end user;
- Value of the material and
- Time sensitivity of the material [1].

In the category of products suitable for air transport belongs the high-value goods, low-weight products and those for which it is necessary to guarantee fast delivery to the end-user. Examples of products that meet the above criteria may include some automotive parts, medication, medical equipment, jewelry, or quickly perishable goods.

Another factor that affects the introduction of a freight airline is the use of the airport during the day. As in the case of passenger transport, and in the case of freight air transport, regular cargo flights may have other connecting cargo flights. Therefore, if the airport is very busy at some times and there is no available runway capacity, it may lead to a decision that the airport is not suitable for line deployment. Another problem can be noise restrictions and night-time flights. In many cases, goods are collected in the cargo terminal during the day, and at night it is shipped to a distant destination airport, from where vehicles are taken to the destination by day. This method corresponds to the Hub & Spoke technology, with the respect to the fact that goods are transported from Hub to Hub mostly during the night hours. Night arrivals and departures at some airports can be a problem and may be restricted or prohibited. Such an airport may not be suitable for the introduction of a freight airline.

In order to decide whether to introduce a freight line at an airport, it is also necessary to determine how the new line affects the airline’s entire network of freight lines. Few airline companies that operate freight transport operate only one or a few unrelated freight lines. It is possible that by adding a new line to an existing network, the amount of goods transported on other lines will be affected. In other words, the flow of goods flows on the network may change. But this does not always have a negative effect. In some cases, there may be a decrease in demand over a particular freight line or an increase in aircraft usage. However, it is also necessary to anticipate a possible negative effect, which will reduce the use of aircraft capacity on other routes. To this factor, a great deal of attention must therefore be given.

An equally important factor that affects the introduction of a new freight line is the presence of competing airlines at the airport. Even here, however, competition may not be perceived only negatively. It is possible that competitive freight lines are only continental (e.g. within Europe) and the newly planned line is intercontinental (e.g. from Europe to the US or China). Competitive airlines can provide goods for transportation by long-distance intercontinental line. This will increase the load on the aircraft. For intercontinental lines, mostly large capacity aircraft are used, so goods from other (shorter) freight lines will contribute to more freight space utilization [2-4].

3. Selection of Location for the Cargo Terminal at the Airport

Freight transport activities are not priority at the airport. Much more attention is paid to passengers traveling through the airports in a very large amounts. For this reason, the airport operator or airport owner paid more attention to the passengers and passenger terminals than to cargo terminals. Passenger terminals are positioned to allow trouble-free and shortest connection to the runway system. It is also necessary to ensure access for passengers from the city. Cargo terminals are often located in the more remote parts of the airport (meaning with respect to passenger terminals).

Selecting a suitable position for a cargo terminal is related primarily to its type. Almost all airports provide spaces where belly-cargo goods can be stored for a temporary period. These spaces may be part of the passenger terminal or may be located in a separate building near to the passenger terminal. This location is chosen because of the short distance between the passenger building for this type of terminal. In this case, too large volumes of goods are not transported at the same time and other logistics services are not provided in the terminal. This type of cargo terminals serves primarily for the short-term storage of goods or the goods are subsequently transported to the cargo terminal.

The second type of cargo terminal is a large separate building, which also has its own handling area for loading and unloading freight aircraft. Additional logistics services such as customs warehouse, consignment consolidation, and the others are provided at this terminal. For location, it is very important for the terminal to be connected to the road and possibly to the rail network from the city side.

Two types of terminals can be located at the airport at the same time. Their presence depends on whether the airport is important for air freight traffic or not. From the point of view of their location, three basic variants of the deployment of these terminals were identified:

- Split cargo areas. Passenger belly cargo building(s) in proximity to passenger (pax) terminal but separated from all-cargo terminal area—Austin Bergstrom International Airport (AUS).
- Contiguous cargo area. Passenger belly cargo building(s) in proximity to pax terminal and adjacent to all-
cargo buildings—Washington Dulles International Airport (IAD).

- Scattered cargo areas. Passenger belly cargo building(s) in proximity to pax terminal but separated from a scattered all-cargo terminal area(s)—Indianapolis International Airport (IND) [1].

The distribution of terminals according to the first model is advantageous where a large volume of goods is only transported by cargo aircraft (therefore a separate cargo terminal), but a large part of the goods is transported as a belly-cargo in passenger aircrafts. Separate and remote location of the cargo terminal has the advantage of providing space for its possible future development. There is also a separation of road freight traffic towards a cargo terminal from passenger road transport, which is directed to the passenger terminal.

The second way of deploying cargo terminals is advantageous for airports where cargo volumes of goods transported by freight aircraft are similar to the volumes of belly-cargo. Belly-cargo may not be transported over long distances for further logistics processing, while cargo aircraft will benefit from the location near the passenger terminal, whose position is more favorable than for aircraft with cargo terminals.

The latter example is advantageous in cases where the flow of goods through the airport is not permanent but is subject to large imbalances (e.g. seasonal changes). Higher number of smaller cargo terminals allow flexible responses to larger or smaller quantities of goods waiting for shipment at the airport. In the off-season, some remote terminals are closed, which reduces operating costs. By increasing the volume of transported goods, the next cargo terminal can be quickly deployed to meet customer needs.

A special case is the cargo terminals of small parcel shipments companies (DHL, UPS, FedEx and similar). These companies usually have their own cargo terminals, which are intended exclusively for shipments transported by a company owned the terminal. These terminals are connected to a network of other terminals (not only for air freight) of one company and participate significantly in the entire shipment process. Often there is sorting of shipments for each region in the country. Shipments from this cargo terminal are transported by trucks to local distribution centers and then directly to customers.

4. Conclusions

The issue of the deployment of air cargo terminals is quite broad and can be understood from several angles of view. In order to create a freight network between cargo terminals and airports, it is important to correctly estimate the magnitude of demand for air freight. A poor estimate of demand can lead to the construction of a cargo terminal where it will not be too much used. A completely different approach to the deployment of cargo terminals should be applied in the event of their deployment at a particular airport. In both cases, it is advisable to use simulation models to help identify design weaknesses, or to gain insight into how the system works after changing some input parameters.

References

Lowering the Costs by Applying Optimised Cost Index

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Abstract

The purpose of this article is to explain and evaluate the issue of Cost Index, a useful tool used by air carriers aiming to reduce fuel cost and reach effective time management. Individual chapters explain the essence of the abovementioned term, its mathematical expression and factors which have a direct impact and also an influence of the parameters on air operators’ economy.

KEY WORDS: cost Index, optimisation, fuel economy, flight planning

1. Introduction

Daily there are around 10 000 civil aeroplanes cruising in the sky, depending on the day phase in each part of the world. Considering the capacity of the airspace, there is a rising pressure on civil air operators to use the airspace and flight corridors as effectively as they can. Last but not least there is remarkable emphasis on ecology and environment [1, 2].

Cycle of economic and oil crises as well as uncertain political conditions are driving air operators to lower the costs associated with fuel. Reduction of fuel consumption is possible not only by applying modern technologies in area of aeroplanes construction and power plant, however also with precise flight planning using the advanced software technology and data analysis [3, 4].

Flight planning is becoming more important and is the key factor to both; higher safety and optimal costs. There are several planning software on the market that are available to air operators for use. One of them, called LIDO, developed by Lufthansa Systems, enable to choose optimal airways, altitude, speed, etc. [5].

The most common method associated with optimal flight planning is the Cost Index. Resource of this method is explained further in this article.

2. Cost Index

Cost Index (CI) method is a tool, which is applied to achieve minimum flight costs by setting up techniques to derive correct balance between required costs for one hour of operation and fuel consumption. Is included in the section of flight regimes optimisation [4]. This method was initially established during the operation of early Performance Data Computers (PDC), predecessors of today’s Flight Management Computers. Mathematical calculation of Cost Index can be expressed as [4]:

\[
CI = \frac{C_{\text{Time}}}{C_{\text{Fuel}}},
\]

where CI is value of cost index, \(C_{\text{Time}}\) is variable defining time costs and \(C_{\text{Fuel}}\) is variable defining fuel costs. This mathematic interpretation can be found in Sperry/Honeywell products or Smiths Flight Management Systems (FMS). Considering Sperry/Honeywell, this scale is coupled with values from 0 to 999, while Smiths FMS uses values from 0 to 99 [6]. Using the Cost Index method can lead to two extreme cases. Either, \(CI = 0\) or \(CI = \text{max}\) (see Fig. 1).

When CI value is set as the lowest possible (\(CI = 0\)), \(C_{\text{Time}}\) is relatively low and \(C_{\text{Fuel}}\) is high. This is referred to as Minimum Fuel Mode for Maximum Range Cruise (MRC), hence it has greatest influence on fuel prices. On the other hand, in the case \(CI = \text{max}\), \(C_{\text{Time}}\) is relatively high and \(C_{\text{Fuel}}\) is low. This is referred to as Minimum Time Mode. CI set at maximum value is preferred when \(C_{\text{Time}}\) is much higher than fuel costs prevailing at that time [6].

Cost Index method is therefore an effective tool to control the amount of fuel flow and length of flight. Knowledge
of statistical data, structure of costs and operational priorities is necessary to optimise costs associated with fuel and time spent in the air [4].

![Cost Index diagram](image)

**Fig. 1 Cost Index extreme cases and its impacts on time and fuel costs**

### 2.1. Calculation of CI for Airbus and Boeing

As mentioned in an earlier chapter, Cost Index value is a rate of time costs $C_{Time}$ and fuel costs $C_{Fuel}$. There are several methods applied by aircraft manufacturers and FMS producers. The most common are Metric CI model used by Airbus (flight price in USD $\text{min}^{-1}$ and fuel price in USD $\text{kg}^{-1}$) and English CI model used by Boeing (flight price in USD $\text{hr}^{-1}$ and fuel price in USD $10^{-2} \text{Lb}^{-1}$) [4, 7].

Calculation used by Airbus and Boeing differs. Boeing values are approximately 30% greater than Airbus values, which are derived during the same time using the same fuel price. Some airlines operate same value of CI for all airplane models in their fleet. It is important to notice, that planning correct value of CI is also affected by upper winds, true airspeed in various flight levels, etc. [4, 7].

### 2.2. Factors Determining Value of CI

The primary factors affecting the Cost Index value are flight schedule, On Time Performance (OTP), costs associated with delayed flight and ATC instructions. Flight schedules influence the efficiency of air operator as they are determined by not only considering on time performance but also fuel costs, crew salary and relevant maintenance costs.

On Time Performance is, on the other hand, a critical aspect for customer satisfaction, while it also minimizes associated costs with flying [4, 8]. Costs analysis should be undertaken not only when flight is expected to experience some level of delays, but also when wind speed is greater than projected or when thunderstorm are forecasted along the flight path. It is vital to consider costs that are directly linked to minimizing the overall costs as a result of above-mentioned reasons, one of them being delay. As a result, delayed flights usually generate further costs, such as compensation of the passengers for any missed connecting flights, baggage transfers and slots [8]. On the other hand, when flight is performing ahead of its schedule, aim is to decrease the value of CI. Cost directly linked with such a scenario is simply a price for holding the gate and others.

As was mentioned before, CI changes also due to ATC instructions. It is reasonable to receive a request from an ATC during the flight to adjust the flight track or flight level. ATC instructions override the initial flight plans and are mandatory for flight crew to follow. As a result, CI value is revised and not necessarily relevant depending on the requests from ATC.

### 3. Comparison of Fuel Flow After Applying Various Values of CI on Airbus Aircraft

Application of CI is possible for all flight phases, or more precisely initial climbing, climb to the cruise altitude, cruise at the given altitude, descent and final approach. Its application is demonstrable in particular during calculation of the optimal cruise altitude with gradual climbing. This is a reason why the following analysis contains comparison of fuel flow during the climbing and descend stage after applying CI. Moreover, comparison of different CI values, chosen for a specific flight, together with their impact on flight economy are shown as well.

For the stated purposes, the Airbus aircraft were analyzed. This company is known as one of the biggest aircraft manufacturers, working on this issue very precisely. Analysis involved aircraft from Airbus A320 family (A119 and A320, equipped with CFM 56 engines and with take-off weight of 75 000 kg), which are generally selected for short-haul flights and Airbus A330 family (A330, equipped with PW 4168 engines and with take-off weight of 200 000 kg) used for long-haul flights.

#### 3.1. Comparison of Fuel Flow During the Climbing Stage After Applying CI

It is evident from Tables 1 and 2, that value of CI has direct impact on fuel consumption. The lower the CI, less fuel (in kg) is required to complete given flight path. Distance to reach Top of Climb (TOC) seem to fluctuate significantly between A320 and A330 based on given CI.

Higher CI is prolonging the distance to reach TOC and flight path is shallower. It is possible to reach the TOC at lower vertical speed while allowing passengers better comfort on-board at the same time. It is important to note that based on the computed CI, climbing phase is shorter in A330 case while A320 is roughly 3-4 minutes behind.
Table 1
Airbus A320 fuel flow during the climbing stage after applying Cost Index

<table>
<thead>
<tr>
<th>Cost Index</th>
<th>Fuel (kg)</th>
<th>Time (min)</th>
<th>Distance (NM)</th>
<th>CAS/MACH</th>
<th>Vertical speed at TOC (FT/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1 757</td>
<td>22.40</td>
<td>150</td>
<td>308/.765</td>
<td>584</td>
</tr>
<tr>
<td>20</td>
<td>1 838</td>
<td>23.01</td>
<td>159</td>
<td>321/.779</td>
<td>566</td>
</tr>
<tr>
<td>40</td>
<td>1 897</td>
<td>23.07</td>
<td>165</td>
<td>333/.783</td>
<td>550</td>
</tr>
<tr>
<td>60</td>
<td>1 980</td>
<td>24.70</td>
<td>175</td>
<td>340/.791</td>
<td>506</td>
</tr>
<tr>
<td>80</td>
<td>2 044</td>
<td>25.60</td>
<td>183</td>
<td>340/.797</td>
<td>461</td>
</tr>
<tr>
<td>100</td>
<td>2 080</td>
<td>26.10</td>
<td>187</td>
<td>340/.800</td>
<td>439</td>
</tr>
</tbody>
</table>

Table 2
Airbus A330 fuel flow during the climbing stage after applying Cost Index

<table>
<thead>
<tr>
<th>Cost Index</th>
<th>Fuel (kg)</th>
<th>Time (min)</th>
<th>Distance (NM)</th>
<th>CAS/MACH</th>
<th>Vertical speed at TOC (FT/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3 568</td>
<td>19.07</td>
<td>122.3</td>
<td>293/.761</td>
<td>963</td>
</tr>
<tr>
<td>50</td>
<td>3 773</td>
<td>20.02</td>
<td>134.6</td>
<td>309/.800</td>
<td>943</td>
</tr>
<tr>
<td>80</td>
<td>3 886</td>
<td>20.50</td>
<td>141</td>
<td>320/.812</td>
<td>917</td>
</tr>
<tr>
<td>100</td>
<td>3 927</td>
<td>20.74</td>
<td>143.3</td>
<td>320/.818</td>
<td>896</td>
</tr>
<tr>
<td>150</td>
<td>4 005</td>
<td>21.25</td>
<td>147.8</td>
<td>320/.827</td>
<td>873</td>
</tr>
<tr>
<td>200</td>
<td>4 068</td>
<td>21.68</td>
<td>151.5</td>
<td>320/.833</td>
<td>786</td>
</tr>
</tbody>
</table>

3.2. Comparison of Fuel Flow During the Descend Stage After Applying CI

To analyse the fuel consumption during descent, values used in calculation are measured on A320 and A330 aircrafts, which is equipped with the same engine types as in Table 1 and 2. Based on the calculation performed, it is noticed that lower the CI value, greater is the primary distance during the decent in both types of aircrafts (see Tables 3 and 4). Furthermore, higher CI value reduces the distance while recording steeper decent flight path. In addition, lower CI value decreases the speed during decent while higher CI on the other hand ensures decent is as a faster rate. Time, distance, speed and fuel consumption are also subject to change during the flight conditions variations.

Table 3
Airbus A320 fuel flow during the descend stage after applying CI

<table>
<thead>
<tr>
<th>Cost Index</th>
<th>Fuel (kg)</th>
<th>Time (min)</th>
<th>Distance (NM)</th>
<th>CAS/MACH</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>138</td>
<td>19</td>
<td>105</td>
<td>252/.764</td>
</tr>
<tr>
<td>20</td>
<td>125</td>
<td>17</td>
<td>99</td>
<td>278/.779</td>
</tr>
<tr>
<td>40</td>
<td>112</td>
<td>14.9</td>
<td>90</td>
<td>311/.786</td>
</tr>
<tr>
<td>60</td>
<td>137</td>
<td>14.6</td>
<td>92</td>
<td>339/.796</td>
</tr>
<tr>
<td>80</td>
<td>142</td>
<td>14.6</td>
<td>92</td>
<td>342/.800</td>
</tr>
</tbody>
</table>

Table 4
Airbus A330 fuel flow during the descend stage after applying CI

<table>
<thead>
<tr>
<th>Cost Index</th>
<th>Fuel (kg)</th>
<th>Time (min)</th>
<th>Distance (NM)</th>
<th>CAS/MACH</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>449</td>
<td>23.5</td>
<td>135</td>
<td>270/.774</td>
</tr>
<tr>
<td>50</td>
<td>444</td>
<td>22.7</td>
<td>134</td>
<td>281/.809</td>
</tr>
<tr>
<td>80</td>
<td>427</td>
<td>20.5</td>
<td>125</td>
<td>307/.819</td>
</tr>
<tr>
<td>100</td>
<td>420</td>
<td>19.6</td>
<td>121</td>
<td>320/.823</td>
</tr>
</tbody>
</table>

3.3. Comparing of Different Values of CI Chosen for a Specific Flight and Their Impact for Flight Economy

This section demonstrates practical impact of optimised CI on both; short-haul and long-haul flights. For the purpose of simulation, chosen aircraft are Airbus A319 and Airbus A330. Simulations are undertaken by LIDO software. Using the optimised CI value produced the most significant results under both types of aircraft and length of flights. In this analysis Aircraft A319 is used for demonstration of applied CI on short haul flight with a distance of 440 NM.

Table 5 highlights CI value of 31 as being the optimal when referring to time, fuel and costs. In comparison with CI 300, length of the flight is only 2 minutes longer, while overall saving in fuel burned is 228 kg.

For long-haul flight analysis with a distance of 4720 NM, Aircraft A330 was used. Table 6 shows the optimal CI value is 44 while highest CI is 300. Optimal CI resulted in 4349 kg of fuel saving and 16 minutes longer flight time compared to CI 300.
Table 5
Airbus A319 CI results for a specific short-haul flight

<table>
<thead>
<tr>
<th>Cost Index</th>
<th>Fuel amount (kg)</th>
<th>Flight time (hh:mm)</th>
<th>Costs (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2884</td>
<td>01:14</td>
<td>3184</td>
</tr>
<tr>
<td>31*</td>
<td>2896</td>
<td>01:12</td>
<td>3175</td>
</tr>
<tr>
<td>50</td>
<td>2920</td>
<td>01:11</td>
<td>3175</td>
</tr>
<tr>
<td>75</td>
<td>2933</td>
<td>01:11</td>
<td>3180</td>
</tr>
<tr>
<td>100</td>
<td>2957</td>
<td>01:11</td>
<td>3190</td>
</tr>
<tr>
<td>150</td>
<td>2959</td>
<td>01:11</td>
<td>3191</td>
</tr>
<tr>
<td>300</td>
<td>3124</td>
<td>01:10</td>
<td>3274</td>
</tr>
</tbody>
</table>

* Optimal CI

Table 6
Airbus A330 CI results for a specific long-haul flight

<table>
<thead>
<tr>
<th>Cost Index</th>
<th>Fuel amount (kg)</th>
<th>Flight time (hh:mm)</th>
<th>Costs (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>55728</td>
<td>09:46</td>
<td>51285</td>
</tr>
<tr>
<td>44*</td>
<td>56353</td>
<td>09:33</td>
<td>51390</td>
</tr>
<tr>
<td>50</td>
<td>56481</td>
<td>09:31</td>
<td>51434</td>
</tr>
<tr>
<td>75</td>
<td>56960</td>
<td>09:27</td>
<td>51634</td>
</tr>
<tr>
<td>100</td>
<td>57317</td>
<td>09:26</td>
<td>51802</td>
</tr>
<tr>
<td>150</td>
<td>57845</td>
<td>09:24</td>
<td>52062</td>
</tr>
<tr>
<td>300</td>
<td>60702</td>
<td>09:17</td>
<td>53537</td>
</tr>
</tbody>
</table>

* Optimal CI

4. Conclusions

Final chapter of this article concerns asset of this method and recommendation for air operators. Optimization applied on short haul flight saved the airline 228 kilograms of fuel while long-haul flight resulted in 4349 kilograms of fuel saving. Both of values are representing reasonable saving for airlines and also for environment.

The result of simulations conducted with LIDO software presented us the justness of Cost Index planning. It is necessary for airline to work with statistical data, smart planning software and sufficient number of staff in flight planning department. Important fact is that fuel costs can vary considerably with various sectors and it is more than important to consider specific costs for specific routes. To manage any variations, these should be readjusted seasonally.

Cost Index method is relevant for both; legacy as well as low-cost carriers. While Cost Index is still unknown concept for airline decision-makers, some air operators are yet to discover the importance of it.

Reasonable amount of fuel can be saved across the airline when precise planning is undertaken at the initial stage of flight preparation. Upfront cost is however involved with software equipment and those personnel involved in detailed flight planning.

Acknowledgement

This work was supported by CTU in Prague research program no. SGS17/150/OHK2/2T/16.

References

Development of the Theory and Methodology of Controlling the Local Tribological Contact Thermomechanical Loading

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Abstract

Theoretical and experimental studies have been carried out, which confirmed the fact that the contact temperature is the most important factor affecting the entire complex of service properties of the contacting materials. The authors of the paper propose the control of the frictional interaction of the tribological contact by controlling the temperature by forced cooling, which will stabilize the coefficient of engagement of the wheel with the rail.

KEY WORDS: rail transport, clutch coefficient, temperature, cooling, clutch control

1. Introduction

Among the existing friction gears (clutches, variators, belt drives, etc.), the most specific operating conditions are the frictional transmission of the locomotive's wheel tractive or braking power.

The specificity of wheels and rails interaction has several aspects. Firstly, the particles of substances of different origin get into the contact of wheel and rail:
- climatic (fallen leaves, moisture, ambient temperature);
- technological (ballast stones, corrosion products, lubricants);
- products of wear of wheels, rails, brake pads;
- transported cargo (oil, coal, cereals, etc.).

Secondly, the frictional conditions of contacting wheels and rails can be actively affected (by abrasive materials supply, friction activators, lubrication). Another feature of the wheel pairs is their multifunctionality. Wheel pairs provide:
- support and direction of the rolling stock while driving along the track;
- transmission of traction (braking) force;
- transmission of traction currents to the ground.

All these functions are realized when the wheels are in contact with the rails, and different functions are realized in different areas of friction surface of both the wheel and the rail. Therefore, the «wheel-rail» system is a combination of two pairs «friction» and «antifriction» [1].

2. Development of the Theory and Methodology of Controlling the Local Tribological Contact Thermomechanical Loading

As known, realization of the tractive (braking) force is accompanied by the wheels slipping relative to the rails. This leads to the fact that part of the locomotive power is spent not on traction, but on warming up and destruction (wear) of surfaces in the contact zone. Therefore, it is more correct to use the concept of transmission efficiency coefficient, first formulated in [2] in addition to the level of cohesion. It offers the following expression for determining the efficiency coefficient:

$$\eta = \frac{W_c}{W_g} = \frac{F_c \cdot V_l}{F_c \cdot V_{sl} + F_c \cdot V_{sl}} = \frac{1}{1 + \frac{V_{sl}}{V_l}},$$

where $\eta$ – transmission efficiency coefficient; $W_c$ – useful power; $W_g$ – general power; $F_c$ – force of wheel and rail cohesion; $V_l$ – locomotive speed; $V_{sl}$ – speed of slipping of the wheel relative to the rail.
One of the fundamental concepts used to describe the process of wheels and rails cohesion is the concept of «cohesion characteristic» - the dependence of the coefficient of cohesion on the relative slipping \( \varepsilon = f(\varphi) \). Considering \( \varepsilon = \frac{V_d}{V_f} \) it seems expedient to transform the formula (1) to the following form:

\[
\eta = \frac{1}{1 + \varepsilon}.
\]  

(2)

From Fig. 1 it follows that in all cases the use of sand increases the coefficient of cohesion and reduces slip, which leads to an increase in efficiency. But there is a «side effect» - an increase in resistance to movement (up to 12% [3]). However during braking this effect can be considered positive.

Fig. 1 Cohesion characteristic of contacting wheel and rail under different conditions

Using the formula (2) and dependences presented in Fig. 1, we determine the transmission efficiency for different frictional states. Considering implementation of the locomotive traction force corresponding to the two levels of the coefficient of cohesion: 0,2 and 0,25. The results of the calculations are summarized in Table 1.

Table1

<table>
<thead>
<tr>
<th>Frictional conditions</th>
<th>Slipping, %</th>
<th>Efficiency, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean surfaces</td>
<td>0,2</td>
<td>0,991</td>
</tr>
<tr>
<td></td>
<td>0,25</td>
<td>0,975</td>
</tr>
<tr>
<td>Water</td>
<td>0,9</td>
<td>0,993</td>
</tr>
<tr>
<td></td>
<td>0,975</td>
<td>0,985</td>
</tr>
<tr>
<td>Oil</td>
<td>3,5</td>
<td>0,966</td>
</tr>
<tr>
<td></td>
<td>12,1</td>
<td>0,892</td>
</tr>
<tr>
<td>Oil + sand</td>
<td>6,5</td>
<td>0,939</td>
</tr>
<tr>
<td>Water + sand</td>
<td>0,7</td>
<td>0,993</td>
</tr>
</tbody>
</table>

On the basis of the results obtained, it is possible to formulate requirements for frictional interaction in the wheel-rail system: providing a stably high coefficient of cohesion together with ensuring the maximum possible efficiency coefficient and minimizing the magnitude of the resistance to movement, taking into account the movement regimes and parameters (traction, braking, acceleration, etc.). Taking this into account, it is necessary to analyze the methods of active influence on the frictional properties of the «wheel-rail» tribosystem.

Improving the wheel-rail system interaction conditions is achieved by improving the design of locomotives, preventive measures and direct impact on the frictional properties of the surfaces of wheels and rails during their operation.

The mathematical model of tribological contact with intensive heat release in the system «wheel-rail-braking elements» which allows to determine the local surface temperature of the interacting elements depending on various factors was created. It involves the use of the experimentally obtained dependences of the coefficient of friction in rolling with slip (hereinafter friction coefficient) on the temperature in the contact zone \( f(\theta) \). The temperature in contact is to be understood as excess of the temperature in contact above the ambient temperature obtained by the relative friction of the roller against the rail.

In this paper, to establish the dependence \( f(\theta) \) the original automated measuring and computing complex «Friction machine» designed to study the frictional properties of the wheel-rail contact during rolling with slipping, both in laboratory and field conditions was used.

In the study of rolling with slip, the coefficient of friction can be considered as a function of the following parameters: absolute slip velocity; relative slip; contact temperature.

The temperature in the contact zone is of special interest. In order to test the effect of this factor on the coefficient of friction, two series of experiments were carried out with different values of the linear speed of the «Friction machine»
movement ($V = 0.09 \text{ m/s}$ and $V = 0.18 \text{ m/s}$). The experiments were carried out on a dry, clean rail.

After appropriate processing, the dependences of the coefficient of friction on the temperature in the contact zone (Fig. 2), the absolute slipping speed (Fig. 3), and the relative slip (Fig. 4) are obtained using the same experimental data. The last two quantities are determined by formulas:

\[ \theta = \omega \cdot R - V; \quad (3) \]
\[ \varepsilon = \frac{\theta}{V} \cdot 100, \quad (4) \]

where \(\theta\) – absolute slipping speed; \(\varepsilon, \omega, R\) – relative slip, angular velocity and working roller radius; \(V\) – friction machine’s linear speed.

In all figures, dots indicate the experimental points obtained at the speed of the friction machine 0.09 m/s, and circles – 0.18 m/s.

As can be seen from Fig. 2, the experimental data shown in the coordinate axes «temperature – coefficient of friction», for the indicated velocities of motion practically match. But the data in the coordinate axes «absolute slipping speed – friction coefficient» (Fig. 3) and «relative slip – coefficient of friction» (Fig. 4) are significantly different.

This result allows us to propose that the dependence of the coefficient of friction on temperature is universal (for specific frictional conditions) and does not depend on the parameters of motion. In order to test this assumption with given temperature and friction coefficient, we determine the absolute slip velocity and the relative slip.

We use the formulas obtained in [3] for determining the mean integral temperature on the rail surface and the distribution coefficient of the heat fluxes between the roller and the rail.

\[ \theta_{mi} = \frac{4 \cdot a_1 \cdot q}{3 \cdot \lambda_1} \sqrt{\frac{L_1 \cdot a_1}{\pi \cdot V}}, \quad (5) \]
\[ a_1 = \frac{1}{1 + \sqrt{\omega \cdot R/V}}, \quad (6) \]

where \(\theta_{mi}\) – mean integral temperature on the rail surface; \(a_1\) – the coefficient of distribution of heat flows between the roller and the rail; \(q\) – power of the heat source; \(\omega, R, V\) – have the same meaning as in (3.1); \(\lambda_1\) – coefficient of thermal conductivity of the rail material; \(L_1\) – the length of the roller contact with the rail.

Using (6) in (5), we obtain equation that relates the mean integral temperature \(\theta_{mi}\) to the angular velocity \(\omega\):
\( \theta_i^{mi} = \frac{4 \cdot P \cdot f \left( \omega \cdot R - V \right)}{3 \cdot \lambda_i \cdot F} \cdot \left( \frac{L_i - a_i}{\pi \cdot V} \right) \cdot \frac{1}{1 + \sqrt{\omega \cdot R / V}}, \)  \hspace{1cm} (7)

where \( P \) is the vertical load from the roller to the rail; \( F \) is the area of contact of the roller with the rail.

From Fig. 2 it follows that the maximum of the \( f \) coefficient that equals to 0.4 corresponds to a temperature of \( \theta_i^{mi} = 450^\circ C \). These values will be used in the calculations.

The values of the remaining values are taken from the experimental conditions and are summarized in Table 2.

<table>
<thead>
<tr>
<th>№</th>
<th>Designation</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>( R ), m</td>
<td>0.02</td>
</tr>
<tr>
<td>2.</td>
<td>( V ), m/s</td>
<td>0.09; 0.18</td>
</tr>
<tr>
<td>3.</td>
<td>( \lambda_i ), J/kg°C</td>
<td>460</td>
</tr>
<tr>
<td>4.</td>
<td>( F ), m²</td>
<td>0.0001230</td>
</tr>
<tr>
<td>5.</td>
<td>( L_i ), m</td>
<td>0.0062583</td>
</tr>
<tr>
<td>6.</td>
<td>( a_i ), W/m°C</td>
<td>74.4</td>
</tr>
<tr>
<td>7.</td>
<td>( P ), Н</td>
<td>240</td>
</tr>
</tbody>
</table>

In this case, in Eq. (7), the unknown is the angular velocity of the roller \( \omega \). Using the values from Table 2 in Eq. (7), we solve it for two values of the linear velocity (0.09 and 0.18 m/s) relative to \( \omega \). This can be done by one of the numerical methods, for example, by the method of half-division. After finding \( \omega \) the quantities \( \vartheta \) and \( \varepsilon \) are determined by the Eqs. (3, 4). The results of the calculations are shown in Figs. 3 and 4 with large circles.

As can be seen from the figures, the error in determining the calculated absolute slip velocity does not exceed 6%, and the relative slip - 11%.

The peculiarity of the experiments was the fact that the «Friction machine” operator increased the voltage of the working roll motor before the onset of slippage, but the slipping time was limited to 3-6 seconds to avoid damage to the «Friction Machine». After the operating roller «Friction Machines» has been thrown into skidding, the frictional force can raise, fade or remain unchanged, but the task of this study was not to study the development and termination of skidding.

The obtained result indicates that, according to the available dependence of friction coefficient on temperature, the remaining parameters of motion can be determined with sufficient accuracy for practical purposes.

According to the data of [4] contact stresses on the track of wheel rolling along the rail can reach up to 600 MPa and higher. In this case, the flash point of interaction of the roughness protrusions of the surfaces of the wheel and rail can reach values corresponding with the melting temperature of the contacting bodies’ material.

As the temperature of the steels of wheel and rail increases, the modulus of elasticity and the tensile strength decrease (Fig. 5), and therefore favorable conditions are created for plastic deformation and the process of setting the roughness protrusions of the contacting surfaces [5, 6]. The process of transferring the torque from the wheel to the rail is accompanied by skidding, as a result of which significant temperature gradients arise in the contact zone, contributing to the appearance of favorable conditions for the grasping of the surfaces. Excess heat release leads to a decrease in the strength of the surface layers, the destruction of the binder in the composite materials of the brake pads of locomotives, thermal stresses, dissociation of adsorbed films on the metal [7].

In the work [8], bench tests were carried out and the friction coefficient and tribospectral characteristics were analyzed in the absence and presence of friction modifiers in the friction interaction zone of the model wheel-rail subsystem of friction modifiers (Fig. 6).
As can be seen from Fig. 6 zone II is the «starting» of the rolling stock, which is accompanied by the periodic formation of local frictional contact sections with a positive and negative gradient of mechanical properties. Zone III is the realization of the tractive effort of the locomotive, in which the friction surfaces are heated to a favorable temperature, forming connecting bridges, the breaking of which leads to instant increase in traction. Zone IV – effective work and stability of the implementation of tractive effort. Zone V – as a result of plastic deformations of the contacting surfaces and their critical thermal heating, there is a drop in the stability of traction, a decrease in the coefficient of cohesion, and the onset of skidding.

Experimental studies carried out in [9] show that the dependence \( f_n = f(\theta) \) (Fig. 7) can be divided into three independent zones within which a different rate of change of the molecular component of the friction coefficient \( f_n \) is observed. When the temperature \( \theta \) varies from 20°C to 200°C (the first zone), the constancy of \( f_n \) is observed, which indicates a weak effect of temperature on the state of the contact layer.

In the second zone (from 200°C to 400°C) there is a severe decrease in \( f_n \) and a very unstable zone of setting. The main protection against setting is the oxide and other non-metallic films on the friction surface of the materials. In the case of static oxidation, the threshold for the reaction of iron is 350°C, where the term «reaction threshold» is understood to mean the temperature at which a significant rate of formation of thermodynamically stable oxide compounds is observed, but in the process of friction, when oxidation of the activated metal occurs, the reaction threshold may be lower.

With a further increase in temperature to 800°C (third zone), a significant increase in \( f_n \) to a temperature \( \theta_c \) of the structural-phase transformation is observed, which indicates qualitative changes occurring in the contact zone of the surfaces under investigation. This zone is characterized by contact grasping with small plastic deformations.

A further increase in temperature above \( \theta_c \) significantly reduces the yield stress and sharply increases the ductility of the contacting surfaces, which leads to the destruction of the bridge junctions between the protuberances of the rough surfaces, so that when the locomotive moves, metal particles are extracted from the surface of the wheel or rail and metal particles are transferred from one surface to another.

Analysis of the obtained temperature curves of the friction characteristics and physical and mechanical properties of steels shows that at a temperature of 350°C the tangential stresses and friction coefficient decrease, but with an increase in this temperature, the diffusion mobility of the atoms and the propensity of the steels to grasp increase.

According to the results of the research on the «Friction Machine» in the range of speeds of 0,1-0,9 m/s in the «shaft-partial bearing» scheme, it is established that the influence of the slipping speed on the coefficient of friction and wear is very insignificant until there is an essential temperature changes in the frictional zone on slipping contacts [10].

With an increase in the slipping velocity of more than 1 m/s, an increase in the friction coefficient is observed. In the case of maintaining an artificial temperature constant slipping contact, an increase in the friction coefficient is observed, and then its stabilization. If, on the other hand, the temperature is kept constant on the surface and in the volume, then when the speed increases, the maximum of the friction coefficient practically does not change at a constant load, and the wear rate remains unchanged.

According to research by Luzhnov Y.M. when the surface temperature in a local contact exceeds 450°C, the mechanical properties of the interacting surfaces significantly deteriorate, which leads to a decrease in the frictional force and their intensive wear [11].

Thus, the theoretical and experimental studies confirmed the fact that it is precisely the contact temperature that is the most important factor affecting the entire complex of service properties of the contacting materials.

The authors of the paper suggest controlling the process of frictional interaction of a tribological contact by controlling the temperature by forced cooling, which will allow stabilizing the coefficient of cohesion. On the basis of numerical experiments and bench tests it is established that controlling the temperature in the zone of tribological contact creates the conditions for controlling the process of cohesion the wheel to the rail, and the forced provision of constant temperature in the contact leads to stabilization of the coefficient of cohesion at the maximum level [12].

3. Conclusions

On the basis of the analysis of theoretical and experimental studies of friction contact, it can be stated that control of the mechanical component is not sufficient to achieve consistently high traction qualities of the rolling stock. Therefore,
it is proposed to control the clutch of the tribological «wheel-rail» system by controlling and regulating the local-mechanical temperature component in the range from 250 to 450°C, depending on the frictional conditions of contact.

Based on the results obtained, an algorithm for controlling the thermomechanical loading of a local tribological contact was developed, consisting in cleaning and cooling the contacting surfaces with a two-phase flow of dry ice granules and forced cooling with compressed air using a Ranque-Hilsch tube to achieve a stable contact temperature.

Acknowledgement

This research was funded by a grant (No. S-LU-18-12) from the Research Council of Lithuania and Ministry of Education and Science of Ukraine. This research was performed in cooperation between Volodymyr Dahl East Ukrainian National University, Ukraine and Vilnius Gediminas Technical University, Lithuania.

References

A Review of Qualitative and Safety-Related Solutions of Tram Interior to Support Their Selection at the Tram Design Stage

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Abstract

The work deals with selected elements of trams equipment that influence the quality of transport perceived by users and their assessment of the safety level. The paper focuses on the passenger space and its most important elements. The equipment can only meet safety requirements, e.g. emergency exits, or only increase the quality level, e.g. seats, and have an impact on both these areas, e.g. handles.

KEY WORDS: public transport, quality in transport, safety in transport

1. Introduction

Tram interior solutions used in public transport that meet certain quality requirements and respond to the transport offers matched to the passenger transport needs, have the highest chance of success. The influence of these solutions on the assessment of the quality of transport services has been described in the works [12, 14-16] in more detail.

However, the carriers are not able to meet all consumer requirements. Often a compromise is needed between what is need, what can be done and what is profitable to fulfil. In addition, market trends and the company's own experience are very common. Each of the entities related to the implementation of tasks (passenger, carrier, service operator) determines its own measures of transport quality due to market requirements, own capabilities, cost-effectiveness of operations, as well as standards and regulations that must be met [5, 6, 10].

One of the criteria used for assessing the quality of transport services is – generally understood – safety. It can be indicated that it is related to the conditions of carrying out transport tasks such as accident and criminal events in the vehicle or passenger exchange point. Despite the different perceptions of safety by assessing quality (passengers, carriers, local authorities, etc.), its significant contribution to the results of these assessments is confirmed [1, 3, 4].

The interior solutions of tram that can be used to achieve the desired level of safety and quality of transport services are related to equipment passenger trams, distribution of equipment, materials used marking, as well as forms of communication. It can be possible to reconcile the two goals using the solutions that meet the quality requirements on the one hand and, on the other hand – fulfill certain security functions. Such solutions are using in rail vehicles, but their selection is usually made only on the basis of one type of attributes mentioned before. For example, it is made only on the basis of features guaranteeing the fulfillment of quality requirements without considering safety functions. In this case the rational selection of the tram interior solutions/equipments is quite difficult. The problem stems from a lack of information what attributes these solutions/equipments have. Therefore, it is desirable to develop a review of solutions used in trams, which have an influence on the assessment of the quality of transport services made by passengers and at the same time fulfil the safety functions perceived by them.

The paper presents the division of passenger space elements of the tram due to their relationship with the quality of passenger space and the level of safety. An overview of selected equipment elements was developed and their influence on the quality of passenger space and the level of safety inside the tram were described.

2. Materials and Methods

Elements of passenger space equipment can be divided depending on their influence on the assessment of the quality of transport services and fulfillment of the so-called safety functions. For the purpose of this article, the term safety function is understood as the manner of reacting elements of safety systems to conditions/factors interfering with the performance of transport tasks, and even – leading to the loss of passengers' health or life. By default, all elements of the passenger space of the tram meet the safety requirements. Therefore, for the purposes of obtaining the solutions presented below, the following classification is proposed:

1. Elements of the tram interior, which perform the safety functions and have an influence on transport services quality assessment. Passengers are aware of the existence of these functions and therefore the influence of these elements on quality is important.

2. Elements of the tram interior, which not perform the safety functions but have an influence on transport services quality assessment. This influence results from the attributes of the elements perceived by the passengers but not related to generally understood safety.
3. Elements of the tram interior, which perform the safety functions but don’t have an influence on transport services quality assessment. Passengers do not see these elements or do not associate these elements with generally understood safety.

4. Elements of the tram interior, which not perform the safety functions and don’t have an influence on transport services quality assessment. Passengers do not consider the issue of meeting safety requirements, therefore the impact of these elements on the assessment of the quality of transport services cannot be demonstrated.

Table 1 presents examples of passenger space equipment for trams with an indication of its influence on safety and quality assessment by passengers.

<table>
<thead>
<tr>
<th>Elements group</th>
<th>Element</th>
<th>Influence on interior quality</th>
<th>Influence on interior safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Doors</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Seats</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Handrail/handholds</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Equipment of areas for wheelchairs and baby carriages</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Handles for transporting bicycles</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Information systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cover at the doors</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Floor</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pictograms</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>Emergency exits</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Emergency brake</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Monitoring</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>3</td>
<td>Timetable</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Tourist information</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ticket machine, ticket punchers</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heating / Air Conditioning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Advertisement</td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>

The market situation forces the producers of rolling stock used in public passenger transport to meet the conditions of the tender specifications. It is also necessary to recognize the preferences of passengers, because it is up to them to offer carriers and transport organizers. Strong competition between the producers did not allow for the emergence of a common standard solution, although specific trends have clearly emerged, which include above all [7, 11]:
- lowering of the tram's floor level as much as possible;
- noise reduction and increased comfort;
- reducing the distance between the vehicle and the tram stop platform;
- reduction of energy consumption of vehicles;
- reducing the scope and costs of service;
- increasing the possibility of keeping vehicle clean;
- the separation of special spaces, especially for the disabled, prams, and possibly bicycles, luggage;
- standardisation of design and equipment outside and inside the vehicle.

The tendencies mentioned above (apart from the confirmed impact on quality and safety) also give directions to the development of drives, control and development of the passenger space.

3. Overview of Selected Elements of Trams Equipment Affecting the Perception of Quality and Safety in Public Passenger Transport

Currently, the tram rolling stock is partly or completely low-floor. This is a significant advantage of this construction in relation to older types of vehicles, as it facilitates entry and egress of elderly, disabled or parents with prams. The low floor level also increases the exchange of passengers at stops. If the floor of the tram is only partially reduced, there is a problem of transitions between the vehicle components and the use of stairs and handrails.

Changing the floor height usually involves the creation of separate tram zones for various purposes. The level of the vehicle floor is not always at the level of the platform, or passengers are getting on the level of the roadway. Thanks to the use of fold-out platforms, people in a wheelchair can enter the vehicle themselves. These platforms, like the entire floor in a tram, should have a non-slip surface and marked with contrasting edges.

Vehicles should have special spaces to set up the stroller, wheelchair, bicycle or large luggage. Entrances behind these zones should be clearly marked with graphic signs (pictograms). In the area for disabled people using wheelchairs, for reasons of safety there should be communication devices enabling contact with the driver. They should be easily accessible to a disabled person. These are buttons indicating the willingness to leave the vehicle by a disabled person or
Additionally, they perform communications functions. It should be push buttons not touch sensors. The zone with special spaces should be monitored. The problem is the ambiguous function of the buttons in the zone. It can only inform the driver about the disabled person in the vehicle or open the door. In addition, it happens that buttons in special tram zones are used by people for whom these buttons are not intended. Then it may be necessary to verify such notification.

The number of seating positions in vehicles should be determined by the travel time. It is assumed that along with the distance of travel, the share of seats increases and the share of standing places decreases. Starowicz reports that the seat share ratio is 40% for new vehicle structures [13]. It can be pointed out that this value in relation to vehicles performing transport within the city due to the character of these services (short time and distance of travel) should be lower. However, seating is needed for the comfort of the elderly, pregnant women, people with reduced mobility and people with disabilities. The arrangement of the seats also affects the distribution of the mass of passengers in the vehicle.

The problem of space development in the vehicle and dividing it between seated and standing passengers in the tram, is solved by using folding chairs. The low-floor part of the tram usually has zones for wheelchairs and children with a limited number of folding seats. The folding chairs are very often mounted on the side walls of the vehicle and positioned sideways to the direction of travel. In practice, conflict situations arise. For standing passengers, it is important to be able to hold the handles comfortably and have a high availability [8].

Bicycle is an important means of transport in many cities, hence the possibility of transporting it by bus or tram is attractive. The bike should be transported in such a way as it is not generating the hazards for passengers. The driver may decide to remove a person from a bicycle from the vehicle in case of danger to other passengers. Vehicles should be adapted to transporting bicycles and equipped with separate spaces with safety systems. The following technical and organizational solutions are applied in this regard:

- belts for attaching bikes;
- luggage racks mounted outside or inside vehicles;
- bike racks or hangers;
- attachments or platforms for transporting bicycles;
- backrest intended for transporting bicycles.

Municipal public transport vehicles usually do not have dedicated zones to carry luggage. Passengers with large luggage usually use space for standing persons or a zone for the disabled. Some vehicle designs offer luggage racks located, for example, at the seats or at the entrance to the vehicle. Such solutions are most often included in vehicles used on bus/tram lines for airports, railway and bus stations. Due to the fact that the majority of passengers travel with small everyday hand luggage (briefcase, briefcase, city backpack, handbag), it is worth of attention to equipping space for people standing in small shelves that can temporarily place (or only support) luggage, e.g. at the windows. The door construction affects the time and convenience exchange passengers at bus/tram stops. The doors in vehicles are most often made as external and pocket sliding door applications. The vehicle doors should have the following safety-related attributes:

- the doors must be visible for the driver in mirrors or the video monitoring system;
- the door mechanism must work regardless of environmental or load conditions;
- each door must be equipped with a manual emergency opening mechanism and its actuating element must be properly secured;
- the door should be equipped with visual and audible alarms informing passengers about the door closing, which works both in automatic mode and by the driver. The signalling should start before closing the door and continue until it is closed;
- the door should have a mechanism to prevent the passenger from being trapped by the door.

In vehicles, the function of opening the door by passengers is available. The problem with its use, however, have people with limited mobility and blind. It is difficult for these people to find the entry / exit from the vehicle, and even more to find the button to open the door. There is a lack of standardization of the appearance and arrangement of the door opening buttons. They are placed both in the middle of the door and sides (both outside and inside vehicles). The location of the door opening button in the middle of the door outside the vehicle causes blocking of passengers getting out by passengers getting on. Characteristics of the tramway doors important for maintaining a satisfactory level of quality are:

- number of doors;
- door width;
- number of passenger exchange streams;
- number of door leaves;
- opening/closing door systems and construction of the door (opening the door by the passenger or only the driver, the door opening inwards or springing outside the box).

The time of opening / closing the door is important - due to the time the vehicle stops at the bus stop. Single-wing doors with a large surface can have a longer closing time than double-leaf doors. Particularly important is the determination and designation of work zone photocell. Passengers often do not know about such a zone and unknowingly delay the time of closing the door and leaving the vehicle at the bus stop.

In vehicles, the door to the driving cabin is variously constructed. Usually, these are the solutions of the doors from the passenger compartment. These are problematic solutions when there is a need to leave the vehicle during rush
hours, e.g. to set the crossover. The driver is forced in extreme cases to ask the passengers blocking the door to temporarily leave the vehicle.

A travel, its planning and implementation depend to a large extent on the flow and availability of information for the passenger. It can be said that many trips in public transport are unplanned or indicatively planned. The passenger arrives at the tram/bus stop and determines the travel route only when the information is available, e.g. the timetable. The vehicle intended for passenger public transport should be marked with tables containing the following information for travellers [11]:

- route (transport relation);
- driving direction (destination stop);
- type of connection due to speed (ordinary, accelerated, hurried, etc.);
- current location (stop).

Signs with the vehicle's line number and other information boards are usually located on the outside, on the front, on the vehicle and on the side of the vehicle (from the side of the door and the stop). It is less common to place these devices on the other side of the vehicle. When moving around in the urban space, the vehicle should be marked on each side giving the opportunity to determine the relation of transportation to passers-by (potential passengers). In terms of information pictograms, the solutions used are not homogeneous and, to a large extent, solutions developed by designers.

Nowadays, Intelligent Transport Systems (ITS) are used in transport systems. The operation of these systems in the aspect of improving safety is accomplished through the following functions: selection of traffic participants, impact on their behaviour, mitigation of consequences of adverse events, reduction of the effects of disturbances, reduction of the time of restoration of normal traffic conditions [9]. ITS also allow you to set priorities in traffic for public transport vehicles and have the ability to locate vehicles in space and control the implementation of tasks in accordance with the timetable. Therefore, the modern urban public transport system should ensure the following functions in vehicles [2]:

- access to a basic set of information about the line/route, possible transfers and ticket prices;
- the ability to transmit current and current information about the location of the vehicle on the route (annunciation of the name of the next stop);
- the ability to display the current time.

In addition to the previously mentioned information, the system should also include the transfer of information through the websites of the carrier, the transport organizer, applications for mobile devices, and in case of failure capable of moving quickly organize mobile information points [2].

Ticket machines, e-ticket terminals, like passenger information systems, are added by the carrier or transport organizer at the usage stage but their location in the vehicles should be analysed before. Ticket punchers should not be installed near the door of the vehicle, because then they slow down the process of passenger entry. However, it is appropriate to place the tickets punchers on the opposite side of the vehicles door. It forces the passenger to take a seat in the interior of the passenger compartment and limits the situation of blocking the doors by passengers validate the tickets.

Public transport entities gain additional revenues from advertisements placed outside or inside vehicles. It is also a carrier of additional information for passengers regarding the transport offer. It happens, however, that advertising measures disrupt the passenger space or even pose a hindrance to passengers. The advertisement should not be placed on the windows from the door side, giving passengers the visibility and the possibility of observation. The other side of the tram can be completely covered with the condition of making the veneer transmitting light at the level of 70%. Visibility is also limited by information boards placed in the window space.

4. The Influence of Tram Interior Elements on the Perception of Quality and Safety in Public Transport

It should be noted that the impact of vehicle interior components on the perception of quality and safety can be both positive and negative. For example, ticket machines, passenger information are equipment desirable in trams, but improper placement of these devices in a vehicle can be perceived negatively. Advertising media are similarly perceived, which in its essence have no impact on the quality of the passenger space. Table 2 Description of the influence of selected tram interior elements on the quality and safety perception in public transport. The description focuses on the tram interior elements, which perform safety functions and have an impact on the assessment of the transport service quality and the impact of these elements on quality is important.

The described elements and their functions (Table 1) influence the perception of transport quality by passengers to varying degrees and perform safety functions to varying ways.

5. Conclusions

The article focuses mainly on such elements of the tram interiors, which have a simultaneous impact on the assessment of the safety level and quality by users. Defining the system's quality requirements is not easy. They are related to various areas of the assessment of the functioning of the entire urban transport system, i.e. from the point of view of the passenger, the carrier, designers and manufacturers, and the surroundings of the system. Discrepancies between the designer's vision, the design of the constructor, the requirements of the customer, the transport operator and the passenger are a permanent element of the existing problems in the construction and equipment of the systems. The
variety of passenger information systems and devices, ticket makers, ticket machines and the fact that the organizer ultimately is responsible for this equipment, makes them not an integral part of the vehicle design, and often only an addition necessary on the tender. This results in the creation of many interior solutions of vehicles uncomfortable for the passenger and disturbing the internal space. It is also a cause the perception of the level of service quality as lower.

All elements of passenger space equipment must meet safety requirements and regulations. Not all of these elements perform safety functions by reacting to factors leading to loss of property, health or life of passengers.

Table 2

<table>
<thead>
<tr>
<th>Element</th>
<th>Influence on interior quality</th>
<th>Influence on interior safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doors</td>
<td>Facilitating the access of passengers to the tram, shortening the time of passenger exchange at stops</td>
<td>Sliding plug, external and pocket sliding door applications</td>
</tr>
<tr>
<td>Seats</td>
<td>Impact on travel comfort, the use of materials and solutions to help maintain cleanliness</td>
<td>Increasing the level of safety for the elderly and with limited mobility</td>
</tr>
<tr>
<td>Handrail/handholds</td>
<td>Impact on the design of the interior, increase the comfort of travel, the use of materials and solutions to help maintain cleanliness</td>
<td>Belaying against loss of balance while driving</td>
</tr>
<tr>
<td>Equipment of areas for wheelchairs and baby carriages</td>
<td>Increasing the availability of services for invalids and baby sitters</td>
<td>Increasing the level of safety for invalids and children in prams</td>
</tr>
<tr>
<td>Handles for transporting bicycles</td>
<td>Increasing the availability of services for people using a bike on a combined journey</td>
<td>Reducing the risks associated with transporting a bicycle by tram</td>
</tr>
<tr>
<td>Cover at the doors</td>
<td>Improving thermal comfort</td>
<td>Separation from the stairs</td>
</tr>
<tr>
<td>Information systems</td>
<td>Information systems on the implementation of tasks and additional services</td>
<td>Warning systems</td>
</tr>
<tr>
<td>Floor</td>
<td>Materials and solutions to facilitate cleaning</td>
<td>Non-slip materials, contrast markings of level differences and stair steps</td>
</tr>
</tbody>
</table>

References

Revising the Phenomenon of Tire Hydroplaning

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Abstract

The invention of car was around 15th century it has focused a lot to attain maximum speed, at maximum efficiency, with safety. The efficiency, speed & safety also depends on the factors around it to attain its maximum. Among that a survey in London states that major accident in that city are caused due to skidding & sliding of vehicle. Later it is found that hydroplaning is the cause. Guaranteeing safety vehicle includes a vehicle with good conditioned tires. The interstate specialists worry about the wet-climate driving wellbeing of vehicles. Among factors identified with this security issue, wet-asphalt grating which prompts hydroplaning has been perceived as a key factor that influences street wellbeing. So the main objective of this paper is to give a detailed information about hydroplaning, types of hydroplaning, causes for hydroplaning, scientific reasons behind the hydroplaning. The proposal would be demonstrated methods to be a useful and convenient tool for predicting skid resistance and braking performance of passenger cars during wet weather.

KEY WORDS: Hydroplaning, Tires, Pavement.

1. Introduction

Hydroplaning or Aquaplaning is a phenomenon in which the tires experiences complete loss of friction or traction while passing over a film of water or snow. So rainy days are good example of hydroplaning where experiences loss of friction or traction force in driving. When in a rainy day passing through a narrow road where there is a depression on the road so film of water is contained. When driving slow on that road the tire of the vehicle gets contact with the surface of the road so there is loss in friction and vehicle is not skid. But while driving fast the vehicle’s tire travel over the film of water so it losses the friction and skill’s. The tire of the car is made up of tread, spies, block, ribs, dimples which makes contact with surfaces and cut through the water. In the event that it jumps out at all wheels at the same time, the vehicle progresses toward becoming, basically, an uncontrolled sled. Aquaplaning is a reality when water on the surface of the roadway simply goes about as an oil. Footing is reduced on wet asphalt notwithstanding while aquaplaning isn't happening [1] .

The pressure given by the water can make your auto ascend and slide over a thin layer of water between your tires and the street.

Friction between wheels or tires and the ground that enables a vehicle to push ahead. It is the protection from turning when a torque is connected to hub the wheel. At the point when a surface is wet, a layer of water can go about as an lubricant, incredibly decreasing the treads are utilized to expand friction [1]. In hustling where the torque on the tires is high, uniquely made tire is utilized to anticipate loss of friction when tires begin to rotate [3].

As indicated by reports by the National Transportation Safety Board and Federal Highway Administration (FHWA), around 14 percent of deadly mishances happened when asphalts were wet in 2003's report. By enhancing asphalt slip obstruction, wet-climate mishaps diminished by no less than 54 percent in 2009's report. In the United Kingdom, it is accounted for that in excess of 25 percent of wet climate mishaps were identified with slide obstruction condition in 1990's report. In 1980, the National Transportation Safety Board (NTSB) and the Federal Highway Administration (FHWA) of USA detailed that wet asphalts added to 29 percent events all things considered. In wet climate, vehicle sliding or hydroplaning can happen if there is insufficient slip opposition accessible on asphalt surface. Hydroplaning is a circumstance when the tire is isolated from the street surface by hydrodynamic powers and slip obstruction declines to low or almost zero levels [2]. From statistic shown by various federal boards it is clear that hydroplaning is important factor to be concerned.

2. Causes of Hydroplaning

The causes of the hydroplaning can be varied upon the situation the vehicle undergoes, but there are some important factors that leads to hydroplaning.

Vehicle Velocity: As speed builds up, wet friction is extensively lessened. Since hydroplaning can result in a total loss of friction and vehicle control, you ought to dependably diminish speed, focusing on the activity around you.

Tire treads depth: As your tires end up worn, their capacity to oppose hydroplaning is decreased.
Water depth: The more profound the water, the sooner you will lose friction, albeit even thin water layers can cause lost friction, including at low speed [4, 6].

Pavement cross slope and grade: Cross slant is the degree to which the cross-area of a street looks like an upturned U. Higher cross slants enable water to deplete all the more effortlessly. Level is the steepness of the street at a specific point, which influences both waste and power applied by the vehicle out and about. Vehicles are less inclined to aquaplane while voyaging tough, and unquestionably liable to do as such at the trough of two associated slopes where water tends to pool. The resultant of cross slant and grade is called waste angle or "coming about review". Most street outline manuals necessitate that the waste inclination in all street segments must surpass 0.5%, keeping in mind the end goal to maintain a strategic distance from a thick water film amid and after precipitation. Zones where the waste angle may fall beneath as far as possible 0.5% are found at the passage and exit of managed an account external bends. These problem areas are regularly under 1% of the street length, however an expansive offer of all slide crashes happen there. One strategy for the street creator to lessen the accident chance is to move the cross incline progress from the external bend and to a straight street area, where parallel powers are lower. On the off chance that conceivable, the cross incline progress ought to be put in a slight up-or downsize, along these lines keeping away from that the seepage inclination drops to zero. The UK street plan manual really calls for arrangement of a cross incline progress in a misleadingly made slant, if necessary. Now and again, penetrable black-top or cement can be utilized to enhance waste in the cross slant changes.

Pavement micro- and macro texture: Cement can be desirable over hot blend black-top since it offers better resistance from groove arrangement, however this relies upon the age of the surface and the development systems utilized while clearing. Concrete likewise requires exceptional regard for guarantee that it has adequate surface [1]. Micro texture is characterized as the adequacy of the deviations with wavelengths not exactly or equivalent to 0.5 mm full scale surface is characterized as the abundance of an asphalt surface with wavelengths from 0.5 to 50mm and mega surface is characterized as the sufficiency of an asphalt surface with wavelengths from 50 mm to 500mm. It is normally portrayed as pain or imperfections in the street surface [2].

3. Types of Hydroplaning

Viscous Hydroplaning
Viscous hydroplaning is because of the thick properties of water (Fig. 1). A thin film of liquid close to 0.025 mm top to bottom is all that is required. The tire can't enter the liquid and the tire moves over the film. This can happen at a much lower speed than dynamic aquaplane, yet requires a smooth or smooth-acting surface, for example, black-top or a touchdown zone covered with the collected elastic of past arrivals. Such a surface can have indistinguishable contact coefficient from wet ice [1].

![Fig. 1 Viscous Hydroplaning](image)

Prevention of viscous hydroplaning
- Land on a scored runway, if conceivable.
- Don't arrive quickly.
- Keep your tires expanded. Under-swelled tires hydroplane less demanding than legitimately expanded ones.
- Use back pressure and aerodynamic braking to back off, and utilize light brake pressure.

Dynamic Hydroplaning
Dynamic hydroplaning is a moderately fast marvel that happens when there is a film of water on the runway that is something like 1/10 inch (2.5 mm) profound (Fig. 2). As the speed of the airplane and the profundity of the water increment, the water layer develops an expanding protection from uprooting, bringing about the arrangement of a wedge of water underneath the tire. At some speed, named the aquaplaning speed ($V_p$), the upward force created by water pressure parallels the heaviness of the air ship and the tire is lifted off the runway surface. In this condition, the tires never again add to directional control, and braking activity is nil. Dynamic hydroplaning is for the most part identified with tire swelling weight. Tests have demonstrated that for tires with noteworthy burdens and enough water profundity for the measure of tread so the dynamic head pressure from the speed is connected to the entire contact fix, the base speed for dynamic hydroplaning ($V_p$) in tangles is around 9 times the square base of the tire weight in pounds per square inch (PSI). For a aircraft tire pressure of 64 PSI, the figured aquaplaning pace would be around 72 hitches. This speed is for a rolling, non-slipping wheel; a bolted wheel decreases the $V_p$ to 7.7 times the square base of the weight. In this way, once a bolted
tire begins aquaplaning it will proceed until the point when the speed lessens by different means (air drag or turn around push) [1].

**Prevention of dynamic hydroplaning**
- Don't arrive quickly on a wet runway. Dynamic hydroplaning occurs at around 8.6 times the square base of your tire weight. For a Cessna 172 with 42 PSI tires, that is around 56 ties.
- Keep your tires expanded. Under-expanded tires hydroplane simpler than appropriately swelled ones.
- Use back weight and streamlined braking to back off. The more weight you have on your tires, the better

**Reverted Rubber Hydroplaning**
Reverted rubber (steam) hydroplaning happens amid substantial braking that outcomes in a delayed bolted wheel slip. Just a thin film of water on the runway is required to encourage this sort of hydroplaning (Fig. 2). The tire slipping creates enough warmth to change the water film into a pad of steam which keeps the tire off the runway. A symptom of the warmth is it makes the elastic in contact with the runway return to its unique uncured state. Signs of an airplane having encountered reverted rubber hydroplaning, are particular 'steam-cleaned' blemishes on the runway surface and a fix of reverted rubber on the tire. Reverted rubber hydroplaning much of the time takes after an experience with dynamic hydroplaning, amid which time the pilot may have the brakes secured an endeavor to moderate the flying machine. In the end the air ship eases sufficiently back to where the tires reach the runway surface and the flying machine starts to slip. The solution for this kind of aquaplane is for the pilot to discharge the brakes and enable the wheels to turn up and apply direct braking. Returned elastic aquaplaning is treacherous in that the pilot may not know when it starts, and it can endure to moderate groundspeeds (20 knots or less) [1].

**Prevention of Reverted rubber hydroplaning**
- Use light brake pressure, and utilize aerodynamic braking to keep most extreme pressure on your arrival equip.
- Use light brake pressure, and never bolt up your brakes on landing.

**Empirical Prediction Models for Hydroplaning**
Agrawal and Henry [2] performed probes completely bolted wheel sliding on asphalt with water film thickness under 2.4 mm. The determined condition for hydroplaning speed is as follow:

$$V_p = 33.7 + 5.28(t_w)^{-0.5},$$

where $V_p$ is the hydroplaning speed in mph and $t_w$ is the water film thickness in inch.

Concentrate by Huebner et al. [2] in light of experimental hydroplaning model proposed by past explores, Huebner et al. (1986) built up an adjusted forecast show for hydroplaning speed:

$$V_p = 26.04(t_w)^{0.259}.$$ 

Anticipated hydroplaning speed in view of water film thickness as it were. It is noticed that these models are observational in nature and are material to the conditions spoken to by the investigations from which they were determined (Anderson et al., 1998). Horne and Dreher [2] called attention to that tire swelling weight might be the most vital
parameter that decides the hydroplaning speed. Research at the Langley Center delivered the outstanding NASA hydroplaning condition:

\[ V_p = 6.36 \sqrt{P_t} \]

where \( P_t \) is the tire expansion weight in kPa and \( V_p \) is the hydroplaning speed in km/h. The hydroplaning speeds got are substantial for smooth tires without escape ways for water and for rib tires on wet asphalt surface where the water profundity is thicker than tire tread profundity.

4. Conclusion

The front of the tire is filled with water and the resulting pressure raises the tire. The water pressure is proportional to the water density and twice the speed. Grease when the tire is fully retracted from the road is called the critical aquaplaning speed. Under these conditions, the car begins to slip inertia, the brakes stop and the car becomes unmanageable. The minimum water level, which may cause aquaplaning depending on the pavement, tire and speed, can range from 2.5 to 10 mm. In most cases, experimental studies of such complex phenomena like hydroplaning are much more reliable than numerical, but are quite expensive. Therefore, to even more precisely investigate the complexity of the phenomenon as the vehicle tire hydroplaning, it would be useful to perform significantly faster and cheaper numerical experiments.

References

Research and design of Middle Range Rocket Target

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Abstract

The main aim of this project is to create a solid rocket motor model and make a detailed analysis of the external ballistics. The basic requirement data are collected and initial rocket functional characteristics are calculated. External ballistics problems and data are observed in the MATLAB where thrust, acceleration, velocity, and rocket mass change with respect to time is measured. Developing an engineering computation of the middle range rocket target was done. The necessary thrust force for the give rocket target and investigation of the external ballistic problems is obtained. After the analysis of external ballistic of the rocket, the construction of the rocket motor is made.

KEY WORDS: rocket, middle range rocket target, solid rocket motor

1. Introduction

Development of the military training equipment is an important aspect for minimising the costs and obtaining the higher training process efficiency. Aerial targets are most commonly used in the military training section. The most efficient way to simulate hostile aircrafts is an aerial target, which has a rocket propulsion system; one of the aspects inspires this project. The main aim of this project is to develop a rocket target for the middle range air defence systems. The rocket must achieve the entire military training equipment requirement, such as low cost to manufacture and it should be conjugated for the military missions as a target for the middle range air defence systems. One such target was RT-400, which was having the capable of flying about 5 km in the distance and 3km in the altitude [1]. Getting inspired by this target there is a one-step forwarded in this project. It is essential to research and design a rocket motor for middle range that is about 15-20 km in distance and in altitude about 5–8 km. But the rocket parameters should be as same as the RT -400 so the rocket diameter will be 0.4 m and 5 m length; this rocket can fly at a velocity of 250-300 m/s. Analysis of the external ballistic characteristics such as velocity, acceleration, thrust, change in mass of the rocket as the propellant burns and trajectory path has been investigated. The rocket motor has been created in which required propellant mass can accommodate.

2. Mathematical Calculation

In the mathematical calculation the fundamentals for the rocket propulsion is calculated where thrust, velocity, acceleration, mass change with respect to time are calculated. Thrust is the basic force, which is needed to move the rocket in the air. The movement of the gases from high-pressure region to the low pressure produces the thrust. Rocket thrust works on the newton’s third law, which states that for every action there is equivalent and opposite reaction in the same way when the gases are made to flow through the nozzle the rocket will propel in the opposite direction.

Newton’s second law is in to the action and it states that the force to be change in the momentum of object with respect to time. Definition of momentum is object's mass times the velocity. When gas is in the action, the basic thrust equation is given as [2]:

\[
F = \dot{m}_e \cdot V_e - \dot{m}_o \cdot V_o + (P_e - P_o) \cdot A_e,
\]  

where \( F \) is equal to the exit mass flow rate \( \dot{m}_e \) times the exit velocity \( V_e \) - the free stream mass flow rate \( \dot{m}_o \) times the free stream velocity \( V_o \) and the pressure difference across the engine \( P_e - P_o \) times the engine area \( A_e \).

There will be on board propellant, fuel and oxidizer for liquid and solid rockets. There will be no free steam air will be entering the engine, so the equation can be reduced to:

\[
F = \dot{m} \cdot V_e + (P_e - P_o) \cdot A_e,
\]
where we have removed the exit designation of the rocket.

Use of algebra, divide by $\dot{m}$:

$$\frac{F}{\dot{m}} = V_e + (P_e - P_o) \cdot \frac{A}{\dot{m}},$$

(3)

Now we have introduced the equivalent velocity $V_{eq}$ that is located on the right-hand side of the equation:

$$V_{eq} = V_e + (P_e - P_o) \cdot \frac{A}{\dot{m}}.$$  

(4)

Then the thrust of the rocket becomes:

$$F = \dot{m} \cdot V_{eq}.$$  

(5)

Once the thrust force is calculated then the next force is to calculate is gravity force and it is obtained as shown below, as the rocket, starts to burn the propellant there will be a reduction of the rocket mass and it is shown graphically in the upcoming figures.

$$F_g = \dot{m} \cdot g.$$  

(6)

Total impulse defined as the average thrust time the total firing time. We can denote the total time as “$\Delta t$”.

$$I = F \cdot \Delta t.$$  

(7)

There will be change in thrust with respect to time; we can define an integral equation for the total impulse. Using integral, we have:

$$I = F \, dt.$$  

(8)

Substituting the in the above equation, we get:

$$I = (\dot{m} \cdot V_{eq}) \, dt,$$  

(9)

$\dot{m}$ rate of mass flow, it is amount of exhaust gas per time that comes out of the rocket. We must assume that velocity equivalent as constant; we now integrate the equation to get:

$$I = m \cdot V_{eq}.$$  

(10)

Total mass of the propellant is $m$. now we have to divide this equation by weight of the propellant to define specific impulse. The word "specific" just means, "divided by weight". The specific impulse $I_p$ is given by:

$$I_p = \frac{V_{eq}}{g_0}.$$  

(11)

where $g_0$ is the gravitational acceleration constant. Now, if we substitute for the equivalent velocity in terms of the thrust:

$$I_p = \frac{F}{(\dot{m} \cdot g_0)}.$$  

(12)

A well-designed nozzle consists of converging and diverging sections where once the combustion takes place in the combustion chamber the hot gases will passes through the nozzle in to the atmosphere. When the gases are burnt it will be in the subsonic flow. Once the gas reaches the throat section the gases will be highly pressurized, and it fusses to the diverging section of the nozzle where the output will be supersonic or greater than the speed of sound. If there is any fault in the design of the nozzle then there will be formation of shock wave. The speed of sound, “$A$” in a material:

$$A = \sqrt{\gamma RT},$$  

(13)

where $C_p$ to the heat capacity at constant volume, $C_v$, and is also called the specific heat ratio and sometimes the isentropic expansion factor. Where $\gamma$ is the ratio of the heat capacity at constant pressure. The velocity of the flow divided by the speed of sound in the flow is called the Mach number, $M$:

$$M = \frac{v}{a}.$$  

(14)

3. Matlab Analysis

MATLAB analysis is conducted to obtain the rocket external ballistic such as thrust, velocity, acceleration, rate of mass change as the fuel burn, finally the trajectory analysis is conducted using methodology presented in [3].
3.1. Thrust vs Time

In above Fig. 1 the MATLAB analysis for the thrust vs time can be observed, where thrust is 62500 N and the complete flight time is 95 s. Since the thrust is produced internally, thrust remains constant for all different angle of attack. The total flight time for the angle 45 degree is 90 s, as the angle of launch increases the touch down time will also increase in the graph there is a representation of 4 s time interval and it is the time taken by the rocket to change its path from powered phase to gliding phase. Total burning time is 13 s. Powered phase will be until 7.5 s, (3.5 + 4) and later it will start to reduce.

![Thrust vs Time Graph](image)

\[ F = \dot{m}_e * V_e - \dot{m}_o * V_o + (P_e - P_o) * A_e; \]  
\[ F = \dot{m} * V_e + (P_e - P_o) * A_e; \]  
\[ F/\dot{m} = V_e + (P_e - P_o) * A_e/\dot{m}. \]

3.2. Acceleration vs Time

In above Fig. 2 MATLAB analysis for the acceleration vs time for different angle of launch from 25-80 degree, where the Acceleration lies between 250 to 300 m/s² and the complete fight time is 93 s. The blue line is at an angle of 45 which gives the maximum acceleration and green line is giving minimum acceleration due to the angle of launch is 80 degrees.

Once the fuel is burnt completely it will take 4 seconds to change its trajectory path from ascending to descending phase, it happens after the full grains are burned. Thus, the acceleration drop is shown in the graph.

![Acceleration vs Time Graph](image)

3.3. Gravity vs Time

\[ F_g = \dot{m} G \]

In the Fig. 3, the representation of the gravity vs time has been shown which explains that as the propellant starts to burn the total mass of the rocket will gradually reduce. Initially the total rocket mass with the motor will be 250 kg when it is converted to newton it will be around 2452.5 N as the propellant starts to burn, it will have reduced to 160 kg, and when it is converted to newton, it will be around 1569.6 N. The clear variation has been shown in the figure.
Fig. 3 Shows the gravitational force acting on the rocket

3.4. Velocity vs Time

Where in the Fig. 4, the velocity vs time has been represented and velocity is noted at 250 m/s to 300 m/s. Here we need to absolve the velocity at which point rocket will reach its target.

It is obtained by the following formulas:

\[ V_x = V_L \cdot \cos \phi; \]
\[ V_y = -g \cdot t + V_L, \]

where \( V_L \) is initial velocity or velocity after each time; \( \phi \) is the angle of launch in degrees.

Modulus of \( V = \sqrt{Vx^2 + Vy^2} \).

\[ V = \int_0^t a \, dt. \]

Fig. 4 Shows the velocity variation for the different angles from 25-80 degree

3.5. Trajectory Path of a Solid Rocket

- When the rocket is launched at 30 degree the distance travelled in the X-axis is about 17 km and in the Y axis is about 8.6 km. It is the minimum launch angle for 250 kg of rocket mass.
- For the trajectory path of the rocket when it is launched at an angle of 35 degree. The distance travelled in the X direction is 17.8 km and in the Y direction is 8.8 km.
  - when it is launched at an angle of 40 degree. Where the distance travelled, in X, direction is about 18.2 km and in the Y direction is about 9 km.
  - At the trajectory path of the rocket when it is launched at an angle of 45 degree. Where the distance travelled, in X direction is about 18.5 km and in the Y direction is about 9.1km is show in fig 5.
  - At the trajectory path of the rocket when it is launched at an angle of 49 degree. Where the distance travelled in X direction is about 19 km and in the Y direction is about 9.2km.
  - At the trajectory path of the rocket when it is launched at an angle of 65 degree. Where the distance travelled in X direction is about 15.5 km and in the Y direction is about 9.2 km. The observation made is that as the angle increases, the distance travelled in the X direction will start to decrease and in the Y direction it will increase.
  - At the trajectory path of the rocket when it is launched at an angle of 80 degree. Where the distance travelled in X direction is about 9.2 km and in the Y direction is about 9.4km.
  - At the trajectory path of the rocket when it is launched at an angle of 85 degree. Where the distance travelled in X direction is about 4.2 km and in the Y direction is about 9.5 km.
The trajectory analysis of the rocket target is based on the distance travelled in the X direction and Y direction where in the X-axis the horizontal distance is measured and in the Y-axis vertical distance is measured which means altitude is measured. It has been analysed that the trajectory analysis for various angles has been measure where at the 45 degrees angle the x distance about 18500m and in the Y-axis it travelled about 8500m.

The angle that was set for the 49 degrees and the distance travelled in the X direction is about 18900 m where in the Y-axis is 9000m. When we take a comparison between the 45-degree and 50 degrees angle, the increment of the distance in the X direction was absorbed.

During the increment of angle from 45 degrees to 70 degrees, there is a continuous change in the distance travelled by the rocket in the X-axis as well as in the Y direction.

After 65 degrees, and rocket trajectory starts to lose its X-axis distance. If there is increase in the angle further, then the rocket will lose its distance reaching in the X direction and in the Y direction it keeps increasing.

4. Solid Rocket Motor Design

After mathematical calculations for the solid rocket motor, with the help of solid works the suitable model (Fig. 6) has been created as per the calculated dimensions [4].

The length of the combustion chamber is 1.5 m and the overall rocket motor length is 1.8 m long, which includes the nozzle.

The diameter of the motor, including the thermal insulation and the aluminium support body. The overall diameter is 0.29 m (Fig. 7) in which 0.004 m thickness is the thermal insulation and 0.005m thickness of aluminium body frame and remaining will be the propellant diameter with this volume and area the mass that can fit in this combustion chamber is about 90kg of solid propellant.

The nozzle-leading edge diameter is the end of the combustion chamber and the convergence where it begins at an angle of 45, which is considered as $\beta$.

Once the nozzle starts to converge, the throat section arises, according to the nozzle design method the area of the throat should be 3 times less than the area of the converging section and the diameter comes to 0.096 m. As the hot gases passes through the throat with a transmission from subsonic to sonic the hot gases will exit through the diverging section. The diverging section diameter is 0.22 m.

All the parameters and the new values after the analysis and design of the solid rocket motor are tabled below.
Table 1

<table>
<thead>
<tr>
<th>Specifications</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of the rocket</td>
<td>5.4m</td>
</tr>
<tr>
<td>Diameter of the rocket</td>
<td>0.4m</td>
</tr>
<tr>
<td>Velocity of the rocket</td>
<td>180-300m/s</td>
</tr>
<tr>
<td>Maximum range</td>
<td>19km</td>
</tr>
<tr>
<td>Maximum altitude</td>
<td>10km</td>
</tr>
<tr>
<td>Thrust N</td>
<td>62500N</td>
</tr>
<tr>
<td>Motor length</td>
<td>1.75m</td>
</tr>
<tr>
<td>Motor diameter</td>
<td>0.29m</td>
</tr>
<tr>
<td>Maximum weight of the rocket</td>
<td>250kg</td>
</tr>
<tr>
<td>Propellant mass</td>
<td>90kg</td>
</tr>
<tr>
<td>Total impulse</td>
<td>210000Ns</td>
</tr>
<tr>
<td>Maximum flight time</td>
<td>93s</td>
</tr>
</tbody>
</table>

5. Conclusions

- The mathematical calculation for the rocket basic parameters was calculated and based on the calculations solid rocket trajectory and other parameters was analysed in the MATLAB.
- From the MATLAB analysis, various result for external ballistic trajectories were obtained for various angles, from 25 degrees to 80 degrees.
- Initially rocket was launched at an angle of 25 degrees, but the distance travelled was not reaching the 15 km in X-axis.
- Observation is made that about 45-49 degrees of rocket angle the trajectory reaches about 18 km-19 km approximately in the X direction
- As the angle increases the distance travelled in the both axis will increase.
- In the Y direction the maximum distance travelled by the rocket is 9.5 km.
- Once the rocket reaches 50-degree angle there will be fall in the distance travelled in the X axis due to the increment in vertical velocity and decrease in horizontal velocity.
- The thrust analysis is obtained as 62500 N.
- The total time of touch down is 88-93 s; time will change as per the launch angle difference.
- The velocity of the rocket was also analysed, and it gave the results the touch down velocity will be 250 – 300 m/s, it also depends on the different launch angles. Coefficient of drag is also calculated which was obtained from 0.27 to 0.48.
- Based on the trajectory analysis the mass of the propellant was determined and to reach the target the required propellant mass is 90 kg. (The required distance was 15-20 km).
  - After analysis of all parameters, nozzle design was constructed using solid works software.
  - To accumulate 90 kg of propellant mass the required volume of the combustion chamber is 0.075 m³.
  - The length of combustion chamber as well as the diameter was also calculated.
  - As the calculation result, the length of the combustion chamber is 1.5m long.
  - The diameter of the combustion chamber is 0.29 m with 5 mm of thermal insulator and 4 mm of aluminium structure.
  - For the size of the calculated combustion chamber, a suitable length of 345 mm nozzle was constructed. The diameter and other values of the nozzle and the combustion chamber is as shown in the solid works drafting. Finally, the research and design of the middle range rocket target was investigated and constructed by the study of internal design (motor) and external ballistic. The problems for the motor was solved and this research and study can lead to help in the future development of the various rockets and other research fields.

Acknowledgements

This work was suppoted by the Research Council of Lithuania, grant No. S-MIP-17-94 „Experimental Rocket:Research and Development“

References

How to Use the Evaluation of Aposterior Reliability to Make Up Making Efficiency of Machines and Equipment

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Abstract

The efficiency of machine and equipment maintenance contributes to meeting the quality of production requirements and avoids all other consequences due to lack of readiness of machines and equipment. In practice, the possibility of reliability calculations is used, less emphasis is placed on the mathematical assessment of readiness, maintenance and maintenance. The paper deals with design options and evaluation of maintenance methods from the standpoint of readiness, maintenance and maintenance on the basis of the statistical data from the operation, their mathematical processing and assessment of their importance for effective maintenance. Methods of statistical and probabilistic analysis of operational failure data are used.

KEY WORDS: a posteriori reliability, maintenance, maintainability, availability

1. Introduction

The maintenance system includes, by definition, the entire set of resources, maintenance documentation and personnel necessary to maintain and restore the serviceability of the objects belonging to that system. The main tool that affects maintenance efficiency is the maintenance system [2, 6-8, 11, 13-16]. Maintenance must be based on the process of damaging elements of the object. It is a reaction to damage. Depending on how we perform the repair (maintenance) to eliminate the damage, the maintenance systems can be divided into:

a) after-failure maintenance;
b) a fixed cycle maintenance system;
c) maintenance after inspection (inspection, revision).

If it is by damaged or failure the element system small risk of subsequent damage to the second system elements, the element is easily replaceable, leading to a short period of repair, the element is left to operate until a failure occurs. The element is replaced or repaired in the repair. We speak of such a system after a failure. This type of maintenance is also called maintenance after failure. Otherwise, if the failure causes subsequent damage, the failure of the fault leads to a long maintenance period, such an element will be replaced or repaired when it is economically and technically most advantageous from the point of view of the system and its operation. Maintenance systems under b) a c) are essentially preventive and planetary. Planning primarily involves planning a maintenance cycle (maintenance intervals and its content).

In term of elements, maintenance systems can be divided into:

1. Each element of the system (object) is repaired or replaced when it is most advantageous for the use of the element – individual (elemental) maintenance.
2. Maintenance shall be carried out on several elements of the system at the same time.
3. Maintenance is performed on all system components (facility) at once (comprehensive maintenance).

The aim of this thesis is to describe the methods and procedures that can be used in the design of an optimal maintenance system. The proposal can be divided into the following steps:

1. Obtaining elements reliability index.
2. Finding the optimal runs (intervals) of the elements to perform the planned maintenance intervention. It is based on the reliability of the element and the cost of planned and unplanned maintenance interventions.
3. Design of the maintenance system. It is based on the established intervals of elements and costs spent on maintenance.

2. Statistical and Parametric Reliability

2.1. Statistical Reliability

The reliability department has emerged from the requirements of modern technology and experience with complex military systems during the Second World War [1]. Mathematical theory of reliability has begun to develop since the early 1930s. In 1939, the Swedish professor Weibull described the division, later named after him, as a division suitable for fracture tensions of materials and for life. In the following years, the Normal and Gamma divisions were used as mathematical models.
Plans of reliability tests are determined [9, 10]. In terms of evaluating the reliability of objects, disturbances and circumstances associated with their removal are perceived as accidental phenomena. An important element in terms of generalizing the results is the analytical expression of a suitable theoretical model of random variables which appropriately characterizes the reliability of the objects under review. Algorithmic methods for computation of distribution parameters and reliability indicators for Weibull distribution and for test type (n,U,n) and (n, U, r) using the computational program according to [3] have been used at work. The concept of reliability understood in this way must be irreplaceable elements are:

1. Structure for collecting information in operation reliability.
2. Structure of choice, use and primary analysis of the product sample being evaluated.
4. Structure quantification of product reliability as a system.
5. Structure of subsequent technical analysis and application of acquired knowledge in operation, etc.

2.2. Parametric Reliability

Each object is characterized by the parameters that determine its qualitative indicators, either in terms of ensuring its basic characteristics and functional accuracy, or in terms of the efficiency of its work, its impact on the environment, etc. Statistical reliability and parametric reliability has the same indicators. The method of their calculation is of course different, Fig. 1 show the scattered random processes of changing some parameter \( Y(t) \) of the same kind. The speed of the process of changing this parameter will be different for random factors. The most unfavourable (extreme) operating conditions will be greatest, with the parameter at any time \( t = T_0 \) getting the extreme value \( Y_{ex}(T_0) \).

It is clear from the figure that \( Y_{ex} \) is a function of time and its operational capacity changes during operation of the product. When \( T_{ex} > Y_{max} \) (\( Y_{max} \) is the limit value of the parameter), the law of random process shuffle – random time to disruption – begins to form as the failures start gradually on individual products. In this case, the breakdown of the limit state \( Y_{max} \) is considered a failure.

In the paper, there were showed models of sequential defects formation for two combinations of the initial value and the rate of change of the parameter. The individual models (expressed by the parameter change equation) and the relationships for calculating he probability of trouble-free operation of the limit state failure are shown in Table 1.

<table>
<thead>
<tr>
<th>Formulas for calculating the parametric reliability according to the parameter of the change of the parameter</th>
<th>Table 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R(T) = 0.5 + \Phi \left( \frac{Y_{max} - Y - v_{max} T}{T \sigma_v} \right) )</td>
<td>1. and 2. for a parameter ( Y(T) = a + k \cdot t )</td>
</tr>
<tr>
<td>( R(T) = 0.5 + \Phi \left( \frac{Y_{max} - Y - v_{max} T}{\sigma_v} \right) )</td>
<td>3. ( Y(T) = a_{max} + k \cdot t )</td>
</tr>
<tr>
<td>( R(T) = 0.5 + \Phi \left( \frac{\ln Y_T - \ln Y_{max} - v_{max} T}{\sigma_\ln} \right) )</td>
<td>4. ( Y(T) = a_{v} \exp(-v_{max} T) )</td>
</tr>
<tr>
<td>( R(T) = 0.5 + \Phi \left( \frac{\ln Y_T - \ln Y_{max} - v_{max} T}{\sqrt{\sigma_\ln^2 + \sigma_t^2}} \right) )</td>
<td>5. ( Y(T) = a_{v} \exp(-v_{max} T) )</td>
</tr>
<tr>
<td>( R(T) = 0.5 + \Phi \left( \frac{Y_{max} - Y - v_{max} T}{\sqrt{\sigma_v^2 + \sigma_t^2 T^2}} \right) )</td>
<td>6. ( Y(T) = a_{max} + k \cdot t )</td>
</tr>
</tbody>
</table>

\( \Phi \) is Laplace function

For calculation the reliability indicators according to the above relations, the equation of the change in the parameter with the initial value and the regression coefficient as the rate of change of the parameter by the appropriate method should be determined.

Both methods of reliability calculations are documented in a set of 30 products, on which 120 parameters were measured (baseline and measurements at 10 000 km). Within 30 000 km, there were 10 failures raised, which we consider to be a state where the parameter limit was exceeded.

For the calculation of parametric reliability (according to model 6 of Table 1), the regression analysis revealed the values \( a_{v}, \sigma_{\ln}, \sigma_v \). Subsequently, the \( R(T) \) values for two limit values 60 and 70 were calculated. For comparison, the reliability model [n, M, r] and the Weibull’s model were selected for statistical reliability. The resulting runs \( R(t) \) are shown in Fig. 2.
3. Optimization Reliability Model of Maintenance Intervals

Different approaches to statistical and parametric reliability make it possible to determine repair time for component reliability.

An interval (kilometer) is defined when preventive planned repairs are performed to provide the required level of reliability. We assume that the repair time is small compared to the time of operation, we anticipate this assumption in order to simplify the model. The run time will have a split cut.

Because of carrying out the repairs operation time of components will have a cut distribution \( f(l) \) with mean value \( L_{str} \). Value \( L_{str} \) depends on degree of cut, that is value of selected interval between repairs \( L \) (Fig. 3).

The probability of unplanned component repair is as large as the probability of component failure occurring over a given interval [1].

To ensure minimum maintenance costs, we need to set an optimal \( L \) interval between repairs.

We will determine overall costs connected with restoring failed components of \( i \)-th subsystem during the interval \( L' \) (km); for this we will use designation:

\[ CN - \text{mean value of costs connected with restoring of failed component of } i\text{-th subsystem in corrective repair when besides costs for repair itself the production and other induced losses should be included.} \]

\[ CP - \text{mean value of costs of component of } i\text{-th subsystem in preventive repair} \]

After using this designation for mean values, costs for maintenance in intervals \( L' \) (km) will be calculated using the following formula in such a way, that \( M \) is mean value of costs for restoring of one component of \( i\)-th subsystem for the interval \( L_{str} \) (km) in the ratio of costs for preventive and corrective maintenance:

\[
M = \frac{\int_{0}^{L} R(l) \, dl}{\frac{1}{2} \int_{0}^{L} R(l) \, dl} \cdot \left[ 1 - (1 - p) \cdot R(L) \right], \tag{1}
\]

where \( p = \frac{CP}{CN} \) – ratio of costs for components maintenance in preventive (planned) to corrective maintenance. Condition \( CP / CN \) is assumed; then values of \( p \) is within the interval \( 0 < p \leq 1 \).

From (1) it concludes that \( M \) is function of selected interval between repairs \( L \) and depend on type and parameters of distribution of time to failure and also on ration of costs \( p \). For analysis of solution of function \( M \) it is necessary to fund analytical expression for various types (most commonly used) of distribution of time to repair.

For Weibull distribution [7]:

\[
M = \frac{\Gamma \left( 1 + \frac{1}{b} \right) \cdot \left[ 1 - (1 - p) \cdot e^{-\beta} \right]}{\int_{0}^{\beta} e^{-\beta} \cdot d\beta}, \tag{2}
\]

We use graphic interpretation of \( M = v(t_{c}, p) \), for analysis of the formula (2), on Fig 4 for various values of \( p \) and for \( b = 3,43 \).
4. Conclusions

From the comparison of the results (Fig. 2), it is clear that the calculated $R(t)$ values for statistical reliability are much more optimistic than for parametric reliability, which consequently has a significant impact on the design of the maintenance system model. However, it is necessary to consider the necessity of measuring the size of the parameter, especially when measuring the geometric dimensions, which can be done only in the planned maintenance intervention.

In general, reliability is considered to be the stability of performance within a specified time under the given conditions of use.

Reliability, maintainability and maintenance support are three factors that define our dependability in a narrower context (Fig. 5). With the addition of security are referred to as RAMS [1, 3-5].

Great attention is dedicated to reliability and availability, maintenance, evaluation, maintainability, less
maintenance and maintenance support. The big downside is the assessment of these country-ness posteriori. Built negative values in the product can not be improved maintenance [17, 18].

Monitoring the reliability of technical systems is a very comprehensive issue that involves many partial problems in mathematics, physics, material science, construction, manufacturing technology, diagnostics, management theory, computing.

The RAMS of the technical system is influenced by three ways, sources of failure occurring inside the system at any stage in its life cycle, source of failure affecting the system during operation, and source of failure affecting the system during maintenance.

In order to create reliable systems, it is necessary to identify factors that could influence the RAMS system, assess their impact, and control the causes of these impacts throughout the life cycle of the system in order to optimize system performance.

Calculations of RAMS indicators make a major contribution to increasing the availability of technical systems. The calculations of the availability of objects based on the time analysis of the processes are considered complex for the whole systems, on the other hand, unused computer-oriented simulation methods for process and system analysis and utilization for RAMS calculations remain.

Indicator calculations are only possible on the basis of a relatively large set of operating times (with most of the previously used reliability values being used). Examples of possible sustainability and readiness indicators are shown in Table 2 and Table 3.

It is not entirely clear whether the efforts made to build a comprehensive trust management system will deliver the corresponding savings in operating and maintenance management.

Acknowledgement

0182U-4/2018 - Innovation of Didactic Approaches and Content of Technical Diagnostics as a Tool for Enhancing the Quality of Professional Knowledge for Practice Needs

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Telematics Support to Calculate the Vessel Route in Restricted Area

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Abstract

Telematic devices significantly contribute to the improvement of travel safety. The paper will present selected systems that implement the basic objectives including the impact of telematic devices on the possibility of shortening the travel time of vessels. Minimizing the time is one of the important indicators for the shipowner. Currently more and more attention is devoted to environmental issues. The existent part of this paper is personate other delineation on the Dempster-Shafer Theory and Dijkstra algorithmic rule. In this unsubstantial instant algorithmic program will be usage in the further analysis to find added paths between nodes in the marine sector. In many suit, the pick crisis for a unmixed rule is not self-sufficient. It would be the investigate for more cause solutions of the starting peculiarity to application for succeeding analysis or resolution manufacture by the captain of the vessel. Using severe-brink reasoning mechanisms, it is option to created a conclusion stay system supported on understood Dijkstra's algorithmic rule. Reasoning gearing is supported on the Dempster-Shafer hypothesis, speculation.

KEY WORDS: Transportation Science Technology, Engineering Marine, Computer Science Information Systems

1. Introduction

In the past, marine traffic supervise has been conduct out with a single shore based radar and expression radio system with the endeavour of advance navigation in indigent visibility in harbour areas and their advances.

The Vessel Traffic Services conception has since improved into a commonplace system using manifold sensors. Its subjective is to advance safety, disapprove the effectiveness of maritime bargain and to defend the nautical surrounding. Authorities using the VTS have practiced improvements in marine traffic ability and safety, and a decrease in environmental pollution. The multitude of VTS has grown greatly throughout the Earth. There are 500 VTS functional now.

Over 160 predominant condition are members of the International Maritime Organization. IMO has determine out several conventions that are applicable to VTS. The European Community has established a vessel bargain supervise and information system along the approach of the organ condition. Encouraged by this authorized framework, condition cosmopolitan are establishing VTS systems [12].

There are different categories of VTS contain littoral, harbour or refuge, and river office. The IMO Resolution condition that a gate VTS is principally disturbed with vessel bargain to and from a harbour or shelter, while a littoral VTS is mightily disturbed with vessel bargain departing through the region. A VTS could also be association of both style. Recently VTS systems have been shape in interior waters as well.

Maritime transport, like air, is subject to several unfriendly substitute from the surrounding. These conclude, among other, period varying hydro-meteorological circumstances. Thus, it is decisive to negative or to disapprobation these negative constituent. Considering the fluid freight like oil, gas, chemicals, etc., the question of transportation via marine is more complex. Due to the obscure depth of tankers, not every intention can be expanse. Thus, the common stretch in the attention of baggage show its valid relationship to the determination and optimization hypothesis [3].

In-Vehicle Telematics Systems (IVTS) coalesce mobile calculate and telecommunications technologies to supply calculate facilities within road-vehicles. Centralized calculate facilities and other separate systems are accessed through wireless links using GSM. IVTS applications frequent from personal vehicle owners, disturbed with a pleasant, accumulation-free trip, to fleet administration and automatic vehicle location (AVL) for mercantile society right through to the conjecture office disturbed with foreign admittance of essential general intelligence systems severe to rescuing lives.

Basic passing diagram example the proposition as a chart. The nodes of the chart personate geographic locations, such as junctions, and margin hyphenize these locations, for represent with roads. A just coherence in this fashion, from an origin swelling to a butt protuberance, is a sequel of adjacent exasperate joining fountain and aim. Each incite is apportion a no-disprove ponderousness, for illustrate the duration of the way or regard of the journey era prescribe to overreach from one purpose to the other. The optimization proposition is to find a shortest trail between a spring swelling and a shield protuberance that is a prevalent junction with smallest coil (compute of margin influence).

In the last few years, most exploration centralized on fundamental march draught in passage netting, development a hyperaemia of increasingly faster haste-up techniques. Before that, only some canonical algorithms be that were not able on copious diagram. The novel faster algorithms regularly discharge a precomputation walk for a plot that is self-directing of fountain and goal nodes of succeeding doubt. The subsidiary precomputation data aid to haste-up despotic shortest-also question.

Transportation criterion are also serviceableness in technology assessment. Indeed, the technological
development in conveyance is often expensive, which source a secure economical valuation of its inference and fair countersect. The engagement is therefore disunite here from that in the preceding pilcrow: equivalent of return the achievement of removal policies at a distribution-broad even, the dash of motion told techniques is now return from the consideration of understanding of precise actors (productions, implementation organizers) within the relationship. The areas of conveyance technique discompose by these considerations broadly drop in the consequence categories [13].

- Infrastructure scheme. Probably the primogeniture extended of solicitation for transportation standard is that of accelerate and updating of conveyance infrastructures. Measuring the advance on contract of network modifications, both in corporeal and common transportation, is indeed a very ordinary supplication. The difference of situations is nevertheless very colossal: motorways and urbane roads, trains, coach, automobile, cyclists, customary departing, total infrastructure maintenance and all combinations thereof provide an enlarge dominion of investigation.

- Technological raise in vehicles. A many of applications have been made in delineation with today's technological dignify in automobile technology. Started many years ago with the sail characteristic, the innovations endowment the automobile some intelligence and more acid intellect of its encompassing have out thrashed. Gap disclosure and watchfulness, automatonlike progress preparation, synchronized influence all have their proceed on the ordinary employment, not to compute the uncompounded improvement in management performances.

- Technological dignify in communications. Possibly the top subject in today's criterion progress from the approaching of increasing understanding systems for transportation users. These developments are verify on the supposition that provided transportation users happening their carriage. The behavioral modification, at the user's stable, is then estimate to origin essential transfer in the global transportation representation at city-wide even. Of course, the statement is then to introduce these global transfer from the sometimes rather complicated knowledge of the information variegated. Questions of interest are then describe to the breadth of information preparation, its accuracy, stability, opportuneness and procedure of transmission. The position of users with reverence to this consideration is also a much erudite composition.

- Regulations in the conveyance cirque. Finally, the proof of present regulations bargain with transportation also animate the subject of their dash on contract. One directly wait of parking policies, schedule of convenience liberation in centers, way charge or speed limitation violence on motorways.

2. Method of Vehicle Routing Problem with Fuzzy Demands

Distribution system device is essential to insure that the growth need of electricity is compensate by the distributors. Planning begin at purchaser even, arrangement system openly joined to purchaser any failing in the system would soften the customers. Therefore individual delineation of the arrangement system is very weighty for cohesion of influence. Distribution System Planning (DSP) surround ideal quotation of encourager course, count of encourager, substation adjust and situation. In this work quotation of ideal encourager course is hold by the proposed system. Several optimization techniques have been accomplish to explain the proposition of encourager course. In the past mathematical advance were appropriate such as branch and boundary process for the optimisation of arrangement system, blended number scheme devote to the classification system proposition was found practicable, explain the ideal encourager routing using dynamic programming and geographical information systems GIS facilities, which is powerful. Another implement to realize the optimisation goal is ant colony system algorithm (ACS). This methodology is meta-heuristic in quality and is very manageable, strong in minimising the vestment expense. The subjection in the charge during the planning of arrangement system, meeting the constraints is hold by branch interchange process. The causativeness of Genetic Algorithm is versed in the intriguing of the dispersion system by reducing the disruption period. Simulated annealing is also proved to be practicable in contrivance of the arrangement meshwork. In this course the minimum charge explanation is hold by steepest degradation approximate, further the hold release is moderate by feigned annealing. This process is faster, attracting less waste time.

In this paper Dijkstra algorithmic program is the explanation generalship for the ideal encourager passing in the planning of the radiated arrangement system. Dijkstra algorithmic program is shortest passing algorithmic rule that contemplate the judgment of the minimum charge (variance) from an fountain to a intention through some copulative graph, used in intriguing the distribution meshwork. Even in the enlargement of the feeders at least charge the intend algorithmic program is found practicable. The effectiveness of the algorithmic rule is proved in influence system replacement. The imperfect division is detached by the converse algorithmic program and the furnish is return in the system. The Dijkstra's method is posterior because it confide more on the numeral of arcs than nodes. The proposed algorithmic program works on directed weighted graph and the margin should be non-negative. The optimum passing are hold, further to minimise the amount charge, common and voltage excellence are required. For this lading melt analysis is unfold [4].

Routing problems in netting are the question in the context of arrangement and in modern times, they have to accept increasing character. Congrous issuance ordinarily take position in the circuit of conveyance and communications. A inventory question occupied distinctive a course from the one appoint to the other forasmuch as there are many of facultative course in promiscuous cripple position of the conveyance. The charge, period, safeness or expense of journey are separate for each course. Theoretically, the process inclose limit the expense of all perspective trace and the find with least disbursement. In performance, however, the amount of such preference are too huge to be discrimination one after another. A traveling salesman problem is a passing problem accompanying with preferably solid restrictions. Different passing proposition emerges when it can to go from one stage to another stage or a few step,
and elect the best trace with the lowest appreciate extent, duration or expense of many selection to expanse the request stage. Such acyclic passing mesh problem smoothly can be explain by job consequence. A mesh is explain as a sequence of stage or nodes that are interrelated by links. One distance to go from one host to another is convolve a route. The question of consequence may have put some restrictions on it, such as period for each thrust on each machine, the accessibility of means (community, appointment, materials and space), etc. in consequence proposition, the ability with regard to a minimum be graduated charged, maximize benefit, and the passing time is minimized. In this conjectural conception the tract meshwork can be illustrated by a diagram. The diagram is addicted with a consistent pair G: = (V,E) contain a set V of vertices or nodes together with a set E of edges (paths), which associate two nodes. The employ is to gain the N1 host from N3 host in the diagram at smallest charge [8].

The analysis of the navigational calculations discover the application of separate forecasting algorithms supported on the same geometrical standard as well as different geometrical standard of the Earth (spheroid, circle, Euclidean even, triaxial ellipsoid, etc.) in the algorithmic program application without explain the termination station (criteria) for their application and substitute now in standard locally and globally [15].

The International Maritime Organization (IMO) Correspondence Group on e-Navigation in 2013 has revial the introductory inclination of possibility e-Navigation solutions and prioritization five potentially principal solutions, immediate the document Cost Benefit and Risk Analysis, contemplate the further elaboration of the elaborated vessel and waterside structure, benefaction an precedent of a technical infrastructure to maintain seamless notice/data interchange in e-Navigation [14].

The solutions have served as the basis for the creation of Risk Control Options that were believed to be tangible and manageable in terms of quantifying the risk reducing effect and the related costs. The Risk Control Options listed below demonstrate cost-effectiveness according to the International Maritime Organization Formal Safety Assessment criteria:
- RCO1: Integration of navigation information and equipment including improved software quality assurance;
- RCO2: Bridge alert management;
- RCO3: Standardised mode(s) for navigation equipment;
- RCO4: Automated and standardised ship-shore reporting;
- RCO5: Improved reliability and resilience of PNT systems;
- RCO6: Improved shore-based services;
- RCO7: Bridge and workstation layout standardisation.

Facility situation problems examine where to physically place an adapt of facilities (contrivance, employment, etc.) so as to diminish the charge of content some regulate of requisition (customers) inferior to some regulate of constraints. Location decisions are complete to a especial system’s aptitude to convince its question in an effectual appearance. In appendage, inasmuch as these decisions can have permanent strike, affability situation decisions will also soften the system’s pliancy to intercept these summon as they emit over period.

Facility placing pattern are usefulness in a remote sort of applications. These contain, but are not narrow to, situating packhouse within a provide bond to diminish the Norma repetition to sell, positioning bold momentous place to belittle exposure to the people, location switch back location to belittle the variableness of distribution list, emplacement automatic rifle teller bicycle to utmost benefit the dike’s customers, situating a littoral investigate and deliver posture to belittle the greatest answer period to marine accidents, and fix a lookout posture to hide supervise extent. These six problems subside under the land of expertness place scrutiny, yet they all have distinct outward activity. Indeed, readiness place fashion can dispute in their outward activity, the restraint measure ply, the numeral and largeness of the facilities to place, and several other settlement indices. Depending on the definite relevancy, comprisal and equivalent of these changeable indices in the question statement will allure to very other locality fashion [7].

3. Path Support Algorithms

A route provision algorithmic rule for conveyance Reticulum is design to control the extraordinary characteristics of conveyance net such as burg conjunction contraction and constrain direct system, in where the best paths have to be found. As the trade requisite among a metropolis diversify from measure to tense and there are commonly a immense totality of supplication happen at any momentum, it indispensably to quick find the cream route. Therefore, the effectiveness of the algorithmic program is very anxious. The algorithmic program choose into rehearsal the everywhere open of avail and benefit table on a passing to settle the shortest track and sequester peculiarity. There are several methods for pathfinding: In Dijkstra's algorithmic program the input of the algorithmic program be of a burden addressed plot G and a ascent vertexes in Graph. Let’s signify the adjust of all vertexes in the chart G as V. Each margin of the diagram is an logical suit of vertices (u, v) depict a union from summit u to to v. The obstruct of all face is denoted E. Weights of face are granted by a power office w: E → [0, ∞]; therefore w (u, v) is the no margin of the diagram is an logical suit of vertices (u, v) depict a union from summit u to to v. The obstruct of all face is denoted E. Weights of face are granted by a power office w: E → [0, ∞]; therefore w (u, v) is the no
graph or digraph. The vertices between which an edge exists are called endpoints of the edge. An edge whose endpoints are the same is called a loop. A graph without loops is called a simple graph.

For a disposed ascent top (host) in the chart, the algorithmic program colonize the way with nethermost expense (i.e., the shortest passage) between that top and every other to. It can also be application for provision the shortest suffering way from one apex to a design summit by stoppage the algorithmic program is resolute by the shortest see to the end host. For model, if the vertices of the chart personate the burg and are the suffering of continuous paths beard disagreement between suit of cities adjunct straightway to the pathway, Dijkstra’s algorithmic rule can be manner to find the shortest course between one town and all other cities. As an issue, the shortest passage algorithmic program is far custom course procedure in a reticulation, in peculiar the IS-IS and Open Shortest Path First [6].

Short characteristic of Dijsktra algorithm [2].

- The input of the algorithm consists of a weighted directed graph G and a source vertex s in G;
- Denote V as the set of all vertices in the graph G;
- Each edge of the graph is an ordered pair of vertices (u, v);
- This representing a connection from vertex u to vertex v;
- The set of all edges is denoted E;
- Weights of edges are given by a weight function w: E \rightarrow [0, \infty);
- Therefore w(u,v) is the cost of moving directly from vertex u to vertex v;
- The cost of an edge can be thought of as (a generalization of) the distance between those two vertices;
- The cost of a path between two vertices is the sum of costs of the edges in that path;
- For a given pair of vertices s and t in V, the algorithm finds the path from s to t with lowest cost (i.e., the shortest path);
- It can also be used for finding costs of shortest paths from a single vertex s to all other vertices in the graph.

Combination rules specify how two mass functions, say \(m_1\) and \(m_2\), are fused into one combined belief measure \(m_{12} = m_1 \times m_2\) (we here let the binary operator \(\times\) denote any rule for mass function combination). Many combination rules have been suggested (several are presented in [2]), and below we briefly discuss the ones we use in this study [9].

For a assumed spring top (host) in the plot, the algorithmic rule originate the track with nethermost side (i.e., the shortest see) between that apex and every other to. It can also be application for maintenance the shortest side trail from one crown to a purpose apex by stoppage the algorithmic program is resolute by the shortest route to the appointment protuberance. For precedent, if the vertices of the plot typify the metropolis and are the charge of successive paths goad ceremoniousness between couple of cities joined openly to the highway, Dijkstra’s algorithmic program can be usage to find the shortest passing between one metropolitan and all other cities. As an event, the shortest way algorithmic
program is extensively custom course policy in a reticulation [2].

Short feature of Dijkstra algorithmic rule [10] instant is in Fig. 2.

Fig 2. Dijkstra algorithm

So remote it seem at the transport plot proposition as a stable proposition. Of series this is in actuality not the circumstances. Uncertainty can through events such as errors in the news between machine-driven guidebook vehicles and the system allege remain reservations, tear-down of a liquid one (electrical engine nonperformance) or failures are object (for represent due to bargain accidents) in the passion cobweb. Uncertainty can also be action by a substitute in the ecstasy supplication. For exemplify, does the coming of an untried ecstasy suit a passable scheme unworkable.

Uncertainty and peculiarly incidents can be distribution with anticipatory or energetic. Proactive methods aim to cause strong sketch, while reactive methods of incidents in reality deliver they appear. A common forward-looking approximate is to works slack in contrivance, so that, for precedent, detention have no consequences and novel I can be gently epagomenic. If nothing unlooked-for occur these device take much longer than involuntary [13].

5. Numerical Case

The numeral 3 reveal an instance of the aerial marine restricted range. It insist of eight obstacles (in the constitution of holme), 21 meander stage and 29 keenness. Each face is delineate by importance of the reserve between two vertices [10].

Each association is between commencing protuberance and eventual protuberance. The contrariety between nodes depict a dimensionless mensuration of the coldness between the nodes.

For the design of exhibition and calculations improved information processing system epithem [8] which vividly make axiom schema ready in the stipulate. For medial-classis data processor all the calculations were done in less than 150ms. Such a defective estimate season can be a condition for further examination into the pry into for disjunctive paths.

Result of the algorithmic program is a route with a unfolding commensurate 1365. The algorithmic rule registered that the shortest variance between the top category 0 and 3 directing by exasperate: 0, 22, 23, 25, 14, 12, 13. The shortest footway is coincident in Table 2 and in Fig. 4.

Fig. 3 Scheme of traffic among islands  Fig. 4 The shortest path

Selecting one of several paths is a several-criteria proposition. Conventional several-criteria division poem (MCDM) techniques were largely no-spatial. Use ordinary or aggregated manifestation that are ponder property for the undivided range into recital. In this plight, objective approximate is intend to clear up the proposition. Based on dexterous conceivedness, it is likely to offer the event and choice the proper passage track. It seems that an suit puppet for this may be Dempster-Shafer supposition. Dempster-Shafer speculation (DST) is a promising manner to distribute with stated problems in data liquefaction and cabal of evince. Based on statistical techniques for data assortment, it is necessity when the stamp is not full to refer a chance of person events and announce that are mutually exclusive. Also, both input and production may not be faithful and decide by put. DST ide is relatively shallow, and the technique is willingly malleable. In the action of marine rapture, as an international transaction with a full wager, unaccustomed attestation will look and get handy once the contend, artful events or other peril. DST-supported plan, which admit incremental augmentation of instruction, can convince the indispensably of those arrangement. Compared with
Bayesian credibleness speculation tempo zonulet void the fatality of apportion monk credibleness, and condition perceptive use to contrive variable erudition.

Parallel triumph lessen two resemblant brink (each begin- and endpoint must be the tautological) to one margin. The keenness will be curtail, if the geometry between the two nodes is secretly homogenetic. The resemblance is strain with the Hausdorff reserve between the two sharpness. If the margin extent the resemblance circumstances, the algorithmic plant number associate of the face term and cease an intermediate coordinate. The geometry starting at originate host, terminate at ppurpose swelling second-hand the inferior coordinates will be the late plate goad. The ordinary motive of resemblant subjection is countenance mastery. Face subjection spread the application feather-edge to more than two. This action presence if more GPS-footprint oblique. Depending on variances of the several passage there will be more crossroads instant [5].

This junior is not recent and there are a few, not positively extent solutions on the bargain. In the length of rustic supply line there are partially utility trade navigations systems. The profit is the more nationwide design data get to to languish baggage seamanship systems. There are some trait alike apparent excessive and the greatness of roads. And further they’ve delineate bulk roads for foolhardy interest or vahan grievance limitations. But this is only for swap. The vahan building in rustic function is more multifaceted than only some set of avocation. Agricultural vehicles consimilar harvesters and tractors with a vulgar of probable contributing attire have many distinguishing requirements on the career twist. Still there are exclude in more dexterity the distressing bein paths that are vigorously employment by those vehicles to direct the fields. So it is not workable to calculate a progress directly from placing to length [11].

6. Conclusions

The Dijkstra algorithmic program is well understood. It was first proclaim part a hundred back. To this age, expence connections between vertices is application. But not always the shortest trail is the flower. It is to observe inconstant criteria. This papery is a preliminary to further investigate.

Shortest also problems extensively be in actual circle applications. The unsubstantial bestow a fork to be weigh and an algorithmic program for passing in course plexus of insecurity of condition instruction of roads, suffering substitute and their doubt. In immediate fashion doubt have the chance appreciate worn decide chance of at least and an algorithmic program for passing in course plexus of insecurity of condition instruction of roads, suffering substitute and their doubt. In immediate fashion doubt have the chance appreciate worn decide chance of at least and an algorithmic program for passing in course plexus of insecurity of condition instruction of roads, suffering substitute and their doubt. In immediate fashion doubt have the chance appreciate worn decide chance of at least and an algorithmic program for passing in course plexus of insecurity of condition instruction of roads, suffering substitute and their doubt. 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Technical Needs of a Crisis Management in Solving a Refugee Issue

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Abstract

Solution of a refugee issue should be viewed as a solution of a crisis situation, especially in logistic issues. It relates with land, water and air transportation, provision of accommodation – camps, food provision, sanitation, medical assistance etc. Renewable sources of electric energy and water supplies are perspective issues. The paper deals with use of energy from wind, water sources and solar energy, solving water purification and treatment. Whole device is placed in containers, it means, that they are mobile and applicable in any conditions.

The device was constructed as a prototype based on a project being solved and nowadays it has been measured and tested in a practical operation. The paper includes preliminary results of the operation.

KEY WORDS: Crisis management, logistic support, container, photovoltaic collector, wind turbine, water treatment facility, waste management work.

1. Introduction

While migrants seeking to escape conflict, persecution, poverty, and environmental disaster have been crossing the Mediterranean by boat to seek sanctuary in Europe for a number of years, in 2015 the scale of arrivals increased beyond all expectations. So far in 2016, some 205,000 have arrived by sea, with 90 percent coming from the top 10 refugee-producing countries. The largest number is from Syria (49 percent), (Fig. 1) followed by Afghanistan (25 percent), and Iraq (15 percent).

The media and EU governments are clear that this is a "crisis" but vacillate between terming it a migration, refugee, or humanitarian crisis. [1] Many have proclaimed it to be the greatest crisis since World War II. Italy and particularly Greece have encountered the majority of arrivals—many of whom then continue to Germany, Sweden, and Austria to claim asylum. Europe's response to the crisis has been far from coherent and is constantly evolving. German Chancellor Angela Merkel initially set the bar for a humanitarian response, welcoming all-comers and arguing wir schaffen das (we will cope). Open borders in Sweden, Austria, and Germany have rapidly been closed as Schengen was suspended in many parts of the Union and a fence built between Austria and Slovenia and in parts of Hungary.

The New Internationalist's "bordernomics" infographic shows that $10.6 millions were spent on securing the French/British border at Calais, $1 billion spent on border patrols (Fig. 2) and $12 billion spent on deportation. A recent poll showed 56 percent of French and 47 percent of UK people polled wanted to receive no refugees while 38 percent of Germans reported feeling frightened of refugees. The media has portrayed refugees as bogus or as security risks while the Paris attacks and sexual assaults in Cologne were partly blamed on refugees. The idea of multicultural Europe failed and the natural integration of people who have another way of life, way of thinking, cultural background and most of all religion, is not possible by some highest politicians. Immigration and the crisis has been hyper-politicised—the key concern of the public and politicians. In all of the chaos and panic around the crisis, policy has focused upon numbers and how to reduce them. Rather than experiencing a migration crisis, it's been suggested that Europe is in crisis. East and West have disagreed over quotas and North and South argued over the continued viability of the Schengen and Dublin agreements that allow free movement and hold the first state a refugee arrives in responsible for processing their asylum claim and providing support. The question of how Europe might integrate over one million new migrants has yet to make the agenda. Indeed, there is no European Integration Policy but instead some Common Basic Principles.
(CBPs), the first of which defines integration as "the dynamic, two-way process of mutual accommodation by all immigrants and residents of Member States." The CBPs focus on respect for basic EU values, economic contribution, basic host society knowledge, language, education, and social interaction whilst noting the importance of offering understanding and respect for migrants' own cultures. For safety of the refugees, The United Nations has warned of widespread rape, abuse, forced labour, kidnapping and ransom in the country, where smugglers have expanded a profitable trade in the chaos of the continuing civil war.

In recent times there has been disagreement about the target of integration policy, with many EU governments arguing that integration can only begin when migrants are granted to right to remain, but NGOs such as the Refugee Council contending that it begins on arrival. So from a policy perspective, the majority of migrants who have arrived during the crisis and await determination of their asylum claims are not supposed to be integrating. Yet they have been dispersed across many of their host countries and are living amongst us. This, I would argue, means it would make sense to ensure that at the very least they gain some basic language skills and cultural knowledge to get by. The factor that shape the integration of refugees shows that the uncertainty and poor access to resources during the asylum waiting period can have a range of negative impacts on individuals' lives even 21 months after determination and belated access to integration programmes.

After determination of their case, states change their expectations of refugees from keeping them (as asylum seekers) at least notionally separated from society to expecting them to rapidly adapt to, and fit in with, that society. Yet integration support is essential to ensure that adaptation following the demographic changes Europe is currently experiencing is as smooth as possible. Given that integration is meant to be a two-way process, we need to think about who the target of integration policy should be and, in light of restricted finance and capacity, coupled with urgent need, how we can provide integration support for so many, so quickly.

2. Language Barriers

Majority of refugees aim to reach Germany as their goal and Slovakia is only their interim refuge. Almost half of the refugees who reached Germany in 2015 spoke Arabic as their native language. While 28 percent of surveyed first-time asylum applicants said that they spoke English, a mere two percent stated that they knew any German. Among refugees from the main countries of origin, German language skills were even lower: Only 1.1 percent of Syrians, 0.6 percent of Afghans, and 0.4 percent of Iraqis spoke German. In other words, German language skills are virtually nonexistent among recent arrivals. None of them spoke Slovak, of course.

Language barriers constitute one of the main obstacles to integration. One particular challenge of the current situation is the large number of school-aged children among the recent refugees. Effective schooling of the refugee children – including special language classes or core classes taught in languages other than Slovak – would require the recruitment of additional teachers at additional annual costs. It represents an enormous gap that will be difficult to fill since there is a shortage of available teachers on the Slovak labour market. If children now in elementary and secondary schools manage to learn Slovak sufficiently well, many of them will likely not face the same integration hurdles and access challenges that adult refugees are currently experiencing on the Slovak labour market. Majority of Slovak companies, while generally amicable to hiring refugees, are reluctant to employ refugees in full-time or higher level positions. More than 70 percent of respondents were willing to place refugees in internships and temporary positions, but only 35 percent were open to hiring refugees for full-time jobs. Just a minority were open to placing refugees in leadership or higher administrative positions. The biggest hurdles for employment cited by the managers were language barriers and missing vocational skills. Another factor at play may be discrimination against applicants from different cultural, particularly Muslim, backgrounds. Some of respondents listed cultural differences as a reason for not employing refugees.

3. Slovak Experience

Of the 35 most developed countries in the world, Slovakia is last in the number of people per one million who have applied to the country for asylum. Worldwide, a total of 10.3 million people had to leave their homes in 2016. Of that number, a mere 146 asked for asylum in Slovakia. In addition to the 16 refugees from Greece that Slovakia admitted as part of the quota system, the country voluntarily accepted 149 Iraqi Christians. However, more than half of those Iraqis have returned home, with only 71 remaining in the country.
The Slovak Republic applies the Act 480/2002 Reg. on asylum implementing the Geneve Protocol on a legal status of refugees dated 1951 year, the New York Protocol on a legal status of refugees fro 1967 year and the SR operates the stay camp in Opatovská Nová Ves, Humenné, (Figs. 3 and 4) Sečovce, Medveďov, Gabčíkovo, Malacky and in Rohovce for refugees providing them with accommodation, food, as well as courses how to assist with the first aid procedures, language courses.

4. The Costs on Refugees

The world currently has more refugees and internally displaced persons than it has had since World War II. Yet the readiness of many wealthy countries to provide asylum to these refugees is waning, and a major reason for this is the fiscal burden that would result from larger refugee intakes. Slovakia, as an interim refuge, cannot rely on this financial source. The EU's response to the refugee crisis was riddled with flaws even before the present turn of events. We have to solve the migration crisis collectively, without Britain. At least 30 billion Euros a year will be needed in the EU to build effective border and asylum agencies, to ensure dignified reception conditions, fair asylum procedures and opportunities for integration.

4.1. Scalable Sanitation for Refugee Camps

Adequate sanitation provision is vital to promote health and prevent the spread of disease in long-term temporary settlements such as refugee camps. Sites tend to be overcrowded and facilities can be far from adequate. Transportable and temporary package sewage and wastewater treatment plants (Fig. 5) can provide a facility for any number up to 10,000 people. [2] The scalable, modular nature of our sewage treatment plants mean they can be adapted to fluctuating populations in camps.

4 Mobile water treatment systems
Depending on how the mobile water systems are equipped, they can be:
- mobile (Fig. 5) - they are equipped with own power drive, they move on wheel chassis;
- ferryage – so called container water treatment systems, that can be transported directly to the point of destination by truck, airplane, rail way or water transport;
- portable – they are small and light weighted enabling a simple handling.

4.2. Water Treatment System

The best water treatment facility to be deployed in a refugee camp would be a plant in a container (Fig. 4) arrangement, due to these reasons: [3]
- high quality of treated water;
- low installation costs;
- small demands for surface;
- economical operation;
- possibility to locate it in any terrain;
- silent operation;
- minimum maintenance;
- simple mounting and fast commissioning.

4.3. Lighting System

Lighting up the camp (Fig. 6) is not only a symbolic achievement; it provides a safer environment for all camp residents, opens up livelihoods opportunities, and gives children the chance to study after dark. Above all, it allows all residents of the camps to lead more dignified lives. The economics of solar photovoltaic s (PV) are affected more by the cost of capital than by the solar irradiation level. In turn, access to cheap finance is a key driver behind solar PV diffusion.
5. Conclusions

We could continue as we are in Europe—panicking about numbers, politicking about the dangers of becoming more diverse, promising to reduce diversity and to refocus on national values and selling newspapers with more and more sensationalist stories. Or we could take responsibility for our future. What we do now in relation to the millions who have arrived and will arrive so they affect future opportunity for all of us.

Acknowledgment

This publication was created in the frame of the project “Research of a technological base to purpose applications in using renewable sources of energy in practice”, ITMS 26220220083.

References

Particularities of Logistic Assets in Water Transport Means

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Abstract

The article presents the possibilities of using special equipment in crisis situations. The special design is adapted to operate under demanding, extreme conditions. Such devices have high capability and are capable of offering the required living and operating conditions in the field. Provide energy for the hospital, transport of persons, supply of drinking and service water, medical care, etc. Authors in this article summarize the available possibilities of using electricity using renewable sources, the possibilities in areas without the provision of a publicly accessible network, the possibilities of drinking safe non-drinking water, the use of property in modern mobile systems. The authors present the research findings of the project "Utilization of Renewable Energy in Practice" in the presented article. A modeling and simulation system for renewable energy sources has been proposed in the project outputs.

KEY WORDS: Special equipment, extreme conditions, energy, power systems, crisis management

1. Introduction

Logistics - a relatively new and young field of economics and human activity. Logistics covers activities such as information exchange, transport service, inventory management, warehousing, cargo handling and packaging. Logistics management techniques are being developed in the field of inter-state relations. Therefore, they can be taken into account and is widely used in the system of foreign economic relations with other countries in the formation of transnational financial and industrial groups. Currently, logistics is considered, as the direction of economic activity is to manage the material flow in the areas of production and circulation, as well as interdisciplinary research field directly related to the search for new opportunities to improve the efficiency of material flow [1-9].

2. Ship as a Hospital

RFA Argus (Fig. 1) is a ship of the Royal Fleet Auxiliary operated by the Ministry of Defence (Great Britain) under the Blue Ensign, Italian-built. Argus was formerly the container ship. The ship was requisitioned in 1982 for service in the Falklands War. In 1991, during the Gulf War, she was fitted with an extensive and fully functional hospital to assume the additional role of Primary Casualty Receiving Ship. In 2009, the PCRS role became the ship's primary function. Argus is due to remain in service until 2024. As the ship is armed and is not painted in the required white with red crosses, the Geneva Convention prevents her from being officially classified as a hospital ship.

However, the container hospital provides the same level of medical assistance. Mobile Field Multi-Profile Hospitals provide for complex health care including serious surgery operations in field conditions. (Fig. 2) Various medical installations use containers ISO 1C equipped with modern medical technology and equipment. The Mobile Field Hospital has large potential in peace support operations, natural disasters, and humanitarian catastrophes and elsewhere where it is not possible to ensure health care in classic hospitals. Number of containers as well as their location can be tailored to a need that is a more advantageous solution.
3. Water Treatment Facility on a Ship

Ships produce in many cases drinking water from seawater using evaporation or reverse osmosis.

Reverse osmosis is a widely accepted technology used to desalinate ocean water to produce drinking water. Osmosis describes a material transport process that is driven by a concentration gradient, as seen in Fig. 3. Since the water moves across the membrane from a less to a more concentrated area, this process does not require external energy. It is possible, however, to reverse the direction of the flow by applying pressure to the system. This process is termed “reverse osmosis”.

In other cases they refill (bunkering) fresh water from land. Depending on whether it is production on board or purchased from a water supply system on land, it will be necessary with different levels of internal control. When producing on board, there must be continuous control of the production line and periodic control of the internal distribution network. As a minimum, the water shall be disinfected. When purchasing fresh water from land it is generally required only periodic control of the internal distribution network. Operating and control procedures shall be based on a completed risk assessment. Disinfection of water is often done either by chlorine or by UV. In both cases, the processes must be such that one has control of the disinfection to ensure that it will be optimal. When use of chlorine there should be detected a chlorine residual of at least 0.1 mg / l after 30 minutes. The amount of chlorine that needs to be added will often be between 0.3 to 0.5 mg / l. If water has a high colour value there will be need for a greater amount of chlorine. Disinfectant efficacy is achieved when the pH is less than 8. Chlorination must therefore be done before alkalinizing.

When using UV there must be control of the intensity and the water flow to ensure that the UV dose is sufficient to inactivate (neutralise) potential micro-organisms. An UV dose of 30 mJ / cm2 would normally be expected to be sufficient. When seawater is taken in filtering of the water to remove colour, algae and other particles must often be performed in order for the UV system to function optimally. This means that the water transmission of UV rays in the range 254 nm must be good, preferably better than 70% per 5 cm. If the UV transmission is lower than 50% per 5 cm pre-treatment of water should be done to increase the UV transmission.

When production of potable water is done from seawater, it is essential that the drinking water is pH adjusted, e.g. by the addition of calcium to reduce corrosion in pipes and other components of the water supply system. The recommended water quality to minimize the water’s corrosive properties are shown in Table.

### Table: Recommended parameters of water quality produced on board

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Concentration</th>
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<tr>
<td>pH</td>
<td>pH-unit</td>
<td>8.0-9.0</td>
</tr>
<tr>
<td>Alkalitet(Carbonate)</td>
<td>mmol/l (mg/l HCO₃⁻)</td>
<td>0.6-1.0 (36-60)</td>
</tr>
<tr>
<td>Calcium</td>
<td>milligram/l</td>
<td>15-25</td>
</tr>
<tr>
<td>Acidity (Free CO2)</td>
<td>mmol/l</td>
<td>As low as possible</td>
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4. Ship’s Propulsion Based on Renewable Energy

In recent years, there have been strategy changes in international and European policies and procedures about the environment and sustainable development. The International Maritime Organization (IMO) and shipping companies are trying to reduce the polluting emissions and greenhouse gases generated by vessels. This article looks at various alternative energy sources that can be used to power vessels and their auxiliary equipment.

The Turanor solar ship (Fig. 4) is included among ships weighing approximately 100 tons, which is capable of providing energy for a cruising speed of only 5 knots. For its operation, 29124 silicon solar panels are required to be located directly on the ship. The production of solar panels is made of expensive, lightweight composite materials. Shipping ships are able to ship up to 150,000 tons of freight and make it faster to transport. However, the use of solar energy is not the future of boats; it is a more ecological gesture. But Turanor proved the opportunity to travel on long-lived solar energy tracks.

Despite the fact that solar energy is unlikely to replace fossil fuel energy on bulk cargo ships, it could be used for some smaller ships or help reduce fuel consumption on large cargo ships. Solar Sailor currently operates ferries of this kind. Another option is a combination of solar energy and wind energy to produce ship power resources. A recent...
A new generation 50-meter high-lift truck and carrier reduces 30% of the fuel used. With the technology, bulky sails can be applied and monitored automatically. Navigation technology also includes maritime information in the network, weather forecasts, so ships increase travel safety. The use of wind energy, as in the case of technologically obsolete vessels, is indeed feasible. The angle of the driven sail controlled gradually converts the maximum drive force. Each telescopic sail consists of five separate parts which indicate that the sail has a contraction when the ship is in the anchor or under adverse conditions. Sails have a curved surface (Fig. 5) and must be hollow, have the possibility of stretching and shrinking. They do not use canvas as ordinary sails. Instead, they use aluminum and fiber-reinforced plastics to make them solid. In other words, with this concept, the ship has wings as an airplane. These sails can reduce fuel consumption by more than 25%.

Ship with Flettner rotors

History of wind power goes back to Anton Flettner in 1924 when assisted by Albert Einstein, Flettner constructed an experimental rotor vessel, and in October 1924 the Germania werft finished construction of a large two-rotor ship named Buckau. Fuel was so cheap at that point that the savings achieved by the rotor were too small for shipping companies to recoup the investment quickly enough. But nowadays the situation has changed and Flettner rotors are mounted on the E-Ship shown in the Fig. 6. In a special ship, the rotor part is positioned vertically. The required stroke is designed at the right angle to the wind to create the drive forward. Boats feature Magnus-powered mast rollers that allow third-party aerodynamic strength to form.

5. Conclusions

The authors of the paper are trying to show, that even if money issue is a problem, it is less if taking renewable sources of energy into consideration, speaking about medical care in container hospitals, providing potable water from own water treatment facilities in ships or transported by ships in containers. The main goal is to deliver an aid in time, providing the population with most important as water, medical care so that they can safely live. All processes in the framework of the individual functions are coordinated with each other and create thus reserves to reduce overall costs. Maritime transportation has high terminal costs, since port infrastructures are among the most expensive to build, maintain and improve. High inventory costs also characterize maritime transportation. More than any other mode, maritime transportation is linked to heavy industries, such as steel and petrochemical facilities adjacent to port sites.

References

Advantage of Lithuanian Transport Companies Applying Green Logistics

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Abstract

Nowadays green logistics is very important in the transport sector. The article analyses a scientific and practical problem concerning the influence of green logistics for Lithuania logistics enterprises. Green competitiveness means promoting a more resource-efficient, greener, and economy that is more competitive. The article presents the results of quantitative research carried out with 280 Lithuanian transport companies. The research focused on the applying factors of green logistics in Lithuania transport companies. During 2017 year, the practical training students filled out an electronic demographic data form online and evaluated the green logistics factors. The results revealed that 70% of Lithuanian transport logistic companies implement quality management certificates and have other awards. After the implementation of green logistics is a key element that increases the advantage of logistics enterprise.

KEY WORDS: green logistics, Lithuanian transport companies, quality management

1. Introduction

The concept of green logistics is strongly interrelated with the sustainable development policy in the transport sector. The importance of the concept of green logistics is mentioned on different levels. Transport companies are responsible for implementing green logistics in their activities.

This article discusses implementation of green logistics concept by using quality management applications in Lithuanian transport companies. First section of the article is dedicated to the scientific discussion about the concept of green logistics. Second section is dedicated to the main developments of quality management in Lithuania and its possibilities for application to “greening” logistics activities.

The aim of the paper is to analyse the quality management standards as green logistics key of Lithuania transport companies.

The methods for research include the comparative analysis of scientific literature, questionnaires, empirical data grouping, comparison and analysis.

2. Concept of Green Logistics

The term “green logistics” relates to such important environmental factors as recycling, packaging, renewable energy use, ecological transport [12, 15, 19].

Some authors notice that green logistics consists of all activities related on customer, supplier, government and transport company relationship [19, 20].

Green logistics consists of all activities related to the eco-efficient management of the forward and reverse flows of products and information between the point of origin and the point of consumption whose purpose is to meet or exceed customer demand [11, 15].

Green logistics can be defined as an organization activity by environmental issues. Very important that company is integrating suppliers and customers and changing they thinking about environmental performance. [9, 15, 19].

Despite the fact that consumption of sources like fuel, other kind of activities such as supply chain management, distribution networks or mode and fleet decisions are subject to green logistics concept [6].

To emphasize the importance green logistics could be named as producing and distributing goods in an environmentally friendly way, paying attention to problems related with economic and social sphere [13, 15].

Green logistics includes many different activities such: green purchasing, green material management and manufacturing, green distribution and marketing, and reverse logistics [5].

Scientists state, that green logistics should be described as: the common logistics system which is based on efficient energy consumption and less environment harming while increasing labour efficiency and competitiveness [7, 8, 21].

The term ”green logistics” is often used interchangeably with “reverse logistics”. However, it is not correct. There are some differences [2, 14, 17, 18]:

• in contrast to the reverse logistics, green logistics include logistics activities related with ecological issues;
• green logistics are in charge of transportation problems and recycling;
• green logistics focuses on the forward flow of the supply chain while reverse logistics is viewed as sustainable development.
Reverse logistics has been defined as the process of planning, implementing, and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods, and related information from the point of consumption to the point of origin, for the purpose of recapturing value or proper disposal [13].

According to many researchers, there are the key drivers of green logistics shown in Table 1 [3, 5, 11, 13, 16, 18, 24, 25].

<table>
<thead>
<tr>
<th>The key drivers of green logistics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stakeholder pressure</strong></td>
</tr>
<tr>
<td><strong>Environmental regulations</strong></td>
</tr>
<tr>
<td><strong>Company size</strong></td>
</tr>
<tr>
<td><strong>Industrial sector and geographical location</strong></td>
</tr>
<tr>
<td><strong>Internationalization</strong></td>
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<tr>
<td><strong>Strategic attitude</strong></td>
</tr>
<tr>
<td><strong>Manager’s characteristics and human resources</strong></td>
</tr>
</tbody>
</table>

Researchers distinguishes four factors affecting green logistics – company, customers, politics, and society. By understanding the consumers important role in green logistics it can be beneficial for the company to use green logistics. For the customer companies delivered product with green vehicles [16, 18].

Very important thing for affecting green logistics are stakeholders and size of the organization, government and environmental regulations, industrial sector and geographical location. [5].

Researchers describing technological, organizational and environmental factors to the adoption of green practices in logistics companies. Technological factors are relative advantage, compatibility and complexity. Organizational factors are organizational support, quality of human resources, company size. Environmental factors are customer pressure, regulatory pressure, government support, environmental uncertainly [11, 18].

Taking into account that the concept of green logistics is related to sustainable development, it can be stated that the concept of green logistics is based on three equivalent levels: economic, ecologic, social. Implementation of ecological principles based on reduction of negative impact to the environment. Economic principles based on increase of enterprise’s performance efficiency. Social principles based on satisfaction of social needs. The concept of green logistics in a particular enterprise should be based on the principles of economic, ecologic and social responsibility [24].

Implementation the key drivers of green logistics based on interaction and cooperation between different logistic players, such as shippers, carriers, transporters, and suppliers that aims to gain a long-lasting competitive advantage. Green logistic activities must be incorporated into corporate environmental methods.

The article emphasizes on the necessity of key drivers of green logistics from a management perspective for delivering quality products and services. The green methods of evaluations may be treated as a barometer for the assessment of performance evaluation of business activities [13].

This is the only approach that consider environmental, economic and social aspects of the organization in an integrated way [24].

It is expected that every organizations should mandatorily follow the environmental regulations with the integration of green practices.

The benefits of green logistics could be to reduce overall business costs, to improve profits, customer satisfaction, employee satisfaction, visibility of green drivers, brand image, sustainable business practices, to reduce greenhouse gas emissions and wastages.
3. A Study on Quality Management Certificates in Lithuanian Transport Companies as Aspects of Green Logistics

Hence, greening of business is very essential to produce a quality product/process in any organizations. If company take care on customers, the high quality includes safety, cost, ecological certificates.

Because of that, reforms connected with green business has a positive impact on high quality products/process. The demand of high-quality products or activities grow gradually with organization, its output and customer’s needs. Other factories of quality-the price, novelty of products, competitive surroundings, safety, engineering, technological equipment. Because of willingness to find a possibility of integrating methods of green logistics in Lithuania.

In order to find out the possibility of implementation of green logistics concept in the Lithuanian transport companies, necessary survey has been conducted. Conducted survey and processing of the results allowed to formulate factors for the implementation of green logistics concept. The successful implementation of green logistics concept in Lithuanian transport companies would help Lithuania to make its input in to implementation of common strategic goals of the EU.

The study took place in 2017 during the practical training of transport logistics students of Vilnius Technology and Design College. In order to investigate the transport logistics company’s implementation some green logistics key drivers. Quantitative research using a questionnaire method was carried out. A questionnaire was prepared to make a quantitative study. The study findings were systematized and analysed via MS Excel. The analysis of the results used descriptive statistics (percentage distribution).

Study sample - survey-sampling bias is calculated according to the Paniott formula [23]:

\[
n = \frac{1}{\Delta^2 + \frac{1}{N}},
\]

where \( n \) – sample size; \( \Delta^2 \) – bias probability; \( N \) – Target population, which ensures approximately a 5% probability of bias.

After the evaluation of the study sample bias, it was found that the minimum number of respondents was to be 277 transport companies. The number of respondents was 280 Lithuanian transport companies.

Data collection method - a questionnaire survey, which was carried out electronically, through www.apklausa.lt and sent to the students via their personal e-mails.

The objective of this article is to introduce one of the green logistics key – quality management, which could support the green activities in Lithuanian transport companies.

After literature review, the main important are customers’ role to implement green logistics. it can be beneficial for the company.

In this research were forwarding, transport, logistics Lithuanian companies. 50% of companies were forwarder, 40% - transport and 10% were logistics companies. There were different companies’ size. The most of respondents were large companies were works more than 250 employees. 5% were micro companies with 9 employees. 25% Lithuanian companies were small and 20% medium.

Transport companies could reach many benefits – not only the goals of green logistics but also enhance quality of services, penetrate into new markets, reach better performance and become more attractive for the investors. One of the key drivers for green logistics after literature review was quality management system. Quality management standards help to health and property protection, to ensure customer and operational safety, help to protect and preserve the environment. Application of standards helps to improve service quality and environmental safety, provide customers with the confidence in stability of quality of the products or services provided and in social responsibility of the organization.

The survey results revealed that the Lithuanian transport companies focused on customer’s needs. They know that quality management in an organisation should be in the first place. 70% of respondent had to implement quality management systems and other institutions, other point out that they are thinking of quality management systems implementation and will do it in the future, evaluated their activities. Thus, according to the theory, Table 1, grouping of key drivers of green logistics, the table shows the environmental factors are very important. Thus the green logistics mentioned above can act like important parameters for quality certifications and evaluations. The standards are presented in Fig. 1.

ISO 9001 tries to make a shift in mind of managers and employees by introducing process orientation as a business principle. 20% of Lithuanian transport companies introduce in processes this standard. This standard helps to do business more success.

Very important key driver for the green logistics is environmental or ecologic factor – such as ISO 14001 certification. Competitors analysis and customer satisfaction, environmental factors are the important for Lithuanian transport companies. So, some of them have used recycling, to design innovative products/processes. The logistics companies have oriented they business to obtain the ISO 14001 certificate.

LEAN has been found to have the potential to enhance the capability of the transport and logistics sector to make it more competitive through the elimination of wastes, increased productivity, and reduced lead times. Lithuania transport companies involved that to optimize the transport business and to do more effectiveness.
Implementation of quality standards are useful for Lithuanian transport companies because their activities not only in local market, but also in international markets. To implement the green logistics for company is needed as it promotes business development, increases the competitiveness in comparison with the other companies.

4. Conclusions

Nowadays more companies try to improve some green logistics factors to the activity. Very important are environmental requirements such as recycling, re-using, eco fuel, renewable energy etc. Researchers describe different key drivers of green logistics. One of more important are consumers satisfaction, competitiveness and using the quality standards. After making questionnaire was revealed that Lithuanian Transport Companies implements quality standards as one of green logistics factor. The most of companies implement ISO 90001 and ISO 14001 standards. The Lithuanian Transport Companies implemented standards and certificates because they interested how to satisfy a customer.

References


Analysis of Risks in Aviation

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Abstract

Hazards and safety have always been important factors of the aviation. It is mainly so under current conditions of continuous development and growth in air transport demand. Aviation organisations of all types face a range of risks that may affect the achievement of their objectives. It became clear that all those risks must be managed. For the purpose of identifying and classifying hazards resulting from air transport, the risk areas have been divided into those associated with human activity (intentional and unintentional), technical, organisational, environmental and other factors. The basis of a proper hazard management process is correct identification of threats in all areas of air transport.

KEY WORDS: risk, hazard, aviation, risk management, risk assessment

1. Introduction

Air transport represents one of the most dynamic sectors of the economy. As a crucial economic entity, it is a key factor for ensuring sustainable development of mobility and integration of new Member States into the European structures. Air transport is also a very complex system connecting human, organizational and environmental actors with the technical measures. All those factors are closely linked, as well as have an impact on each other and are supportive together. In the age of proactive approach to safety management, the process of risk management correctly became the most necessary element.

Proactive approach to risk management is used to defend accidents in aviation. The process contains data gathering in order to identify negative future events, analyzing system to identify potential future risks.

The occurrence of aircraft accidents is in comparison with other transport departments much lower, but the consequences of accidents in air transport are often, for the crew of the aircraft and passengers, fatal. Starting of using the proactive safety management strategy leads to reducing the risk of accidents and offers acceptable level by taking the necessary preventive measure to eliminate recurrence of similar incidents. It is essential to determine, identify and quantify all existing hazard sources and distinguish the relations between them [1, 3-5, 7, 8].

2. Hazards and Risks in Aviation

According to the European air law, hazard situation is defined as an activity or an object that can cause injury or death to a person, damage to equipment loss of material or reduction of ability to perform a prescribed function.

Aviation occurrence is defined as a safety-related situation that endangers an aircraft, its occupants or any other person and includes an accident or a serious incident [9].

Entire elimination of risk in aviation is an unachievable goal (the perfectly safe would be stopping all aviation activities and grounding all aircraft). A small rate of risks in aviation is accepted. Risk management plays important role in addressing the risk in practical terms. It represents a structured approach and systematic actions aimed to achieve balance between the identified and assessed risk and practicable risk mitigation (Hailey, Jonason, 2013).

2.1. Risk Management

The international standard responsible for risk management is ISO 31010 – Risk Management – Risk assessment techniques (ISO 31010 Risk assessment techniques). Nowadays, organizations of all types face a range of risks that may affect the achievement of their objectives. It became clear that all those risk must be managed. Risk management contains three essential elements: hazard identification, risk assessment and risk mitigation. The most important part of the risk management process is risk assessment [6]. It is an overall process of risk identification, analysis and evaluation, but it is not an independent activity and must be fully integrated with other risk management parts. The flow chart below depicting the Risk Management process:
2.2. Methods of Risk Management in Aviation

Risk management should be applied to all the processes that affect the process of transportation and organisation of transportation (transport, infrastructure management, maintenance, ...). In transportation there are used the estimation and evaluation of risks. The basis for risk management in transport industry is realisation of sources of hazards and thus awareness of specific hazards. This action ensures estimation process of identified risks and – in the case of exceeding the risk of hazards – to introduce preventive procedures, constant monitoring as well as inform people directly involved into process (employees) and the customers (passengers) about the risks.

Achievements in risk assessment process, which determines the appropriate running of risk management and the safety procedures, are:

- **Risk analysis** – systematic using of all available data to identify risks. A result of this process is made a hazard record for analysis.

- **Risk assessment** – defining hazardous scenarios and existing safety procedures for identified risks. Estimation of significance of the adverse effects resulting from the identified hazards. Risk assessment mostly consists of the following steps:
  1. **Analysis of all processes related to organization** – the aim is to review all the processes performed by organization. Possible areas of risks should be analysed in relation to activities, e.g.: process of realisation transport, personnel management, maintenance of aircrafts/vehicles, document management, coordination activities.
  2. **Risks identification** – the goal of this stage is to make a list of possible hazards in organisation due to hazards arising from the activities of third parties (including social risks) and initial recognition of consequences.
  3. **Risk assessment** – The objective of this stage is to value identified risks and hazards. Important elements in the process of hazard valuation is:
    - **P** – probability of occurrence of potential threats and hazards. The only way to minimize probability is to integrate defenses or preventive procedures to eliminate the errors in the system.
    - **S** – possible consequences or outcomes of a hazard or situation.
      Risk is a predicted probability and severity of the consequences or outcomes of a hazard, which may be calculated with equation: $R = P \times S$ (ISO 31010 Risk assessment techniques).
  4. **Verification of the effectiveness of the preventive measures** – implementation of preventive measures should be continuously monitored and the effects should be verified. After the process of implementation of preventive measures, there should be the calculation of a new risk index $R$. If the particular hazard exceeds the accepted threshold, it is crucial to define additional risk control measures. Then the assessment body checks again the level of risk. There are three areas where the hazard can occur – own risk (source of threats on the same transport organization), shared risk (threats beyond transport system) and external risk (threats outside the transport system) [10]
    - **Valuation risk** – comparing the risk assessment results with given criteria.
3. Analysis

For the purpose of identifying and classifying hazards resulting from air transport, the risk areas have been divided into those associated with human activity (intentional and unintentional), technical, organisational environmental and other factors (Tables 1-5). A table with identified sources of hazard was created for each of the factors. All the mentioned risks are conditioned from external threats.

### Table 1

<table>
<thead>
<tr>
<th>Human factor</th>
<th>Intentional</th>
</tr>
</thead>
<tbody>
<tr>
<td>False alerts</td>
<td>Intrusion into restricted area of airport with prohibited items; Bomb threat on board of the aircraft; Act of sabotage or diversion; Vandalism; Damage of technical facilities with consequences</td>
</tr>
<tr>
<td>Mental illness</td>
<td>Runway incursions; Runway excursions; Controlled flight into terrain; Loss of control in flight; Intrusion into controlled Airspace; Fire, smoke and fumes; Intrusion into restricted area of airport; Intrusion into restricted area of airport with prohibited items; Bomb threat in buildings and facilities; Bomb threat on board of the aircraft; Act of sabotage or diversion; Vandalism; Damage of technical facilities with consequences</td>
</tr>
</tbody>
</table>

| Terrorism | Runway incursions; Runway excursions; Controlled flight into terrain; Loss of control in flight; Intrusion into controlled Airspace; Fire, smoke and fumes; Intrusion into restricted area of airport with prohibited items; Bomb threat in buildings and facilities; Bomb threat on board of the aircraft; Act of sabotage or diversion |
| Panic | Controlled flight into terrain; Loss of control in flight; Fire, smoke and fumes; Bomb threat in buildings and facilities; Bomb threat on board of the aircraft; Act of sabotage or diversion; Vandalism |

| Alcohol | Runway incursions; Runway excursions; Controlled flight into terrain; Loss of control in flight; Intrusion into controlled Airspace; Fire, smoke and fumes; Intrusion into restricted area of airport; Intrusion into restricted area of airport with prohibited items; Bomb threat in buildings and facilities; Bomb threat on board of the aircraft; Act of sabotage or diversion; Vandalism; Damage of technical facilities with consequences |
| Nervousness | Runway incursions; Runway excursions; Controlled flight into terrain; Vandalism |

| Drugs | Runway incursions; Runway excursions; Controlled flight into terrain; Loss of control in flight; Intrusion into controlled Airspace; Fire, smoke and fumes; Intrusion into restricted area of airport; Intrusion into restricted area of airport with prohibited items; Bomb threat in buildings and facilities; Bomb threat on board of the aircraft; Act of sabotage or diversion; Vandalism; Damage of technical facilities with consequences |
| Lack of awareness of the consequences | Runway incursions; Controlled flight into terrain; Loss of control in flight; Bomb threat in buildings and facilities; Bomb threat on board of the aircraft; Vandalism; Damage of technical facilities with consequences |

| Prohibited articles (weapons, bacteria, radioactive material) | Runway incursions; Runway excursions; Controlled flight into terrain; Loss of control in flight; Fire, smoke and fumes; Intrusion into restricted area of airport with prohibited items; Bomb threat in buildings and facilities; Bomb threat on board of the aircraft; Act of sabotage or diversion |

Source: Authors, based on [2]

In general, the human factor is the area where most of threats and dangers arises. A frequent source of danger in this area is a mental illness of a passenger or a crew member, that can be considered as unintentional source of hazard. Other unintentional sources of hazards are determined by the lack of awareness of the consequences or ignorance of the law or consequences. Errors due to intentional behaviour are often the consequences of people who were under the influence of drugs and alcohol.
There is often a risk of loss of control over an aircraft, reduced visibility or other threats. Mitigating measures. The pilot cannot influence weather anomalies, bird movements or volcano eruptions. Therefore, a technical factor is an area where improvements can be made to reduce the risk of an accident to an acceptable level.

### Technical factor and the resulting hazards

<table>
<thead>
<tr>
<th>Factor</th>
<th>Hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unauthorised access to facilities</td>
<td>Runway incursions; Runway excursions; Mid-air collisions; Controlled flight into terrain; Loss of control in flight; Fire, smoke and fumes; Intrusion into restricted area of airport; Intrusion into restricted area of airport with prohibited items; Bomb threat in buildings and facilities; Bomb threat on board of the aircraft; Act of sabotage or diversion; Vandalism; Damage of technical facilities with consequences</td>
</tr>
<tr>
<td>Unauthorised access to the aircraft</td>
<td>Runway incursions; Runway excursions; Mid-air collisions; Controlled flight into terrain; Loss of control in flight; Fire, smoke and fumes; Intrusion into restricted area of airport; Intrusion into restricted area of airport with prohibited items; Bomb threat in buildings and facilities; Bomb threat on board of the aircraft; Act of sabotage or diversion; Vandalism; Damage of technical facilities with consequences</td>
</tr>
<tr>
<td>Damage due to break of technical measures</td>
<td>Runway incursions; Runway excursions; Mid-air collisions; Controlled flight into terrain; Loss of control in flight; Fire, smoke and fumes; Intrusion into restricted area of airport; Intrusion into restricted area of airport with prohibited items; Bomb threat in buildings and facilities; Bomb threat on board of the aircraft; Act of sabotage or diversion; Vandalism; Damage of technical facilities with consequences</td>
</tr>
<tr>
<td>Design errors</td>
<td>Runway incursions; Runway excursions; Mid-air collisions; Controlled flight into terrain; Loss of control in flight; Intrusion into controlled Airspace; Fire, smoke and fumes; Intrusion into restricted area of airport; Intrusion into restricted area of airport with prohibited items; Damage of technical facilities with consequences</td>
</tr>
</tbody>
</table>

Source: Authors, based on Commercial Aviation Safety Team, 2013

Threats resulting from the design errors or an inappropriate technical condition of an airport, aircraft or facility may cause serious threats such as: unauthorised access to facilities or to the airport, damage due to break of technical measures. A technical factor is an area where improvements can be made to reduce the risk of an accident to an acceptable level.

### Environmental factor and the resulting hazards

<table>
<thead>
<tr>
<th>Factor</th>
<th>Hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fierce gusts of wind</td>
<td>Runway incursions; Runway excursions; Controlled flight into terrain; Loss of control in flight; Fire, smoke and fumes; Aircraft crashes not related to human activity; Damage of technical facilities with consequences</td>
</tr>
<tr>
<td>Whirlwinds</td>
<td>Runway incursions; Runway excursions; Controlled flight into terrain; Loss of control in flight; Fire, smoke and fumes; Aircraft crashes not related to human activity; Damage of technical facilities with consequences</td>
</tr>
<tr>
<td>Fog</td>
<td>Runway incursions; Runway excursions; Controlled flight into terrain; Loss of control in flight; Fire, smoke and fumes; Aircraft crashes not related to human activity; Damage of technical facilities with consequences</td>
</tr>
<tr>
<td>Heavy rain</td>
<td>Runway incursions; Runway excursions; Controlled flight into terrain; Loss of control in flight; Fire, smoke and fumes; Aircraft crashes not related to human activity; Damage of technical facilities with consequences</td>
</tr>
<tr>
<td>Heavy snowfall</td>
<td>Runway excursions; Controlled flight into terrain; Loss of control in flight; Fire, smoke and fumes; Aircraft crashes not related to human activity; Damage of technical facilities with consequences</td>
</tr>
<tr>
<td>The eruption of volcanoes</td>
<td>Loss of control in flight; Fire, smoke and fumes; Aircraft crashes not related to human activity; Damage of technical facilities with consequences</td>
</tr>
<tr>
<td>Birds</td>
<td>Mid-air collisions; Controlled flight into terrain; Loss of control in flight; Fire, smoke and fumes; Aircraft crashes not related to human activity; Damage of technical facilities with consequences</td>
</tr>
</tbody>
</table>

Source: Authors, based on [2]

Compared to a technical factor, the environmental factor is an area where it is often not possible to take risk-mitigating measures. The pilot cannot influence weather anomalies, bird movements or volcano eruptions. Therefore, there is often a risk of loss of control over an aircraft, reduced visibility or other threats.

### Organisational factor and the resulting hazards

<table>
<thead>
<tr>
<th>Factor</th>
<th>Sources of hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of awareness of safety</td>
<td>Runway incursions; Controlled flight into terrain; Loss of control in flight; Fire, smoke and fumes; Intrusion into restricted area of airport; Intrusion into restricted area of airport with prohibited items; Vandalism</td>
</tr>
<tr>
<td>Lack of knowledge of the airport requirements</td>
<td>Intrusion into restricted area of airport; Intrusion into restricted area of airport with prohibited items; Vandalism</td>
</tr>
<tr>
<td>High concentration of people in a small space</td>
<td>Fire, smoke and fumes; Bomb threat in buildings and facilities; Bomb threat on board of the aircraft; Vandalism</td>
</tr>
<tr>
<td>Lack of proper law regulations</td>
<td></td>
</tr>
</tbody>
</table>

Source: Authors, based on Commercial Aviation Safety Team, 2013

Organisational factor represents threats such as lack of awareness safety, law regulations and also lack of
knowledge of the airport requirements. High concentration of people in small space makes space for the arising of hazards too. Preventive measures have to be taken to contribute the increasing the safety of air traffic.

<table>
<thead>
<tr>
<th>Other factors</th>
<th>Hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance of drones, remotely piloted aircrafts, models of flying vehicles</td>
<td>Mid-air collisions; Loss of control in flight; Intrusion into controlled Airspace; Intrusion into restricted area of airport; Intrusion into restricted area of airport with prohibited items; Bomb threat in buildings and facilities; Act of sabotage or diversion; Vandalism; Damage of technical facilities with consequences</td>
</tr>
<tr>
<td>Appearance of unauthorized flying objects (paragliders, balloons)</td>
<td>Mid-air collisions; Controlled flight into terrain; Loss of control in flight; Intrusion into controlled Airspace; Bomb threat on board of the aircraft; Vandalism; Damage of technical facilities with consequences</td>
</tr>
<tr>
<td>Fireworks</td>
<td>Mid-air collisions; Loss of control in flight; Fire, smoke and fumes; Vandalism</td>
</tr>
<tr>
<td>Hackers</td>
<td>Mid-air collisions; Controlled flight into terrain; Loss of control in flight; Intrusion into controlled Airspace; Intrusion into restricted area of airport; Intrusion into restricted area of airport with prohibited items; Bomb threat in buildings and facilities; Bomb threat on board of the aircraft; Act of sabotage or diversion; Vandalism; Damage of technical facilities with consequences</td>
</tr>
</tbody>
</table>

Source: (Authors, based on [2])

Drones or Remotely Piloted Aircrafts have become a serious threat to air transport. They could be used as a tool for attack, because they can carry explosives, biological or chemical weapons, jam the signals and also can be used to hack airport’s information systems.

It is necessary to realise, there is never only one element that causes the rise of threat. For example, intrusion into a restricted area of the airport with prohibited articles may be caused by variety of intentional or unintentional sources. It can be caused by technical factors but also it may be the result of organisation. Due to highly developed system of aviation security, entering the prohibited item into a security restricted area is always result of the compilation of many sources. At least one element of the system of security would have to fail, while at the same time someone would try to bring a prohibited item into the airside.

4. Conclusion

Hazards and safety have always been important factors of the aviation. It is mainly so under current conditions of continuous development and growth in air transport demand. Risk is defined as the probability of occurrence of a hazardous event in given period. The most important thing for a risk management is to use proactive approach. It means that managers should not wait to see what negative situations occur and react to them – they should be proactive and use the preventive measures and plans. The aim of risk management is to eliminate or – it this is not possible – minimalize the size of the damage that can be caused by aviation occurrences. It is also necessary to realize all the possible steps which should be implemented before the event occurs and should be based on risk analysis (proactive approach). The basis of a proper hazard management process is correct identification of threats in all areas of air transport.

References
Research and Development of a Rocket with Predefined Parameters

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Abstract

A computational fluid dynamic simulation was carried out to investigate the aerodynamic parameters of a rocket with predefined parameters. The results of the simulation were used to investigate the external ballistics of the rocket. Using the results of the presented research a rocket was developed and experimentally tested.

KEY WORDS: rocket, drag coefficient, external ballistics.

1. Introduction

The present design required developing a solid-propellant rocket which is 1.6 meters in length and 0.096 meters in diameter with a flight range over 10 km and suitable to reach supersonic speeds. The estimation of the exterior ballistics characteristics is one of the most important stages in rocket design. Various numerical methods are used to determine initial ballistic parameters in order to optimize the design [1]. To carry out this stage with a required precision, the assessment of the aerodynamic drag characteristics has to be done as well. Currently, computational fluid dynamic (CFD) techniques are used to predict aerodynamic characteristics of rockets as it is a very efficient and economical method in compare to wind tunnel tests [2-5].

This paper presents a research on aerodynamic and external ballistic used in development and implementation of a rocket with predefined parameters.

2. CFD Simulation

ANSYS CFX software was used in order to estimate the drag characteristics of the rocket shown in Fig. 1. A quarter of the model was discretized applying symmetric boundary conditions to save computational time (Fig. 2).

The mesh with the quantity of 6 million tetrahedral elements was used for the simulation. The size of elements was set to 1 mm near the surface of the rocket. Also, five inflation layers consisting of prism were created on this surface with the smooth transition option ant the growth rate 1.2.

The surface of the rocket was defined as a non-slippery wall, while the outside walls of the domain were defined as free slip walls. The air temperature was set to 15°C and the reference pressure was 101325 Pa. The SST turbulence model was selected due to its highly accurate predictions of flow separation. The simulation was carried out in the range of Mach number from 0.5 to 2.

The results of the simulation of airflow around the rocket were obtained. The total air pressure distribution is shown in Fig. 3 while Fig. 4 shows the streamlines of airflow at the Mach number 2.

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The simulation showed that the drag force is 1926.5 N when the Mach number of the air flow is 2 (Fig. 5). When the Mach number is increasing, the drag force increases almost linearly under the subsonic speed (M < 0.8). Under the subsonic speed range, the drag coefficient of the rocket is almost constant and approximately equal to 0.51 (Fig. X). When the airflow reaches the transonic range (0.8 > M > 1.2) the growth of the drag force distinctly increases. The drag coefficient of the rocket rises sharply and large increases when the speed reaches the transonic range. This wave drag is due to the unstable formation of shock waves which transforms a considerable part of the available propulsive energy into heat, and to the induced separation of the flow from the rocket surfaces. Throughout the transonic range, the drag coefficient of the rocket is greater than in the supersonic range because of the erratic shock formation and general flow instabilities. The drag coefficient reaches its maximal value (about 0.899) when the Mach number is 1. Once a
Supersonic flow has been established, however, the flow stabilizes and the drag coefficient is reduced. When the Mach number of the flow is 2, the drag coefficient is about 0.708. The character of the drag force increase is linear under supersonic speed ($M > 1.2$) (Fig. 5).

Fig. 3 Total pressure, $M = 2$

Fig. 4 Streamlines of airflow, $M = 2$

![Fig. 3 Total pressure, $M = 2$](image1.png)

![Fig. 4 Streamlines of airflow, $M = 2$](image2.png)

Fig. 5 Drag force and drag coefficient vs. Mach number

3. External Ballistics Calculations

Using the methodology presented in [6], an external ballistics model was developed and implemented using MATLAB Simulink which was used in order to estimate the parameters of the rocket propellant which would meet the requirements for supersonic speeds and analyze the characteristics of the flight trajectory of the rocket along with taking into account the obtained air drag characteristics.

The initial parameters of the external ballistics model and the obtained results are shown in Table.

| Initial parameters of the external ballistics model and the obtained results |
|---------------------------|-----------------------------|
| **Initial parameters**    | **Calculated parameters**   |
| Rocket mass, kg           | 15.2                        |
| Engine mass, kg           | 3.8                         |
| Impulse, Ns               | 6800                        |
| Thrust, N                 | 2086                        |
| Launch angle, deg         | 55                          |

| Maximum flight height, m  | 5272                        |
| Maximum flight distance, m| 11072                       |
| Maximum flight time, s    | 66.6                        |
| Burn time of the propellant, s | 3.3                     |
| Maximum speed, m/s        | 605.4                       |
| Maximum acceleration, m/s$^2$ | 187.2                   |

The trajectory of the rocket is showed in Fig. 6 and the acceleration and speed over time is showed in Fig. 7

![Fig. 6 Rocket trajectory](image3.png)

![Fig. 7 Acceleration (1) and speed (2) over time](image4.png)

4. Implementation

The results of the external ballistics modelling allowed to develop an engine for the rocket (Fig. 8) with the
following characteristics: impulse 6800 Ns; diameter 90 mm; engine mass 8.7 kg; propellant mass 3.8 kg; nominal thrust 2100 N; engine length 0.7 m; burn time 3.3 s. In this design, the neutral star type of propellant grain was used. By this way, the surface area of the burning propellant is constant or deviates very little despite time increment, until sliver of the propellant is reached.

Fig. 8 rocket engine with solid-propellant: 1 – nozzle with a graphite insert; 2 – housing; 3 – igniter

The results of the presented research were used to developed a solid-propellant rocket system (Fig. 9) which was successfully and experimentally tested (Fig. 10).

Fig. 9 Developed solid-propellant rocket system

Fig. 10 Launching of the rocket

5. Conclusions

A computational fluid dynamic simulation was carried out to investigate the aerodynamic parameters of the rocket. The simulation showed that under the subsonic speed range, the drag force increases almost linearly when the air speed is increasing and the drag coefficient is almost constant and approximately equal to 0.51. When the airflow reaches the transonic range the growth of the drag force distinctly rises. The drag coefficient of the rocket rises sharply due to the unstable formation of shock waves. The drag coefficient reaches its maximal value (about 0.899) when the Mach number is 1. Once a supersonic flow has been established, however, the flow stabilizes and the drag coefficient is reduced. When the Mach number of the flow is 2, the drag coefficient is about 0.708. were used to investigate the external ballistics of the rocket.

Taking into account the results of the CFD simulation, an external ballistics model was developed and implemented using MATLAB Simulink which was used to define the required thrust of 2086 N and other initial design parameters for the rocket engine in order to ensure a flight distance of 11072 m and a maximum speed of 605.4 m/s.

Using the results of the presented research a rocket was developed and experimentally tested.

Acknowledgements

This work was supported by the Research Council of Lithuania, grant No. S-MIP-17-94 „Experimental Rocket: Research and Development“

References

Experimental Study of the Influence of Friction Surfaces Cooling Parameters on the Efficiency of the Braking System of a Railway Vehicle Operation

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Abstract

The purpose of the study is to evaluate the effect of cooling frictional surfaces on the efficiency of the braking system by experimentally determining the coefficient of friction and the temperature of the interacting surfaces under different methods and regimes of cooling. Experimental research established that the mathematical model of the disc brake thermophysical characteristics, which takes into account the adaptive cooling system, ensures a satisfactory match of the results of calculations to experimental data; the discrepancy does not exceed 10-12%. Analysis of the experimental data obtained allows concluding that adaptive cooling of the brake friction surfaces has a positive effect on the braking efficiency. Thus, the coefficient of friction when using this system is 15-30% higher, depending on the performance and temperature of the cooling air, than without its use. The average integral temperature of surfaces in frictional interaction is lower by average of 20-30% compared to the case when adaptive cooling is not used.

KEY WORDS: rail transport, braking, friction interaction, disc brake, energy efficiency, experimental study

1. Introduction

The effectiveness of the braking equipment is one of the most important factors that determine the possibility of increasing trains’ weight and speed, the throughput and carrying capacity of railways. The motion safety significantly depends on the properties and condition of the brake equipment of the rolling stock.

Considering constant increase in the speed of trains there are high requirements to brake devices. The application of known designs of the block and disk brakes is limited by permissible heating of the friction surfaces.

In order to increase braking effectiveness of the rolling stock, it is necessary to create sufficient braking power with the braking devices and ensure a stable grip of the wheels with rails. Analysis of the problems of existing brake equipment led to the choice of a promising direction of research on the braking effectiveness: control of the temperature of brake friction surfaces.

On the basis of the complex analysis of experimental and theoretical studies [1-6] it was determined that one of the most important problems of braking devices is maintaining the surface temperatures of their frictional pairs within certain limits. Exceeding the permissible temperatures of the friction surfaces leads to the loss of their wear and friction properties, destabilization of the operating parameters (dynamic coefficient of friction, mechanical and thermal deformations, wear, etc.) of brake devices.

In order to determine the most effective method of increasing the thermoregulation and energy dissipation capacity in braking systems, the system of intellectual decision support based on the software developed by the authors [7] was used. A survey of competent experts has allowed to identify the most promising methods for improving the braking friction system in order to increase the braking efficiency by controlling the temperature in the friction pairs.

As a result of the conducted expert research the estimation of innovative methods of the modern rolling stock braking system efficiency increasing has been evaluated. It has been established that the most promising method of increasing the braking efficiency is air supply with its temperature adjusted depending on the braking conditions.

In view of this, it is advisable, in order to meet the requirements for stabilizing the temperature of the friction brake pairs, to develop an adaptive control method for cooling the friction surfaces and to experimentally prove the expediency of using the advanced brake equipment to increase the energy dissipation capacity of the braking system friction elements; provide an assessment of effectiveness of the developed method for improving the railway vehicle brake equipment performance.
2. Experimental Study of the Influence of Friction Surfaces Cooling Parameters on the Efficiency of the Braking System of a Railway Vehicle Operation

The mathematical model of thermophysical characteristics of the rail brakes friction pairs considering adaptive cooling system [8, 9] describes the dependence in the contact temperature on the process parameters. With the increase in temperature in the friction pair elements field of interaction the next processes take place:

- significant increase in the pad wear intensity;
- significant change in friction coefficient affecting the braking performance.

The mathematical model of the thermophysical characteristics of the disc brakes allows to estimate the temperature of the friction surfaces of the brakes, taking into account adaptive cooling.

The disadvantage of compressed air supply to the frictional contact during braking as a method of improving the conditions of interaction in the friction system of the brake pad and disk is the low coefficient of convective heat transfer, which is caused by the insufficiently low temperature of the compressed air supplied to the contact area for its cooling. When braking, the temperature in the brake pad and disk contact severely increases, accordingly it is necessary to reduce it in order to avoid plastic deformations and danger of skidding.

The task of friction elements interaction efficiency increasing is achieved by the use of the Ranque-Hilsch Effect in the air supply system in the zone of friction contacts, while cooling the contact between the brake pad and disk, a cooled air from the vortex tube (Fig. 1) is supplied into the frictional contact. When temperature in the contact rises during braking, the coefficient of adhesion reduces while the probability of skidding increases. To prevent this phenomenon, compressed air is supplied to the brake disk and pad contact, which helps achieving maintaining the maximum value of the coefficient of friction (Fig. 2).

![Fig. 1 The Vortex Tube](image1)

![Fig. 2 Dependence of the friction coefficient on the temperature in contact](image2)

Thus, the application of the proposed method for improving the friction elements of the disc brakes interaction conditions will stabilize the brake disc and the pad adhesion ratio during braking.

Experimental study of the braking process was carried out with the help of a full-scale laboratory bench developed by the Department of lifting-transport vehicles of the Volodymyr Dahl East Ukrainian National University [10]. The stand is designed to test different designs of brake devices and control their output parameters.

The general view of the stand and its schematic diagram are shown in Figs. 3 and 4.

![Fig. 3 The general view of the stand](image3)

The brake 1 (Fig. 4) is mounted on the rocking frame 2 and is connected by means of elastic couplings 3 to the drive motor 4 and a rotating mass 5 which consists of 18 disks and allows changing the moment of inertia from 2 to 60 kg • m² by attaching to the shaft or disconnecting the flywheel disks from it. The frame 2 and the rotating mass 5 are supported by rolling bearings reinforced on the struts. The stand allows to vary the moment of inertia with the help of rotating discs, the speed of rotation, the duration of the drive, and record such output parameters of the brake and drive as the braking torque, thrust force, the opening time of the brake and the drive, the response time of the brake, frequency of the drive rotation, temperature of friction surfaces.

The brake torque created by the brake is measured using the dynamometric rings 6 (Fig. 4, AA) connected by
spherical hinges to the base. The rocker 7 is rigidly fixed to the rocking frame 2. The strain gauges are glued to the dynamometric rings, connected by a half-bridge circuit. The electrical signals from the strain gauges are amplified by the amplifier 8ANCH-7M and registered by a light-beam daisy-chain oscillograph H-117 type.

The thrust force, which is proportional to the braking torque, is measured with the help of the sensor 9, made in the form of a dynamometric ring with glued strain gauges and a brake installed on the brake rod (Fig. 4, BB). Electrical signals from the datacenter are applied to the amplifier, and then to the recording device, which is an analog-to-digital converter type B7-35.

The opening and ramping times, trip and deceleration times are measured and recorded by the device for monitoring the output parameters of the brakes, which includes a pulse generator, a pulse counter and a set of sensors.

The opening time is counted from the moment the power is applied to the brake actuator until the pads go off, with the contact sensor installed on one of them, from the brake pulley. Acceleration time of the drive is counted from the moment the voltage is applied to the drive (M) until the nominal speed is reached. The frequency of rotation of the drive shaft is removed by a tachogenerator of direct current type TGP-5. The speed of the drive (M) is measured by a TG-1 direct current tachogenerator type TMG-38. For visual observation of the rotational speed of the flywheel (MM), a TG-2 tachometer of the type D1-MM with a measuring instrument type TM and ZP is used. The shaft of rotating masses is connected with the shafts of tachogenerators by a belt transmission.

The temperature of the friction surfaces of the brake is measured with a thermocouple sensor (Fig. 5). A chromel-kopel thermocouple designed for heating up to 600°C was used. Structurally, the thermocouple is made in the form of a porcelain cylinder through which the thermocouple electrodes are passed through the holes. The thermocouple is installed in the body of the brake shoe and fixed with a screw. As a recording instrument a universal device type B7-35 was used.

The design of the stand is complemented by a compressor and a vortex tube, the construction of which is based on the Ranque-Hilsch Effect. The air is supplied into the pipe, in which there is a thermal separation into cold and hot air, which are diverted from different openings. The cooled air is supplied to the frictional contact area. To measure temperature and air velocity pyrometer and anemometer were used (Fig. 6).

The task of the study is to show experimentally the dependence of the coefficient of friction and temperature in the contact “brake disc-overlay” on the temperature and the productivity of the air supply to the frictional contact, to the friction track, the lining and the disk.

For example, the results of experiments with and without cooled air supply are presented in Figs. 7 and 8. Values obtained in parallel experiments were checked for errors using Student's criterion [11].
3. Conclusions

Experimental research established that the mathematical model of the disc brake thermophysical characteristics, which takes into account the adaptive cooling system, ensures a satisfactory match of the results of calculations to experimental data; the discrepancy does not exceed 10-12%. Analysis of the experimental data obtained allows concluding that adaptive cooling of the brake friction surfaces has a positive effect on the braking efficiency. Thus, the coefficient of friction when using this system is 15-30% higher, depending on the performance and temperature of the cooling air, than without its use. The average integral temperature of surfaces in frictional interaction is lower by average of 20-30% compared to the case when adaptive cooling is not used.

Acknowledgement

This research was funded by a grant (No. S-LU-18-12) from the Research Council of Lithuania and Ministry of Education and Science of Ukraine. This research was performed in cooperation between Volodymyr Dahl East Ukrainian National University, Ukraine and Vilnius Gediminas Technical University, Lithuania.

References

The Research of the Metal Hydride Compressor for the Hydrogen Transport Vehicles Service and Fueling Station

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Abstract

Researched and developed the high pressure metal-hydride compressor on the base of lanthanum alloys in wide range of operation parameters. An experimental test bed was created and adopted for these researches. Sorption, desorption and kinetic characteristics was researched and developed. It was showed that alloy LaNi₄.₅Al₀.₅ is the most efficient material for hydrogen compressors which must supply vehicle fuelling station with high pressure 15…30 MPa.

KEY WORDS: Metal-Hydride compressor; hydrogen sorption; kinetic characteristics; fuelling station

1. Introduction

At present time internal combustion engines are the most spread as main and auxiliary ICE for vehicles, vessels, power generation, etc. Their application is associated with low energy efficiency, negative impact on the environment due to high emissions of harmful substances and the use of oil fuels. The vehicles with electric motors are alternative upon to existing ones.

There are two ways of the electric vehicles development: battery electric vehicles and electric vehicles with fuel cells. The main advantage of the battery electric vehicles is the developed infrastructure of power grids and charging stations, but the charging time is too prolonged: from 20 minutes in the fast charging mode and up to 8…10 hours.

These problems can be solved by creation of the complexes for local hydrogen production with water electrolysis on the base of photovoltaic panels, hydrogen purification and compression on the base of metal-hydride technologies and hydrogen storage in modern high pressure tanks on the base of reinforced with carbon nanotubes or composite materials.

During last year's metal-hydride technology is researched and developed very successfully. Some technological metal-hydride technology methods allow to create high pressure hydrogen compressors which have high efficiency and are safe.

The theoretical researches allowed to defining main equations and dependences which describe the connections and relationship of parameters of the processes of hydrogen compression with metal-hydride devices.

Hydride-forming materials are the most important component of the high pressure hydrogen compressors. These materials must have high hydrogen capacity, satisfactory kinetic characteristics and be resistant against destruction and poisoning by oxygen, sulfur etc.

The basic characteristic of the hydride-forming alloy is sorption capacity which is the relation of the absorbed hydrogen mass to the metal-hydride compound mass.

The sorption capacity is defined via the temperature and pressure under which the reaction of hydrogen absorption/desorption takes place. The connection of the indicated parameters is shown as R–S–T dependences which are called a thermo-sorption characteristic of metal-hydride material.

The thermo-sorption characteristic is significantly affected by the chemical compound, production technology, dispersion, the amount of activation cycles, etc. It is necessary to perform individual study of each party of metal-hydride material.

Next important property of the hydride-forming material is kinetics. This property obtains charging and discharging duration of hydrogen tank, mass and dimension of the high pressure hydrogen compressor which have supply fuelling station and its cost.

There for selection of the rational hydride-forming material is the determining factor in high pressure hydrogen compressor design process.

Methods of analysis and synthesis of the complicate metal-hydride systems for hydrogen high pressure compression is one of the important problems [1-5].
2. The Main Principal

**Governing Equations.** The Van't Hoff's equation in chemical thermodynamics relates the change in temperature \((T)\) to the change in the equilibrium constant \((K)\) given the standard enthalpy change \((\Delta H)\) for the process.

\[
\frac{d \ln K}{dT} = \frac{\Delta H}{RT^2} .
\]  

(1)

It was defined, if the enthalpy change of reaction is assumed to be constant with temperature, the definite integral of this differential equation between temperatures \(T_1\) and \(T_2\) is given by

\[
\ln \left( \frac{K_2}{K_1} \right) = -\frac{\Delta H}{R} \left( \frac{1}{T_2} - \frac{1}{T_1} \right) .
\]  

(2)

In this equation \(K_1\) is the equilibrium constant at absolute temperature \(T_1\) and \(K_2\) is the equilibrium constant at absolute temperature \(T_2\). \(\Delta H\) is the standard enthalpy change and \(R\) is the gas constant.

Since:

\[
\Delta G = \Delta H - T\Delta S
\]  

(3)

and

\[
\Delta G = -RT \ln K .
\]  

(4)

It follows that

\[
\ln K = -\frac{\Delta H}{RT} + \frac{\Delta S}{R} .
\]  

(5)

Therefore, a plot of the natural logarithm of the equilibrium constant versus the reciprocal temperature gives a straight line. The slope of the line is equal to minus the standard enthalpy change divided by the gas constant, \(-\Delta H/R\) and the intercept is equal to the standard entropy change divided by the gas constant, \(\Delta S/R\). Differentiation of this expression yields the Van’t Hoff equation.

The Arrhenius’ equation gives "the dependence of the rate constant \(k\) of chemical reactions on the temperature \(T\) and activation energy \(E_a\), as shown below:

\[
k = Ae^{-E_a/RT},
\]  

(6)

here \(A\) is the pre-exponential factor or simply the pre-factor and \(R\) is the gas constant. The units of the pre-exponential factor are identical to those of the rate constant and will vary depending on the order of the reaction. If the reaction is first order it has the units \(s^{-1}\), and for that reason it is often called the frequency factor or attempt frequency of the reaction. Most simply, \(k\) is the number of collisions which result in a reaction per second, \(A\) is the total number of collisions (leading to a reaction or not) per second and \(e^{-E_a/RT}\) is the probability that any given collision will result in a reaction. When the activation energy is given in molecular units instead of molar units, e.g. joules per molecule instead of joules per mole, the Boltzmann constant is used instead of the gas constant. It can be seen that either increasing the temperature or decreasing the activation energy will result in an increase in rate of reaction.

Assuming thermal equilibrium between the metal hydride alloy and hydrogen, a single energy equation can be used. For a two-dimensional (axi-symmetric) modeling, with \(r\) and \(z\) axes, the energy equation is:

\[
\left( \rho c_p \right)_g \frac{\partial T}{\partial t} = \frac{1}{r} \frac{\partial}{\partial r} \left( rk \frac{\partial T}{\partial r} \right) + \frac{\partial}{\partial z} \left( k_z \frac{\partial T}{\partial z} \right) - m \left( \Delta H + T \left( c_{pg} - c_{ps} \right) \right) .
\]  

(7)

here \(k_r, \Delta H, c_{pg}, c_{ps}\) and \(m\) are effective thermal conductivity of the hydride bed, the enthalpy change of the hydriding reaction, specific heat of the gas and solid phases respectively, and the rate of hydrogen mass absorbed per unit volume.

The \(m\) term accounts for both absorption and desorption, but as it is used in this thesis the positive form of \(m\) represents absorption, and negative form represents desorption. The \((\rho c_p)_g\) term is the volume averaged heat capacity of the gas and solid and is given below as equation.

The gas velocity within the reactor can be calculated using Darcy’s law:

\[
V_g = -\frac{K}{\mu_g} \nabla P_g ,
\]  

(8)

here \(K, \mu_g,\) and \(P_g\) are the permeability of the porous medium, the dynamic viscosity of hydrogen, and the pressure of the hydrogen respectively. The mass balance expression for hydrogen gas is:

\[
\varepsilon \frac{\partial (\rho_g V_g)}{\partial t} + \nabla \cdot (\rho_g V_g) = -m ,
\]  

(9)

here \(\varepsilon\) is the porosity of the metal hydride bed, \(\rho_g\) is the density of the hydrogen gas, and the \(m\) term is the rate of
hydrogen mass absorbed per unit volume, as noted above for the energy equation. When solving this equation the hydrogen is assumed to be an ideal gas. Assuming the solid volume is fixed, the mass balance for the solid is:

\[(1 - \epsilon) \frac{\partial (\rho_s)}{\partial t} = m, \tag{10}\]

here \(\rho_s\) is the density of the metal hydride alloy. The expression for the rate of hydrogen absorbed per unit volume is:

\[m_{abs} = C_a \exp \left( -\frac{E_a}{RT} \right) \ln \left( \frac{P_g}{P_{eq}} \right) \left( \rho_{sat} - \rho_s \right), \tag{11}\]

here \(C_a\) is the absorption constant, \(E_a\) is the activation energy for absorption, \(P_g\) is the equilibrium pressure for absorption, and \(\rho_{sat}\) is the density of the metal hydride alloy when it has absorbed all of the hydrogen gas that can reversibly be absorbed. The equation for the equilibrium pressure is given below as equation. \(C_a\) is equal to 60.08 1/s and \(E_a\) is equal to 15.55 J/mol. It should be noted that these values are for the metal hydride alloy LaNi5. However, because heat transfer is the rate limiting factor, and metal hydride alloys have similar reaction rates, these values are a good approximation for other metal hydride alloys. The expression for the rate of hydrogen desorbed per unit volume is:

\[m_{des} = C_d \exp \left( -\frac{E_d}{RT} \right) \times \left( \frac{P_g - P_{eqd}}{P_{eqd}} \right) \left( \rho_s - \rho_{emp} \right), \tag{12}\]

here \(C_d\) is the desorption constant, \(E_d\) is the activation energy for desorption, \(P_{eqd}\) is the equilibrium pressure for desorption, and \(\rho_{emp}\) is the density of the metal hydride alloy when it has desorbed all of the hydrogen gas that can reversibly be desorbed. The equation for the equilibrium pressure is given below as equation. \(C_d\) is equal to 9.43 1/s and \(E_d\) is equal to 15.55 J/mol. The same is true for these values as noted above for the absorption rate expression.

These two expressions have been combined in the model by allowing the final \(m\) term to assume the value of either \(m_{abs}\) or \(m_{des}\). The logical statements that have been applied to Eq. (5) and Eq. (6) allow for only one of \(m_{abs}\) or \(m_{des}\) to have a local value other than zero. The \(m\) term will assume the value of whichever one is not zero, if both are zero then the \(m\) term will also be zero. If \(m_{des}\) is used, a negative value is generated since the governing equations are formulated to consider a positive \(m\) term as absorption.

This allows the model to simulate absorption and desorption simultaneously, which is essential because within the hydride bed there may be areas that are absorbing hydrogen locally while other areas are desorbing hydrogen. This is especially true of dynamic simulations where there may be rapid variations in hydrogen demands as well as pressure and external temperature. From the energy equation, the \((\rho c_p)_e\) term is calculated as:

\[\left( \rho c_p \right)_e = \left( \epsilon \rho c_{pe} + (1 - \epsilon) \rho c_{pw} \right). \tag{13}\]

The ideal gas relation used to determine gas density is as follows:

\[\rho_e = \frac{M_e P_g}{RT}. \tag{14}\]

The temperature dependent dynamic viscosity term is calculated:

\[\mu_e = 9.05 \times 10^{-6} \left( \frac{T}{293} \right)^{0.68}. \tag{15}\]

The equilibrium pressure for absorption and desorption is calculated using the van’t Hoff relationship:

\[LnP_{eq} = A - \frac{B}{T}, \tag{16}\]

here \(A\) and \(B\) for \(P_{eqa}\) and \(P_{eqd}\) are determined from the Hydride Material Database. Hysteresis results in different values of \(A\) and \(B\) for \(P_{eqa}\) and \(P_{eqd}\). Utilizing different equations for \(P_{eqa}\) and \(P_{eqd}\), allows the model to more accurately represent the behavior within the tank, because hysteresis is accounted for.

During the adjustment tests, it was impossible to capture the absorption of hydrogen by the activated metal-hydride compound immersed in the liquid layer. A reactor design of active type has been created. A design involves the presence of a mechanical activator (mixer) of a metal-hydride slurry in a sealed volume. For experimental research the circuit of an asynchronous electric motor with a "wet" rotor is adopted. Windings of the stator are outside the sealed volume, which greatly simplifies their switching, and the tightness of the contour is provided with a special sheath. Hydrogen circulates through the technological holes in the bearings of sliding and technological gaps between the rotor and the walls of the shell.

Measurement of the frequency of rotation was carried out by a sensor installed and balanced on the shaft of the rotor. The control of the activator rotor speed of the is carried out by means of a voltage change. The connection of the
reactor to the hydrogen circuit of the experimental booth is carried out using a nipple compound located on the top. The power supply and control system is in a separate housing and connects to the stator windings with a shielded electric cable.

3. Test Bed and Experimental Results

The experiments are performed on a special experimental stand.

The purpose of the test bed: reading thermo-sorption characteristics of metal-hydride materials; activation of metal-hydride materials; hydrogenation and dehydrogenation of metal-hydride materials; reduction of the size of metal-hydride material particles; filling up of hydrogen balloons or hydrogen pumping from the balloon into another one.

The test bed, Fig. 1, includes: hydrogen system; vacuum system; heating system; cooling system; automatic driving and controlling system; metering system.

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The experiments are performed on a special experimental stand.

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The test bed, Fig. 1, includes: hydrogen system; vacuum system; heating system; cooling system; automatic driving and controlling system; metering system.
The recalculation of the direct measurement data is performed considering the following dependency. The change in the mass of hydrogen $\Delta m_{H2}$ is recalculated from the changes in the volume of hydrogen $\Delta V_{H2}$ using the known dependence

$$\Delta m_{H2} = \rho_{H2} \Delta V_{H2},$$

(17)

here $\rho_{H2}$ is the hydrogen density, $\rho_{H2} = 0.09 \text{ kg/m}^3$; $\Delta V_{H2}$ is the change the volume of hydrogen in the measuring container, taken at the atmospheric pressure

$$\Delta V_{H2} = P_1 V_f - P_2 V_f = V_f (P_1 - P_2),$$

(18)

here $V_f$ is the volume of the measuring container stand, $P_1$ is the pressure before the beginning of the process, $P_2$ is the pressure after the end of the process. The sign of a numerical value in this case indicates the direction of the process. If $P_1 > P_2$, it is the process of hydrogen absorption. If $P_1 < P_2$, it is the process of hydrogen evolution (desorption).

The concentration of $c_{H2}$ hydrogen is a ratio of the mass of absorbed hydrogen $\Delta m_{H2}$ to the mass of hydride-forming alloy

$$m_{mg} c_{H2} = \frac{\Delta m_{H2}}{m_{mg}},$$

(19)

The result of processing is the characteristic of a batch of material, constructed in the form of a T–S diagram for a specific range of pressures. The diagram is shown in Fig. 3. It indicates that the maximum sorption capacity value exceeds 1.2% for the pressure range of 0.45...0.85%.

This is a satisfactory value for this material. The material from this batch can be used in metal-hydride facilities and devices.

4. Conclusions

Hydride-forming materials on the base of Lanthanum, like as LaNi$_{4.5}$Al$_{0.5}$, are efficient for creating metal hydride compressors of the vehicle hydrogen fuelling station. These materials have high hydrogen capacity, satisfactory kinetics and are resistant against destruction and poisoning by oxygen, sulfur etc.

References

Investigation of Hydraulic Throttling Within Geothermal Injection Well Filter Using CFD Simulation

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Abstract

The study presented in this paper is dedicated to determining parameters that sufficiently represent fluid flow throttling of a geothermal system injection well filter affected by sediment formation. The aforementioned parameters are to be used in a custom mathematical model that includes all significant elements of a geothermal system necessary to conduct hydrodynamic studies on a macroscopic scale. The calculations were done using computational Fluid Dynamics (CFD) CFD software supplied with 3D geometry of a filter segment, consisting of a cylindrical hole obstructed by several rows of trapezoid wire, providing narrow gaps through which the geothermal fluid exits the injection well pipeline. Fluid flow was computed for 100 cases of varied inlet and outlet pressure difference and filter geometry based on proposed sediment formation model. The calculated multiple case fluid flow values were used to determine the throttling parameter array of the geothermal well filter based on fluid flow equation that is to be used in a custom model. The resulting data array covers all filter gap and pressure difference values needed for a related study with a custom model, making it possible to accurately represent small-scale processes when modelling a relatively large system.

KEY WORDS: Geothermal system, Hydraulic throttle, Computational Fluid Dynamics

1. Introduction

Over the years CFD simulation of turbulent fluid flow has become a go-to method of analysis for various systems where experimental data is lacking or is difficult to obtain. The subject of the CFD studies varies from simple engineering optimization tasks to studies of complex fluid flow parameters. Fluid flow has a lot of characteristics which are difficult to measure experimentally, e.g. the flow in a complex geometry and turbulent flow. However, the rapid growth of computer hardware and software technology during the last couple of decades makes it possible to be able to use it as a supplement for experimentally impossible and complex problems, by using a computational fluid dynamics (CFD) program [1]. The direct solution of the Navier–Stokes equations for industrial flows in complex geometry is probably not feasible for several years. Two alternative approaches are typically implemented to simulate these complex flows configurations: the Reynolds-Average Navier–Stokes (RANS) method and the Large Eddy Simulation (LES) method. These two methods induce additional terms in the governing equations that need to be modelled in order to achieve “closure” to the unknowns [2]. Furthermore, a larger number of mesh cells generally leads to more accurate solutions, though it might be more restrictive to model larger systems, since more computation resources are needed. The capacity of a computer, or even a computer cluster, can be easily overcome with a large number of cells or nodes in a mesh [3]. The results of a numerical experiment, in which the Reynolds-averaged transport equations are solved using the time-averaged flow field obtained by LES, were presented by Tominaga and Stathopoulos [4]. The superiority of flow field in LES has been shown to have much influence on the concentration diffusion field [5] presented the results of a comparative 2D and 3D simulation of the fluid dynamics and heat transfer during an oxidation process in an oxidation reactor. According to the results obtained, the temperature fields, velocity and oxidation localization can be predicted. CFD analysis is often used to predict fluid flow in multiphase environments. For example, turbulent flows which transport particulates are quite often encountered in a vast array of environmental, industrial, and medical applications [6]. In such cases, additional equation governing particle motion are introduced. In a study presented by Zhang and Li [7] numerical analysis methods of particle deposition in turbulent duct flows is investigated. It was determined that Reynolds stress transport model seems to be most suitable as the model of airflow field. In a work by Arellano et al. [8] the results of a numerical simulations of air blowing into a copper matte were presented. The fluid flow in a Peirce-Smith converter with more than one injection points has been investigated. A CFD simulation of turbulent flow in a rod bundle with spacer grids was carried out by Cinosi et al. [9]. When comparing different turbulence models used for the experiment it was observed that it is reasonable to infer that the standard K-epsilon method is sufficient to predict, within a good degree of accuracy, the velocity profiles of the flow occurring in the presented study. A study presented by Leung et al [10] is dedicated to prediction of transient turbulent dispersion by CFD–statistical hybrid modeling method. A CFD–statistical hybrid modeling method had been developed to predict the transient turbulent dispersion of a gaseous contaminant. A reasonable agreement was also found in comparison with the k–ε modeling results. The major benefit of the CFD–statistical hybrid modeling method is that significant computation time saving can be achieved.

During the long-term operation of a geothermal facility by “Geoterma”, UAB in Klaipeda, Lithuania it was
determined that, among other related problems, the injection well has been operating sub optimally with over time decreasing fluid injection efficiency. The causes could not be properly investigated due to the necessity of uninterrupted geothermal well operation as well as technical difficulty in observing the outer surface of the geothermal pipeline filter deep underground. However it is known, that, among other factors, the geothermal pipeline components that come in direct contact with the geothermal fluid suffer prolonged exposure to highly mineralized environment which, in turn, is known to cause the formation of solid sediment on exposed surfaces.

The study presented in this paper is closely related to overall investigation of internal hydrodynamic and thermodynamic processes that produce negative impact in regards to the overall efficiency of the geothermal facility. Such investigation proves to be challenging due to highly limited ability to produce physical experiments on the system, thus making mathematical modelling the most viable option for investigating critical aspects of the geothermal system operation.

The goal of the presented study is to determine an array of throttling parameters within predicted boundaries to be used with a more suitable custom mathematical model created to evaluate fluid flow throughout the geothermal system on a significantly larger scale, since the specifics of fluid flow through the filter of the injection well must be taken into considerations. Having a valid array of computed performance data will present an opportunity to simplify complex flow at a relatively small, yet undoubtedly significant segment of the geothermal loop.


For any type of fluid flow simulation, conservation equations for mass and momentum have to be solved. The general form of the mass conservation equation and is presented below and is valid for incompressible as well as compressible flows:

$$\frac{\partial p}{\partial t} + \nabla \cdot (\rho \vec{v}) = S_m,$$

where $p$ – pressure, $\rho$ – density, $\vec{v}$ – velocity vector, $S_m$ - right side parameter.

Conservation of momentum in an inertial (non-accelerating) reference frame is described by the follow equation [11]:

$$\frac{\partial p}{\partial t} + \frac{\partial}{\partial x_j} (\rho v_j) + \frac{\partial}{\partial r} (\rho v_r) + \frac{\partial p}{\partial r} = S_m,$$

where $v_j, v_r$ - velocities projections.

The computations are carried out with commercial CFD software ANSYS® FLUENT®. The simulation software was configured for steady-state incompressible (as the compressibility effects for the case in question are negligible) fluid flow study in 3D geometry, the realizable $k-\varepsilon$ turbulence model was chosen to conduct fluid flow analysis. When applying the realizable $k-\varepsilon$ turbulence model the following transport equations for turbulent kinetic energy $k$ and turbulent dissipation $\varepsilon$ are implemented [12-14]:

$$\frac{\partial}{\partial t} (\rho k) + \frac{\partial}{\partial x_j} (\rho k u_j) = \frac{\partial}{\partial x_j} \left[ \frac{\mu}{\sigma_k} \frac{\partial k}{\partial x_j} \right] + G_k + G_b - \rho \varepsilon - Y_d + S_k;$$

$$\frac{\partial}{\partial t} (\rho \varepsilon) + \frac{\partial}{\partial x_j} (\rho \varepsilon u_j) = \frac{\partial}{\partial x_j} \left[ \frac{\mu}{\sigma_\varepsilon} \frac{\partial \varepsilon}{\partial x_j} \right] + \rho C_1 \varepsilon S_c - \rho C_2 \varepsilon \varepsilon \frac{\varepsilon}{k + \sqrt{\varepsilon}} + C_{1_s} \frac{\varepsilon}{k} C_{2_s} G_b + S_\varepsilon,$$

where $u_j$ – velocity component for corresponding direction, $G_k$ – generation of turbulence kinetic energy due to the mean velocity gradients, $G_b$ – generation of turbulence kinetic energy due to buoyancy, $Y_d$ – contribution of the fluctuating dilatation in compressible turbulence to the overall dissipation rate, $\sigma_k, \sigma_\varepsilon$ – turbulent Prandl numbers for $k$ and $\varepsilon$, $\mu$ – eddy (turbulent) viscosity, determined from the following equation: $\mu = \rho C_{\mu} \frac{k^2}{\varepsilon};$ $C_{1_s}, C_{2_s}, C_{3_s},$ are constants.

Unlike the standard $k-\varepsilon$ model, the parameter $C_{\mu}$ is not constant and is computed from the equations:

$$C_{\mu} = \frac{1}{A_0 + A_s \frac{U^*}{\bar{e}}}, \quad U^* = \sqrt{S_{\bar{c}} S_{\bar{j}}} + \tilde{\Omega}_{ij} \Omega_{ij}, \quad \tilde{\Omega}_{ij} = \Omega_{ij} - 2 \epsilon \omega_{ij} k \omega_h, \quad \Omega_{ij} = \bar{\Omega}_{ij} - 2 \epsilon \omega_{ij} k \omega_h,$$

where $A_0, A_s$ - model constants. $C_1$ is computed using the following expressions:

$$C_1 = \max \left[ 0.43, \frac{\eta}{\eta + 5} \right], \quad \eta = \frac{S k}{\bar{e}}, \quad S = \sqrt{2 S_{\bar{c}} S_{\bar{j}}},$$
The model constants are used for the simulation and are assigned the following values: $C_1 = 1.44$; $C_2 = 1.9$; $\sigma_I = 1.0$; $\sigma_x = 1.2$.

The geothermal injection well filter consists of a vertical pipe, 110 meters in length, which is perforated throughout its surface with holes 16 mm in diameter. The internal geometry of the geothermal filter can be seen on Fig. 1, containing a photograph taken by lowering a camera to the depth of 1055 m below the surface level. The outer surface of the filter has trapezoid wire wound around it to prevent larger particles from entering the geothermal pipeline from the outside. For this computational experiment, the case for only one filter hole is analyzed, since there is no experimental data for filter clogging distribution, thus making it practical to consider the clogging to be distributed evenly, making it possible to minimize the amount of computations. For the presented study, a geometric model of the filter segment, consisting of a cylindrical hole obstructed by several rows of trapezoid wire that has 0.2 mm gaps (without filter clogging) through which the geothermal fluid exits the injection well pipeline. In order to improve convergence inlet and outlet volumes preceding and following the filtering surface are extended.

The generated mesh cross-section of the 3D model used for the CFD analysis is shown on Fig. 2. It can be observed that mesh density is significantly higher in the more narrow zones, corresponding to the gaps formed by the trapezoid wire.

Fluid flow through the filter is analyzed with two varying factors: filter gap geometry, determined by the chosen method of sediment formation representation, shown on Fig. 3 and pressure difference between the inlet and outlet of the injection well filter. The filter gap is set within the interval of 0.2 to 0.02 mm with a 0.02 mm decrement, whereas the pressure difference varies from 100 Pa to 1000 Pa with 100 Pa increment, thus forming a data array of 100 study cases.

The resulting output parameter is the outflow rate through the filter outlet, expressed in m$^3$/s. The experiment results are then used to determine the throttling (pressure loss coefficient) $\zeta$ of the filter segment at all of the set parameter values. The formed data set is to be implemented directly in the suggested custom mathematical model.

The solution convergence was reached in all previously defined cases. In Table the fluid flow values are presented.
The pressure loss coefficient increases significantly when simulating the fluid flow through very narrow gaps.

3. Conclusions

The determined flow rates correspond to appropriate estimated values and form a smooth function, thus making the computed results suitable for use in a custom mathematical model with a possibility to rely on interpolated values when higher precision is required. The high amount of filter clogging can be predicted due to significantly higher than in actuality flow rate values through “clean” filter gaps computed during the CFD study. The reduction of flow rate due to filter gap clogging of over 86% described by the introduced model of sediment formation can be expected.

The pressure loss coefficient \( \zeta \) was determined for every presented case as a function of filter gap size and pressure difference. The results show that \( \zeta \) value greatly varies depending on flow specifics, which justifies preliminary determination of \( \zeta \) data array to be further used for a custom mathematical model.

Acknowledgments

This work has been supported by the research council of Lithuania within the project “simulation software and the investigation of thermo-hydrodynamic processes in the geothermal loop”, project no. mip-090/2012.

References

The Problem of Dock-Door assignment in a Cross-Docking Terminal

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Abstract

This article presents the mathematical formula of an optimization problem for dock-door assignment in a cross-docking terminal. The developed model can be used in order to optimize the assignment of suppliers and customers to dock-doors in a way that guarantees the minimization of the number of forklifts used to transport materials between dock-doors. The model ensures the possibility of defining various parameters, such as: customer order size, determining the consolidation time of a shipment resulting from the requests of individual customers and the rate of labor consumption. The developed mathematical model was verified. The article contains a sample calculation.

KEY WORDS: dock-door assignment optimization, cross-docking terminal

1. Introduction

Cross-docking terminals play a key role in supply chains. Their defining characteristics are: lack of material storage (only temporary storage - short-term buffering), segregation and separation of loads, and used when there is a high cargo rotation. Moreover, cross-docking terminals are buffering elements, which consolidate and redirect material flows.

According to [1] cross-docking is a process of consolidating cargo (from various locations) intended for the same shipping direction while minimizing the labor consumption of this process, as well as its interference in the load and bypassing material storage between the unloading and loading phase or, in some cases, storage in the nature of short-term buffering.

The cross-docking process encompasses: handling incoming cargo into the cross-docking terminals, which is unloading cargo from vehicles into the handling areas, transporting cargo onto the appropriate dock-doors in order to prepare shipments, and next, loading the vehicles with cargo and sending them to customers. During this process, it is also possible to repack and reform cargo to a limited degree.

Regarding the above, cross-docking terminals are flow-through facilities and their productivity is affected by the organization of loading and unloading vehicles as well as the internal transport organization. These productivities depend on the number of repacking areas, the capacity of buffering zones (intermediate storage area), technical readiness of loading devices as well as performance efficiency of workers. Moreover, the terminal’s working efficiency may be affected by the location of buffering zones relative to dock-doors corresponding to the inbound and outbound areas of the facility. These dock-doors correspond to transport relations and an appropriate number of intermediate storage areas is assigned to each of these areas.

In literature regarding the productivity of terminals we can find extensive research on assignment of loading docks to vehicles taking into account the transport vehicle sequence as well as load structure on the examined vehicle considering the internal transport productivity. Articles with this approach were presented by N. Boysen, M. Fliedner [2], Y. A. Bozer, H. J. Carlo [3], Y. Cohen, B. Keren [4], K. R. Gue [5], K. Lewczuk [6], L. Y. Tsui [8] and L. Y. Tsui, CH. Chang [8]. Their research focused on, among other topics, the maximization of internal transport productivity, however, at the same time, they do not consider the minimization of labor consumption of consolidating cargo between dock-doors (for cross-docking type inbound/outbound facility), time limits for load consolidation resulting from individual customer demands, as well as minimization of the number of forklifts assigned to complete the consolidation tasks. Taking the above into consideration, a need to develop a mathematical model, in which the lacking elements will be included, was identified.

2. Mathematical Formulation

For the data encompassing:
- the set of customer numbers is expressed as \( O = \{1, \ldots, i, \ldots, n\} \), where \( n \) is the number of customers and \( i \) is the customer number;
- the set of suppliers is expressed as $D = \{1, \ldots, j, \ldots, m\}$, where $m$ is the number of suppliers and $j$ is the supplier number;
- the set of inbound dock-door numbers at the cross-docking facility $WE = \{1, \ldots, l, \ldots, q\}$, where $q$ is the number of inbound dock-doors and $l$ is the inbound dock-door number;
- the set of outbound dock-door numbers at the cross-docking facility $WY = \{1, \ldots, s, \ldots, y\}$, where $y$ is the number of outbound dock-doors and $s$ is the outbound dock-door number;
- $z_{ij} \in R^+, i \in O, j \in D$, interpreted as the order size of the $i$-th customer from the $j$-th supplier;
- $d_{ls} \in R^+, l \in WE, s \in WY$, interpreted as the Euclidian path distance from the $l$-th inbound dock-door to the $s$-th outbound dock-door at a cross-docking facility;
- $t_{ls} \in R^+, i \in O$, representing the shipment consolidation time for the $i$-th supplier in the cross-docking terminal;
- $f \in \langle 0, 1 \rangle$, representing the rate of labor consumption;
values of the following decision making variables should be determined:
- $b_{lj} \in \{0, 1\}$ dla $l \in WE, j \in D$, assignment of the $l$-th dock-door to the $j$-th supplier;
- $c_{si} \in \{0, 1\}$ dla $s \in WE, i \in O$, assignment of the $s$-th dock door to the $i$-th customer;
- $tp_{ls} \in R^+, l \in WE, s \in WY$, loading cycle time between $l$-th dock-door and the $s$-th dock-door;
- $R_{ls} \in R^+, l \in WE, s \in WY$, labor consumption resulting from consolidation between the $l$-th dock-door and the $s$-th dock-door in the cross-docking terminal;
- $R_{nls} \in R^+, l \in WE, s \in WY$, intensity of labor consumption resulting from consolidation between the $l$-th dock-door and the $s$-th dock door in the cross-docking terminal;
- $n_{uls} \in R^+, l \in WE, s \in WY$, the number of loading devices required to perform consolidation tasks in the cross-docking terminal;
so that the following constraints are fulfilled:
- for the assignment of suppliers to inbound dock-doors:
  \[
  \forall j \in D \sum_{l \in WE} b_{lj} = 1; \] (1)
- to ensure the assignment of an inbound dock-door to only one supplier:
  \[
  \forall l \in WE \sum_{j \in D} b_{lj} = 1; \] (2)
- for the assignment of customers to outbound loading ramps:
  \[
  \forall i \in O \sum_{s \in WY} c_{si} = 1; \] (3)
- to ensure the assignment of an outbound loading ramp to only one customer:
  \[
  \forall s \in WY \sum_{i \in O} c_{si} = 1; \] (4)
- for the completion time of consolidation tasks between dock-doors for inbound and outbound dock-doors in the cross-docking terminal:
  \[
  \forall l \in WE \forall s \in WY \ t_{ls} = 1.1959 + 0.0113 \cdot d_{ls}; \] (5)
- for the labor consumption resulting from consolidation tasks between inbound and outbound dock-doors in the cross-docking terminal:
  \[
  \forall l \in WE \forall s \in WY \ R_{ls} = \frac{t_{ls} \cdot \sum_{i \in O} \sum_{j \in D} z_{ij} \cdot b_{lj} \cdot c_{si}}{60}; \] (6)
- for the intensity of labor consumption resulting from consolidation tasks between inbound and outbound dock-doors in a cross-docking terminal:
  \[
  \forall l \in WE \forall s \in WY \ R_{nls} = \frac{R_{ls}}{\sum_{i \in O} c_{si}}; \] (7)
- for the number of consolidating devices required to carry out consolidation tasks between specific inbound
and outbound dock-doors of the cross-docking terminal:

$$\forall l \in W_E \forall s \in W_Y \ nu_{ls} = \frac{Rn_{ls}}{f} \quad (8)$$

and so that the criterion function for the minimization of the number of devices used for consolidating between dock-doors in the cross-docking terminal:

$$\sum_{l \in W_E} \sum_{s \in W_Y} nu_{ls} \rightarrow \text{min} \quad (9)$$

assumed a minimum value.

3. Sample Calculation

The dock-door assignment model presented in the previous section was implemented using the LINGO programming language. In order to assess and verify the optimization model, many sample calculations were defined and solved. One of these sample calculations is presented in this article. The problem of assigning four suppliers ($i = 1, 2, 3, 4$) and four customers ($j = 1, 2, 3, 4$) for dock-doors (inbound - $l = 1, 2, 3, 4$; outbound – $s = 1, 2, 3, 4$) in a cross-docking terminal (Fig.1) was solved so that the labor consumption for internal transport of cargo and the number of fork lifts assumed a minimum value. The path distance (expressed in meters) from inbound dock-doors to outbound dock-doors are defined by the matrix elements $D = [d_{ls}]$. Next, the customer demand (expressed in loading units) are defined by matrix elements $Z = [z_{ij}]$. Acceptable times for load consolidation (expressed in hours) for each customer are defined by matrix elements $T = [t_{ij}]$. The parameter $f$ in this case assumes the value of 0.8.

$$D = \begin{bmatrix}
25 & 25\sqrt{2} & 25\sqrt{5} & 25\sqrt{10} \\
25\sqrt{2} & 25 & 25\sqrt{2} & 25\sqrt{5} \\
25\sqrt{5} & 25\sqrt{2} & 25 & 25\sqrt{2} \\
25\sqrt{10} & 25\sqrt{5} & 25\sqrt{2} & 25 \\
\end{bmatrix};$$

$$Z = \begin{bmatrix}
10 & 15 & 70 & 50 \\
20 & 20 & 30 & 30 \\
13 & 23 & 40 & 32 \\
30 & 14 & 27 & 10 \\
\end{bmatrix};$$

$$T = [0,4, 1,2, 1, 0,7].$$

![Fig. 1 Cross-docking facility with labeled inbound and outbound dock-doors](image)

Optimization of the dock-door assignments was conducted with the help of an optimization task implemented in the LINGO programming language.

The criterion function for the obtained solution is shown below:

$$\begin{bmatrix}
u_{11} + u_{12} + u_{13} + u_{14} + u_{21} + u_{22} + u_{23} + u_{24} + u_{31} + u_{32} + u_{33} + u_{34} + u_{41} + u_{42} + u_{43} + u_{44}\end{bmatrix} =$$

$$= \begin{bmatrix}0.25872 + 0.6642604 + 0.3803906 + 0.1115705 + 0.2657042 + 0.8624 + 0.3321302 + 0.2633474 \\
0.1749797 + 0.1992781 + 0.2053333 + 0.1365505 + 0.1131325 + 0.1521562 + 0.2214201 + 0.2369231 \end{bmatrix} =$$

$$= [4.578297] = 5$$

In the solved sample calculation, the suppliers (numbered 1 to 4) were assigned to dock-doors numbers 4, 3, 2, 1 respectively. However, the customers (numbered 1 to 4) were assigned to dock-doors numbers 2, 3, 1, 4 respectively. The obtained values of decision-making variables for this solution, which represent these dependencies, are presented in...
Table 1. Moreover, in the sample calculation solution, the labor consumption of consolidation tasks between select intermediate storage areas $R_{11}$, $R_{12}$, $R_{13}$, $R_{14}$, $R_{21}$, $R_{22}$, $R_{23}$, $R_{24}$, $R_{31}$, $R_{32}$, $R_{33}$, $R_{34}$, $R_{41}$, $R_{42}$, $R_{43}$, $R_{44}$, which are equal to 1.034880 man-hours (mh), 1.328521 mh, 0.9129375 mh, 0.3481 mh, 1.062817 mh, 1.7248 mh, 0.7971125 mh, 0.8216438 mh, 0.6999188 mh, 0.3985562 mh, 0.4928 mh, 0.4260375 mh, 0.45253 mh, 0.3043125 mh, 0.5314083 mh and 0.7392 mg respectively. However, for the consolidation task intensity of labor consumption $R_{11}$, $R_{12}$, $R_{13}$, $R_{14}$, $R_{21}$, $R_{22}$, $R_{23}$, $R_{24}$, $R_{31}$, $R_{32}$, $R_{33}$, $R_{34}$, $R_{41}$, $R_{42}$, $R_{43}$, $R_{44}$ the following values were obtained respectively, 0.2069760 mh/hr, 0.5314083 mh/hr, 0.3043125 mh/hr, 0.08925641 mh/hr, 0.2125633 mh/hr, 0.68992 mh/hr, 0.2657042 mh/hr, 0.2106779 mh/hr, 0.1399838 mh/hr, 0.1594225 mh/hr, 0.1642667 mh/hr, 0.1092404 mh/hr, 0.090506 mh/hr, 0.1217250 mh/hr, 0.1771361 mh/hr and 0.1895385 mh/hr. In order to complete the consolidation tasks for this cross-docking facility (Fig. 2), 5 fork lifts are necessary.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b_{11}$</td>
<td>0</td>
<td>$c_{11}$</td>
<td>0</td>
</tr>
<tr>
<td>$b_{12}$</td>
<td>0</td>
<td>$c_{12}$</td>
<td>0</td>
</tr>
<tr>
<td>$b_{13}$</td>
<td>0</td>
<td>$c_{13}$</td>
<td>1</td>
</tr>
<tr>
<td>$b_{14}$</td>
<td>1</td>
<td>$c_{14}$</td>
<td>0</td>
</tr>
<tr>
<td>$b_{21}$</td>
<td>0</td>
<td>$c_{21}$</td>
<td>1</td>
</tr>
<tr>
<td>$b_{22}$</td>
<td>0</td>
<td>$c_{22}$</td>
<td>0</td>
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<tr>
<td>$b_{23}$</td>
<td>1</td>
<td>$c_{23}$</td>
<td>0</td>
</tr>
<tr>
<td>$b_{24}$</td>
<td>0</td>
<td>$c_{24}$</td>
<td>0</td>
</tr>
<tr>
<td>$b_{31}$</td>
<td>0</td>
<td>$c_{31}$</td>
<td>0</td>
</tr>
<tr>
<td>$b_{32}$</td>
<td>1</td>
<td>$c_{32}$</td>
<td>1</td>
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<tr>
<td>$b_{33}$</td>
<td>0</td>
<td>$c_{33}$</td>
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<tr>
<td>$b_{34}$</td>
<td>0</td>
<td>$c_{34}$</td>
<td>0</td>
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<tr>
<td>$b_{41}$</td>
<td>1</td>
<td>$c_{41}$</td>
<td>0</td>
</tr>
<tr>
<td>$b_{42}$</td>
<td>0</td>
<td>$c_{42}$</td>
<td>0</td>
</tr>
<tr>
<td>$b_{43}$</td>
<td>0</td>
<td>$c_{43}$</td>
<td>0</td>
</tr>
<tr>
<td>$b_{44}$</td>
<td>0</td>
<td>$c_{44}$</td>
<td>1</td>
</tr>
</tbody>
</table>

Fig. 2 Obtained solution of the optimization task used to assign suppliers and customers to inbound and outbound dock-doors in a cross-docking facility

4. Conclusion

The developed optimization task allows for the assignment of suppliers and customers to dock-doors in a cross docking terminal when it is necessary to consider the following: order size of each customer, performing consolidation tasks between dock-doors, acceptable load consolidation times resulting from each customer’s demand, minimization of consolidation task labor consumption and, at the same time, minimization of the number of fork lifts used to complete the consolidation tasks.

The obtained solution to the optimization task, with the help of LINGO, ensures optimal assignment of suppliers and customers to dock-doors due to the minimization of the number of required fork lifts to complete the consolidation tasks. The quality of the obtained solution to the optimization problem as well as the studies conducted for other sample calculations enable us to assess the developed mathematical formulation for the problem of dock-door assignment of suppliers and customers to dock-doors and its implementation in LINGO as correct.

References

Trends in the Development of on-Board Electrical Power Sources of Modern Aircraft

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Abstract

This article is focused on the field of on-board primary power sources of modern aircraft in the context of vision of their further development and overall design of the aircraft's electrical power system. Development of concepts of All Electric Aircraft (AEA) and Electric Aircraft/ Hybrid aircraft (EA) with electrical propulsion brings increased requirements for power of installed power sources. Their realization is not possible without the use of new technologies and untraditional approaches.

KEY WORDS: primary power sources, more electric aircraft, hybrid aircraft

1. Introduction

On-board electrical power sources are part of aircraft equipment since the start of their development. Gradual increase of power consumption and quantity of on-board electrical loads has led to increasing of electrical power sources requirements. According to means of their generation the on-board electrical power sources can be divided into two basic groups: primary and secondary. Electrical energy is in aircrafts primary generated in electrical generators or batteries. Secondary sources – electrical power converters – have been part of aircraft electrical power system since the onset of on-board electrical power equipment. They provide the required type and parameters of electricity by transforming it from primary electrical sources.

On-board electrical power sources in conventional on-board power systems can perform different functions. They are used as main, auxiliary or emergency sources of power supply.

2. Electrification of on-Board Aircraft Systems

Since the beginning of aircrafts development the designers are devoted to implement wider use of electrical energy in aircraft systems. Electrification of on-board systems at first expanded during the introduction of new technologies at the level of element and process management. Digitization (implementation of digital technologies, data busses and microprocessors) was an important accelerator of development. The most significant development programs of this period were IDEA (integrated digital electric aircraft) and FTEPS (fault tolerant electrical power system) \cite{1}.

A term "Fly-By-Wire" \cite{2} has become a distinctive concept for this stage of aircraft development. It was the introduction of electrical / electromechanical elements in conjunction with electronic control systems to perform functions previously assured by mechanical connections. Extending the electrification of on-board aircraft systems over the next decades can be characterized by modifying the term Fly-By-Wire, through “Digital-Fly-By-Wire” \cite{3} to the "Power-By-Wire" \cite{4}. The development of this concept already represents changes in the power field, it is a replacement of previously used hydraulic or pneumatic power systems with electrical power systems - electric drives, electric anti-freeze system, electric brakes, and so on. The main benefits of these changes in aircraft systems due to their electrification include reduced operating costs, reduced fuel consumption, increased operational reliability and improved aircraft management.

The development of aircraft projects based on the complex design of their power systems has made it possible to reduce the complexity of systems and reduce their weight. The gradual elimination of non-electrical energy sources and the transition to one type of energy - electricity, not only brings increased energy efficiency, flexibility and availability of power, but also broad possibilities of improving diagnostics and forecasting of operation.

The above-mentioned activities in the development of aircraft construction with a wider use of electric power are fulfilling the vision of “All electric aircraft” (AEA) \cite{5} (Fig. 1). Under the term "All electric aircraft" it is meant an aircraft with fully electrified on-board equipment, i.e. with a single on-board power system (electric power system). The ultimate aim of the designers is to use mechanical energy taken from the aircraft propulsion unit only to power the electric generators. These should cover the entire energy consumption of on-board equipment, without the currently used hydraulic and pneumatic power systems.

The fulfilment of this vision has been going on for a long time and is supported globally by many projects (Power Optimized Aircraft - POA, More Electric Engine - MEE, More Open Electrical Technologies - MOET, Totally...
Integrated More Electric Systems - TIMES, Energy Optimized Aircraft and Aircraft Equipment Systems - EOASYS, More Electric Architecture for Aircraft and Propulsion - MEAAP). At present, it has been reached the stage when aircrafts with wider use of electricity are built and operated, so called MEA, e.g. A 380, B787, F35. Based on the current technological capabilities, these aircrafts represent a transition stage in the electrification of on-board systems, where the use of two traditional power systems - pneumatic and hydraulic systems - is gradually diminishing [6].

![Fig. 1 Visions of the development of aircraft electrification](image)

In connection with the global environmental trend of reducing fossil fuel consumption and associated emissions, vibrations and noise, the reality has also been the fulfilment of the vision of emission-free aircraft construction. This is a development of the concept referred to as "Propulsion-by-Wire", i.e. aircraft with electric drive - electric motor, "Electric Aircraft" (EA). Their current development takes place in the form of so-called "Hybrid electric aircraft" (HEA). These aircrafts also use gas turbine engines, but their primary function is not to create a thrust, but to drive electric generators to produce electricity (Fig. 1) [7, 8].

Fulfilling both of these visions of electrified aircraft of the new generation is associated with the significant energy performance of many on-board systems, with an increase in requirements for power of installed power source and to ensure their extremely high operational reliability. As the use of conventional concepts of on-board power systems is no longer possible, various non-traditional solutions and approaches are sought.

3. On-Board Electrical Power Generators

Aircrafts fly in complex meteorological conditions, at any time of the year, at different geographical positions, at different heights and with a large flight velocity range. The working conditions of the engines located outside the cabin, and also of the air generators, which are different from the working conditions of generators of industrial types, also change rapidly. The greatest influence on their design and operation has: atmospheric conditions, flight velocity, mechanical forces and chemical influences.

The basic element of the on-board power sources are electrical generators. Their power and number depends on a number of factors, the most important of which are: type, designation and operating conditions of the aircraft, total power consumption of onboard electrical appliances and type of on-board power supply system.

Depending on the type of generated power, on-board power generators are divided into direct current “DC” generators and alternating current “AC” generators. According to the design they are divided to generators with brush contact (classic) or brushless generators without sliding contact (contactless).

![Fig. 2 Principal schemes of contactless generators of traditional concepts: a - generator with rotating rectifier; b - generator with permanent magnets](image)
The classic concepts of on-board source systems have been used by DC generators with commutator (dynamos) and synchronous generators (alternators) with rings. In both cases, they are rotating electric machines in which the energy transfer from the rotor to the stator is performed by sliding contacts (commutator - carbons, rings - carbons). DC power generators are also used in motor mode to start aircraft engine (starter-generators). Due to the low output voltage (27 V), the power of conventional DC generators has been limited (12-18 kW) due to an increase in current values. Therefore, the gradual increase in the power consumption of AC appliances has resulted in wider use of AC generators of different types and designs. Unlike DC generators, it is also possible to construct them with higher power outputs and output voltage. Among the main drawbacks of AC generators used in conventional aircraft, it is possible to include problems with frequency stabilization and their parallel operation.

The development of modern aircraft concepts, coupled with increasing levels of electrification of on-board systems, brings new requirements to ensure a reliable and uninterrupted power supply with electricity and its normalized parameters. The required power of electrical power sources is growing significantly and it is likely to continue in this trend. In systems of large commercial planes, it is the transition from values of 10 kVA to 100 kVA, for instance electrical power of aircraft B787 reaches up to 1450 kVA [9].

The increase in performance requirements has been reflected in the development of on-board electric power systems on modern aircraft (MEA) in the following changes: 
- transition from AC systems with a stabilized frequency value of \( f = 400 \text{ Hz} \) to systems with a non-stabilized frequency value of \( f = 360 \div 720 \text{ Hz} \),
- transition to higher voltage values: for DC from 28V to 270V DC (± 270V / 540V HVDC - High Voltage DC), for AC from 3x115 / 200V to 3x230 / 400V.

These changes made it possible to implement power units with integrated starter-generator and power electromechanical actuators. A further shift in development brings benefits to new technologies in the field of power electronics and convertors, digital signal processors in conjunction with switched reluctance electrical machines.

It is very advantageous to use a switched reluctance machine in the function of an integrated starter-generator, as for the aircraft starting mode or as the primary source of electric power. Its advantageous properties include mechanical compactness of the construction - there is no winding on the rotor, which makes it possible to increase power and operating speeds (the possibility of direct drive of an aircraft engine without the need for a gearbox). It is suitable for use in aviation conditions, for operation at an increased thermal loads. The winding location allows to reduce rotor dimensions, simplify cooling compared to DC or asynchronous machines. In the reluctant machines, the individual windings / phases are electrically independent of each other, i.e. failures in one phase will not affect the action of others.

An example of the application of these electrical machines may be the development of an integrated power unit with a higher degree of electrification - with an integrated electric power sources system “More electric engine” (MEE) [10].

4. Superconducting Electric Machine

The realization of visions of AEA and EA (Fig. 1) is not possible without the development of high-power electric machines (generators, motors) with power ranks in megawatts. Reaction to these requirements is the use of superconducting technologies for superconducting electrical machines that would be able to meet these power requirements. This is a new stage in the development of electrical power systems of aircrafts, called Superconducting Electric Power Systems (SEPS), which is coupled with a radical new approach to the development of their individual components - superconducting electric wires, switches, power converters, etc. The use of superconducting devices in existing on-board systems would lead to further technical problems. The development of these unconventional aviation high-performance and weight-minimized architectures represents a long-term process planned over the next few decades. It represents the next stage of development with a vision of the so called “Superconducting electric aircraft” (SEA). [11]
5. On-Board Electrochemical Power Sources

Besides the electric generators, as a source of main electric power on a board of the existing aircrafts, the accumulator batteries are used as an emergency sources of electric power.

Accumulators belong to a group of electrochemical power sources. The electrical energy is obtained by direct conversion of chemical energy throughout chemical processes between the active substances of electrodes and electrolyte.

At present, small aircrafts mainly use lead-acid accumulators where the decisive factor is price and affordability; military aircrafts predominantly use silver-zinc accumulators, where weight is the decisive factor; large commercial aircraft use nickel-cadmium and lithium-ion batteries, where decisive factors are their performance parameters.

For large commercial aircrafts, two major accumulators are generally used. One, denoted as “APU BAT”, is used for APU starting. The second one, denoted as “MAIN BAT”, serves to supply “HOT BUS” (this bus is permanently supplied) from which, in case of loss of remaining electrical power sources, “DC ESS BUS” is supplied. After an inversion of DC to AC “AC ESS BUS” is supplied. ESS buses supply all equipment necessary for safety landing. This is the main reason that batteries will be still part of on-board emergency system [12].

The energy density of Li-ion batteries (up to 250 Wh/kg) is much less than that of fuel. But there is continuing research on lithium-sulphur (Li-S), lithium-air (Li-air) and solid-state batteries, which energy density is for Li-S four times bigger and for Li-air batteries five times bigger as than that of Li-ion batteries. During discharging of Li-S battery, the lithium anode is consumed and sulphur transformed into particular chemical compounds. During charging, the reverse process takes place. In solid-state batteries, the liquid electrolyte is replaced by a solid compound which nevertheless allows lithium ions to migrate within it. It has several advantages over liquid electrolyte. The first one is safety, because inorganic solid electrolyte is non-flammable when heated, unlike their liquid counterparts. The second advantage is, that it permits the usage of high-voltage high-capacity materials, enabling denser, lighter batteries with better shelf-life as a result of reduced self-discharge.

6. Fuel Cells

An increase in requirements for the power of on-board power sources in modern aircrafts has also increased interest in introducing non-traditional sources of electricity - fuel cells. Initial research activities are headed towards their use as auxiliary or emergency power sources. Replacing Auxiliary Power Units (small motors) with fuel cells would lead to reduced fuel consumption and reduced emissions. Fuel cells are the electrochemical conversion devices that produce electricity directly by the oxidation of the fuel. They work with high efficiency and low impact on the environment. In addition, because they work without fuel burning, they produce energy with minimal harmfulness. Water could be considered as a side product of their operation and is meant to be used for galleys, so it will not be necessary to carry such amounts of reserve water [13].

On the other hand, this water could be used as a source of oxygen and hydrogen. The system called Regenerative Fuel Cell using electrolyser for such a conversion. The advantage of such a system is in having smaller tanks for hydrogen and oxygen. During a flight the hydrogen and the oxygen are gradually refilled and could be used again after landing as a source of energy for taxing [5].

The first small aircraft with installed fuel cells was HK 36 Super Dimona, in 2008, with total fuel cell power of 20 kW [14]. The propulsion system of such an aircraft is depicted in Fig. 5, where it is also compared with traditional
There are a lot of researches on solid oxide fuel cell power units (SOFCPO) [13], which would operate throughout the flight, and not only during taxiing, to maximize fuel savings. The power output of SOFCs will be for big commercial aircrafts about 900kW.

Fig. 5 Scheme of propulsion systems for a - classical concept; b - concept with fuel cell

7. Conclusions

The requirement for a more efficient, safer and more environmentally friendly way of transporting goods and passengers has prompted a complete overhaul of the aircraft’s energy system. This can only be achieved by increasing the use of electricity. The work focuses on major projects such as POA, MEE, MOET, TIMES, EOASYS and MEAAP, which are devoted to greater use of electricity on board of an aircraft. The paper also points to the two major developmental branches of the large commercial aircraft electrical system, MEA and EA, and points to the technologies used in them. In the last part, attention is focused on the description of current aviation generators and alternative sources of electricity which will strikingly affect future airplanes, not only their electrical power system, but also the whole design of the airplane.

References

The Analysis of the Errors in Standardised Phraseology of Student Pilots and ATC

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Abstract

The paper deals with the analysis of the pilot and ATC students’ errors when learning standard phraseology which reduces the risk that a message will be misunderstood. The first part describes the requirements for knowledge of the phrases and continues with the grammar description of some of problematic ones. The basic part an article focuses on the error analysis in grammar, vocabulary and word order. The final part discusses the importance of the read-back/hear-back process so that any error is quickly detected, and the role of aviation communication in human factors.

KEY WORDS: aviation, communication, errors, students, human factor

1. Introduction

The standard for aeronautical operations was laid down by International Civil Aviation Organization (ICAO) in its 1944 Chicago convention. Most of the standards for communication (equipment, standards and procedures) are laid down in Annexe 10 Vol. 2 to the convention. By convention, messages are agreed standardized phrases, placed into categories.

The use of correct and precise standard phraseology in communication between pilots and ground personnel is vitally important. Incidents and accidents have occurred in which a contributing factor has been the misunderstanding caused by the use of non-standard phraseology. Therefore, we have to ensure that we use the correct technique, phonetic sounds for letters and numbers, format for time, phraseology and call signs.

We have focused on some problems in training of students studying to be pilots and air traffic controllers. The task was to find out and analyze the most frequent errors which make the standardized phraseology unclear, not precise or even change the meaning. It is important to know in English language training to avoid the communication in simulator training and later practical flights [1-5].

2. Communication Errors

Communication error is the biggest causal factor in both level busts and runway incursions in Europe. This document aims to provide Commercial Air Transport (CAT) pilots and other pilots flying IFR within controlled airspace with a quick reference guide to commonly used radiotelephony (RTF) phrases that may be encountered during a routine CAT flight in European Airspace. It also explains some of the rationale behind the use of certain words and phrases to aid understanding and reinforce the need for compliance with standard phraseology.

2.1. Safety

The aim is to improve safety by raising RTF standards.

The need for clear and unambiguous communication between pilots and Air Traffic Control (ATC) is vital in assisting the safe and expeditious operation of aircraft. It is important, therefore, that due regard is given to the use of standard words and phrases and that all involved ensure that they maintain the highest professional standards when using RTF. This is especially important when operating within busy sectors with congested frequencies where any time wasted with verbosity and non-standard, ambiguous phrases could lead to flight safety incidents.

Phraseology has evolved over time and has been carefully developed to provide maximum clarity and brevity in communications while ensuring that phrases are unambiguous. However, while standard phraseology is available to cover most routine situations, not every conceivable scenario will be catered for and RTF users should be prepared to use plain language when necessary following the principle of keeping phrases clear and concise.

2.2. Non-Standard Phraseology

Where non-standard phraseology is introduced after careful consideration to address a particular problem, it can make a positive contribution to flight safety; however, this must be balanced with the possibility of confusion for pilots.
or ATCOs not familiar with the phraseology used. This phraseology is not in accordance with ICAO but is based on careful study of the breakdown of pilot/controller communications. Some other European countries have also adopted similar non-standard phraseology.

2.3. Phraseology as a Contributing Factor

B737, Gran Canaria Spain, 2016 (On 7 January 2016, a Boeing 737-700 was inadvertently cleared by ATC to take off on a closed runway. The take-off was commenced with a vehicle visible ahead at the runway edge. When ATC realised the situation, a 'stop' instruction was issued and the aircraft did so after travelling approximately 740 metres. Investigation attributed the controller error to "lost situational awareness". It also noted prior pilot and controller awareness that the runway used was closed and that the pilots had, on the basis of the take-off clearance crossed a lit red stop bar to enter the runway without explicit permission.)

3. Research and Analysis of Frequent Errors

The research was attended by 18 students studying at the Aeronautical Faculty in the Pilot Study Program and Air Traffic Controller, and during two semesters they were tested and verbally examined during the semester and at the end of the semester. The students completed 42 lessons of standardized aviation phrases, were analysing the pronunciation, grammar, and made short dialogues. Testing was focused on the accuracy of phrases, vocabulary, grammar, word order and writing, which could change the meaning of the phrase. In the analysis, we mainly noted uncertainty about the phrase or certain words and the use of another but not the correct word. The correctness of the word order and the incorrect grammatical form played an important role in the analysis, as they interfered with the meaning of the phrase.

3.1. Vocabulary

The first prerequisite for correctness of standardized phraseology is knowledge of vocabulary. Compared to the general English vocabulary, standard verbs, nouns and prepositions that cannot be confused are used in standardized phrases.

<table>
<thead>
<tr>
<th>Correct word</th>
<th>confirm</th>
<th>check</th>
<th>disregard</th>
<th>out, over, roger</th>
<th>request</th>
<th>verify</th>
<th>cleared</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of incorrect answers</td>
<td>6%</td>
<td>4%</td>
<td>17%</td>
<td>3%</td>
<td>8%</td>
<td>5%</td>
<td>8%</td>
</tr>
</tbody>
</table>

In the table there are the correct terms instead of which students used the synonyms of these words as e.g. ask instead of request, control instead of check, or the meaning of the words verify and confirm, also out, over, roger, interchange with each other. The most difficult to remember was a word disregard, to which up to 17% did not write correctly (Table 1).

<table>
<thead>
<tr>
<th>Incorrect phrases because of incorrect word</th>
</tr>
</thead>
<tbody>
<tr>
<td>One orbit left</td>
</tr>
<tr>
<td>Resume own navigation</td>
</tr>
<tr>
<td>Expedite climb</td>
</tr>
<tr>
<td>Unable to comply</td>
</tr>
<tr>
<td>Revert to flight plan call sign</td>
</tr>
<tr>
<td>Traffic in sight</td>
</tr>
<tr>
<td>Caution work in progress</td>
</tr>
<tr>
<td>Runway damp</td>
</tr>
<tr>
<td>Ruts and ridges</td>
</tr>
<tr>
<td>Cruise climb between (levels)</td>
</tr>
<tr>
<td>Commence approach</td>
</tr>
<tr>
<td>Start up at own discretion</td>
</tr>
<tr>
<td>Request time check</td>
</tr>
</tbody>
</table>

The reason for not following the exactness of the phrase is again the use of words that students know from general English knowledge, or complete skipping. In particular, words such as commence, comply, revert, orbit, expedite, and discretion are the most common mistake (Table 2).
3.2. Grammar

We cannot deny the importance of the grammatical form of the word in English professional aviation terminology for a correct understanding and safety. Rather than ignorance of grammar, students, especially in oral communication, in speed training and readiness to use phrases, are unaware of the difference of some verbal forms, and they change the word or omit the preposition (Table 3).

<table>
<thead>
<tr>
<th>Correct phrase</th>
<th>Incorrect phrase</th>
<th>% of errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Report starting acceleration</td>
<td>Reporting start acceleration</td>
<td>2%</td>
</tr>
<tr>
<td>Expedite climb</td>
<td>Expedite climbing</td>
<td>16%</td>
</tr>
<tr>
<td>Resume position reporting</td>
<td>Resume report position</td>
<td>12%</td>
</tr>
<tr>
<td>Advise if able to cross</td>
<td>Advise to cross</td>
<td>5%</td>
</tr>
<tr>
<td>Revised expected approach</td>
<td>Revised expecting approach</td>
<td>21%</td>
</tr>
<tr>
<td>Make short approach</td>
<td>Making short approach</td>
<td>3%</td>
</tr>
<tr>
<td>Transmit for identification</td>
<td>Transmit identification</td>
<td>23%</td>
</tr>
</tbody>
</table>

The forms of words with the suffixes -ed and -ing students often confused or add in words where they are not needed. From the point of view of grammar, the simple phrase Transmit for identification requires attention in training due to the use of a preposition for. The student must be aware of the difference between the individual grammar patterns and the mistakes they make in the training to understand the correctness of the used phrase especially in the fast communication. Student pilots and ATC in the simulator and real training should no longer make mistakes of this kind.

3.3. Pronunciation

The similarity of the pronunciation of some words causes oral misunderstanding and unnecessary requests to repeat a phrase or explain it. It is a delay that can cause a serious incident in real communication. It is in the training where it is necessary to pay attention to the accuracy of pronunciation and to prevent any mispronunciation, miscommunication in the future (Table 4).

<table>
<thead>
<tr>
<th>Correct word</th>
<th>Pronounced like...</th>
<th>% of errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>beacon</td>
<td>bacon</td>
<td>5%</td>
</tr>
<tr>
<td>bearing</td>
<td>boring</td>
<td>3%</td>
</tr>
<tr>
<td>heading</td>
<td>heating</td>
<td>17%</td>
</tr>
<tr>
<td>lighting</td>
<td>lightning</td>
<td>12%</td>
</tr>
</tbody>
</table>

The similarity of pronunciation of words like lightning, heading and heating, and the difference in importance, students have to train through frequent repetitions and training. These pronunciation errors are often repeated in the oral examination.

3.4. Word Order

Errors in words appear mainly in longer phrases. Often they do not make a fundamental change of meaning, but they disrupt the accuracy of the standardized phrases, and in some cases they can also cause a change of meaning and misunderstanding.

<table>
<thead>
<tr>
<th>Correct word order</th>
<th>Incorrect word order</th>
<th>% of errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic right 2 o’clock same level converging</td>
<td>Traffic right 2 o’clock converging same level</td>
<td>6%</td>
</tr>
<tr>
<td>Frequency change approved</td>
<td>Approved frequency change</td>
<td>32%</td>
</tr>
<tr>
<td>Secondary power supply not available</td>
<td>Not available secondary power supply</td>
<td>4%</td>
</tr>
<tr>
<td>Request detailed taxi instruction</td>
<td>Detailed taxi instruction request</td>
<td>2%</td>
</tr>
<tr>
<td>Cleared to land runway B</td>
<td>Runway B cleared to land</td>
<td>8%</td>
</tr>
<tr>
<td>Execute instructions immediately upon receipt</td>
<td>Immediately execute instructions according to advise</td>
<td>28%</td>
</tr>
</tbody>
</table>

Increased attention in training requires longer phrases not only from the point of view of vocabulary, but also
from the use of the correct expression. The biggest problem for students was the phrase "Execute instructions immediately upon receipt, where we recorded up to 28% of errors (Table 5).

4. Conclusions

Of the many factors involved in the process of communication, phraseology is perhaps the most important, because it enables us to communicate quickly and effectively despite differences in language and reduces the opportunity for misunderstanding.

Standard phraseology reduces the risk that a message will be misunderstood and aids the read-back/hear-back process so that any error is quickly detected. Ambiguous or non-standard phraseology is a frequent causal or contributory factor in aircraft accidents and incidents. Failure to use standard phraseology can lead to misunderstanding, breakdown of the communication process and eventually to loss of separation.

For oral and written testing, standardized phrases were used, which pilots and ATCs must operate accurately, reliably, readily, quickly, with the correct pronunciation and agreed standardized phrases. Students come from secondary schools where General English is taught, and Aviation English classes at university are their first encounter with standardized aviation phrases. From the studies of the students, we have found out that mistakes appear in all language skills. It is therefore important for students to master thoroughly vocabulary, structure, grammar, vocabulary and phrases in the professional English lessons, and to avoid sometimes serious mistakes that are long-term fixed in memory and could interfere with safety of air traffic.

References

2. ICAO Phraseology Reference Guide ALL CLEAR AGC safety initiative.
Vibro Acoustic Measurement at Sea: How Predictable Are Motor Failure by Means of Vibration Measurement?

R. Klaucans

Institute of Aeronautics, Riga Technical University, Kālļu street 1, Latvia, E-mail: rauls72@gmail.com

Abstract

Vibration problems in induction motors can be frustrating and may lead to greatly reduced reliability. It can vary from a mere nuisance to an indication of imminent motor failure. With solid knowledge of motor fundamentals and proper diagnostic procedures of vibration analysis, it is possible to identify and pinpoint the root cause of the problem, and more significantly correct, or ascertain the impact of increased vibration on motor reliability and longevity. Hereby below described research will monitor and analyse centrifugal pump and electric motor vibration signal evaluation as overall velocity, high resolution velocity, shock pulse and bearing envelope measurements change for period more than one year. Task was based to discover how precise is our measurement techniques and how early we are warned about future damage to happen.

KEY WORDS: vibration; vibscanner; bearing characteristic frequencies; vibration velocity; shock pulse measurement; vibration displacement; vibration acceleration

1. Introduction

Vibration and its measurement is ongoing important and complex subject. Continually extended knowledge and experience based on progress in diagnostic and analytical tools or methods. For this reason, it is worthwhile periodically to present any new methods as well as to review prior knowledge. Vibration can occur at any time in the installation and root cause of it should be eliminated immediately to prevent further damage of equipment. The proper diagnostic test and measurement analysis will indicate true source of the problem as many work has been carried out in past to make it easy separate different causes. However, it is still unclear how fast we should react or how fast problem can evolve and are there any correspondence or it is merely a coincidence? This research outlines the current vibration amplitudes and frequencies as measured from the listed machinery. It highlights with concern or problem and is intended as an aid to maintenance and not a replacement for any scheduled maintenance procedures [2-5, 7-8].

Table 1: Vibration standard(s) used [9]

<table>
<thead>
<tr>
<th>DIN ISO 10816-3</th>
<th>Group 1</th>
<th>Group 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine type</td>
<td>Large machines 300 kW &lt; P &lt; 50 MW</td>
<td>Medium sized machines 15 kW &lt; P &lt; 300 kW</td>
</tr>
<tr>
<td>Foundation</td>
<td>flexible</td>
<td>rigid</td>
</tr>
<tr>
<td>Velocity $v_{rms}$</td>
<td>11,0 mm/s</td>
<td>7,1 mm/s</td>
</tr>
<tr>
<td>50 Hz &gt; 100 Hz</td>
<td>10 &gt; 600 Hz</td>
<td>10 &gt; 600 Hz</td>
</tr>
<tr>
<td>5 Hz &gt; 600 Hz</td>
<td>10 &gt; 600 Hz</td>
<td>10 &gt; 600 Hz</td>
</tr>
<tr>
<td>2 Hz &gt; 600 Hz</td>
<td>10 &gt; 600 Hz</td>
<td>10 &gt; 600 Hz</td>
</tr>
<tr>
<td>1 Hz &gt; 600 Hz</td>
<td>10 &gt; 600 Hz</td>
<td>10 &gt; 600 Hz</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DIN ISO 10816-7</th>
<th>Category 1</th>
<th>Category 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump type</td>
<td>Rotodynamic pumps with high reliability, availability or security requirements.</td>
<td>Rotodynamic pumps for general or less critical applications.</td>
</tr>
<tr>
<td>Power</td>
<td>&lt; 200 kW &gt; 200 kW</td>
<td>&lt; 200 kW &gt; 200 kW</td>
</tr>
<tr>
<td>Velocity $v_{rms}$</td>
<td>7,0 mm/s</td>
<td>9,5 mm/s</td>
</tr>
<tr>
<td>10 Hz &gt; 600 Hz</td>
<td>10 &gt; 600 Hz</td>
<td>10 &gt; 600 Hz</td>
</tr>
<tr>
<td>5 Hz &gt; 600 Hz</td>
<td>10 &gt; 600 Hz</td>
<td>10 &gt; 600 Hz</td>
</tr>
<tr>
<td>2 Hz &gt; 600 Hz</td>
<td>10 &gt; 600 Hz</td>
<td>10 &gt; 600 Hz</td>
</tr>
<tr>
<td>1 Hz &gt; 600 Hz</td>
<td>10 &gt; 600 Hz</td>
<td>10 &gt; 600 Hz</td>
</tr>
</tbody>
</table>

By returning to the root of defect indication, we can assume that noise of electric motor bearing defect heard by human ear can be set as critical and imminent when motor failure can occur. At this point immediate electric motor overhaul are required (in our case, critical measurement dated: 19.01.2018). Here we compare first fixed measurement above alarm point setting Table 1 [9] (as per ISO 10816-3 and ISO 10816-7) with one year time period until audible intelligible sound was registered.
2. Methodology

Test Object
Centrifugal pump electric motor (Fig. 1): Nom. Rev. – 3515rpm, Real rev. – 3565rpm, Current – 33.5Amp, Power – 21.4kW, bearing in use: 2 X SKF 6309 2ZC3 (Single row deep groove, two side metal shield, radial clearance larger than normal), 45mm I.D, 100mm O.D

Vibration main Source
Bearing SKF 6309 2ZC3 (Single row deep Groove, Two sided metal shielded, Radial clearance larger than normal) (Table 2).

Table 2

<table>
<thead>
<tr>
<th>SKF bearing reference data [10]</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Measuring equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibscanner VIB 5.400Ex; S.N.51541/2016. Manufacturer: Pruftechnik AG (Fig. 2).</td>
</tr>
</tbody>
</table>

Centrifugal pump electric motor condition has been analysed at period as per below Table 3.
Table 3

<table>
<thead>
<tr>
<th>No.</th>
<th>Date</th>
<th>Motor working hours</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>05.01.2017</td>
<td>45126</td>
<td>First measurement (First time alarm limit reached)</td>
</tr>
<tr>
<td>2.</td>
<td>30.07.2017</td>
<td>47225</td>
<td>Middle measurement</td>
</tr>
<tr>
<td>3.</td>
<td>19.01.2018</td>
<td>48960</td>
<td>Acoustic noise identified measurement (critical condition)</td>
</tr>
<tr>
<td>4.</td>
<td>22.02.2018</td>
<td>49224</td>
<td>After overhaul measurement. New bearing installed.</td>
</tr>
</tbody>
</table>

Motor first 60Month / 20.000Hrs overhaul with bearing renewal carried out 22.11.2011 at 19913wHrs.

OMNITREND calculates roller bearing characteristic frequencies from the bearing geometric data that are entered in the Frequency Editor. The geometric data can be found in the manufacturer catalog. Structure and content of a file with bearing characteristic frequencies see below (Table 4).

Table 4

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Bearing No</th>
<th>Inner race speed</th>
<th>Inner race pass (Hz)</th>
<th>outer race pass (Hz)</th>
<th>Roll. elem. pass (Hz)</th>
<th>Cage rotation (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SKF</td>
<td>6309</td>
<td>1000</td>
<td>82,767</td>
<td>50,567</td>
<td>65,017</td>
<td>6,317</td>
</tr>
</tbody>
</table>

By utilizing the proper data collection and analysis techniques, the true source of vibration can be discovered. This includes, but is not limited to: Electric imbalance; Mechanical unbalance – motor coupling, or drive; Mechanical effects – base, driven equipment, misalignment, etc.; Resonance, critical speed etc.. In our case source of vibration is electric motor top bearing defect.

This paper provides analytical approach for understanding and analyse of vibration data within period and early discovery of problem.

Define measurement points (Fig. 4).

Housing vibration obtained with magnetically mounted accelerometer. Vibration measurements obtained with the motor operating under the following conditions: Loaded, Coupled, Full voltage, all conditions stabilized (i.e. normal operation conditions: constant speed, stable discharge pressure of media).

Before we can proceed to the measurements the Database structure to be set as per example below used for our tests (Fig. 5).

Fig. 4 Measurement point location [9]

Fig. 5 Pruftechnik AG Omnitrend database structure set for task [9]
When database measurement is setup, it is very important to define right values. At Omnitrend it can be chose as per below list (Fig. 6).

**3. Measurement and Results**

Task chosen and values measured for the measuring point (MOH – motor outer horizontal) giving highest signal values indicating the worst bearing condition:

1. **101. Overall velocity >600** (indicate if we got problem);
2. **1004. Hi Resolution velocity 60K/6400: Unbalance / Misalignment / Looseness** (give answer what problem is);
3. **106. Shock pulse m.>120** (indicate if we have problem with bearing);
4. **1005. VSC R.b.env. 60K/6400** “Acceleration enveloping” is globally recognised as an immensely powerful method to detect bearing wear and bearing damage (answer what is the bearing problem).

Now that the mechanical source of vibration is understood, it is time to establish a systematic approach to measurements.

Vibration can be measured in units of displacement (peak to peak, mils), units of velocity (zero to peak, mils per second), or units of acceleration (zero to peak, g’s). Acceleration emphasizes high frequencies, displacement emphasizes low frequencies, and a velocity gives equal emphasis to all frequencies. This relationship better illustrated in Fig. 7 where comparison of vibration amplitudes are expressed in acceleration, velocity, and displacement.

Data trend collected and extracted from vibscanner as per below.

**Path of Location:** NMM\Stena Perros\1 MONTHLY\ENGINE ROOM\FW GENERATOR EJECTOR

**PUMP MOTOR MOH 101 Overall velocity >600**

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Zero-Peak</th>
<th>Peak-Peak</th>
<th>RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>04.01.2017</td>
<td>18:09:58</td>
<td>21,16 mm/s</td>
<td>42,31 mm/s</td>
<td>8,46 mm/s</td>
</tr>
<tr>
<td>05.01.2017</td>
<td>13:31:04</td>
<td>16,58 mm/s</td>
<td>33,16 mm/s</td>
<td>9,68 mm/s</td>
</tr>
<tr>
<td>05.01.2017</td>
<td>19:36:22</td>
<td>14,95 mm/s</td>
<td>29,89 mm/s</td>
<td>9,19 mm/s</td>
</tr>
<tr>
<td>30.07.2017</td>
<td>10:22:44</td>
<td>14,07 mm/s</td>
<td>28,14 mm/s</td>
<td>7,42 mm/s</td>
</tr>
<tr>
<td>19.01.2018</td>
<td>17:47:08</td>
<td>30,43 mm/s</td>
<td>60,86 mm/s</td>
<td>14,85 mm/s</td>
</tr>
<tr>
<td>22.02.2018</td>
<td>17:21:10</td>
<td>7,71 mm/s</td>
<td>15,41 mm/s</td>
<td>2,79 mm/s</td>
</tr>
</tbody>
</table>

**PUMP MOTOR MOH 1004 Hi Res Vel 60K/6400 UNBALANCE/MISALIGNMENT/LOOSENESS**

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Meas. Value UNBALANCE</th>
<th>Meas. Value MISALIGNMENT</th>
<th>Meas. Value LOOSENESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>04.01.2017</td>
<td>18:10:30</td>
<td>18:10:300,96 mm/s</td>
<td>18:10:300,12 mm/s</td>
<td>18:10:301,56 mm/s</td>
</tr>
<tr>
<td>05.01.2017</td>
<td>19:36:50</td>
<td>19:36:500,89 mm/s</td>
<td>19:36:500,21 mm/s</td>
<td>19:36:500,04 mm/s</td>
</tr>
<tr>
<td>22.02.2018</td>
<td>17:21:10</td>
<td>17:21:100,05 mm/s</td>
<td>17:21:100,23 mm/s</td>
<td>17:21:100,16 mm/s</td>
</tr>
</tbody>
</table>
For more easy data visual analyse displayed graphs used as per below:
Where possible I have made spectral graphs on the same vertical and horizontal scales (Figs. 8-11).

Fig. 8 MOTOR\MOH\101 Overall velocity > 600

Here we can see that all Overall velocity readings before motor overhaul are above ISO 10816-3 Alarm zone [Table 1, [9]] at \( v > 7 \text{mm/s} \). After motor overhaul it is in 2,79 mm/s zone.

Fig. 9 MOTOR\MOH\106 Shock pulse \( m. > 120 \)

Fig. 9 Shock pulse \( m. > 120 \) indicate that on 19.01.2018 carpet and max values have increased to above the alarm thresholds what means that there is clear problem with outer end bearing. Further this problem are analysed by 1005 VSC R.b.env. 60K6400 data collection.

Fig. 10 MOTOR\MOH\1005 VSC R.b.env. 60K6400 for all dates - 3D graph
At Fig. 11 1005 VSC R.b.env. 60K6400 reference lines added for FTF – Fundamental train frequency (22.20Hz), BPFO – Ball pass frequency outer race (177.74Hz), 2xBSF – Ball spin frequency (228.53Hz), BPFI – Ball pass frequency inner race (290.92Hz). BPFI max value pike is exactly align as per SKF6309 bearing data [10]. These visual markers help us identify particular cause of vibration at particular frequency.

4. Conclusion

Vibration problems can vary however this example highlights early prediction possibility for future breakdown of equipment. From other point industry still need more precise timing when evaluate condition and remaining time period till imminent breakdown of equipment. That means that different vibration sources should be evaluated by different algorithms.

It was observed, that, at constant real time electric motor condition monitoring it is possible to prolong installation work period per 50% if compare with time based maintenance. The factor limiting the vibration limits at these levels is the motor bearings. The obtained results show that real trip limits can be safely set at 10% above the Industry alarm limits.

As additional advice for industry I would like to point that sound measurements [1] can provide valuable clues about a motor and overall equipment condition. Future sound monitoring technique improvement as on database set online sound monitoring and analyse (comparison between noise change) systems can be used as alarm trigger for future alarm and monitoring systems in different industries.

References

8. CM-P1-11604-14-EN-Vibration-Sensor-Catalog, PUB CM/P1 11604-14 EN April 2016
9. Pruftechnik OMNITREND and VIBEXPERT manuals download at www.pruftechnik.com
Non Destructive Testing in the Case of Aircraft Wheel Overhaul

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Abstract

In the aircraft maintenance program, especially in the case of aircraft wheel overhaul, it is important to examine the mechanical damages such as cracks, corrosion and some other surface irregularities and evaluate the extent of repair work. But within finite time of maintenance procedure, it is difficult to find the defects rapidly. During aircraft and its component’s maintenance ‘NON DESTRUCTIVE TESTING’ (NDT) is the most effective way of performing inspection and discovering defects. In simply It can be told, NDT detects cracks and other irregularities in the airframe structure, wheels, engine components which are clearly not visible to the unclad eye. Structure and assembly of aircraft wheel are made from various materials, such as aluminium, steel, magnesium, and composite materials. To dismantle the aircraft wheel assembly in pieces and then analyze each of the components would take a long period, so the NDT method and the selection of equipment must be fast and effective.

KEY WORDS: active suspension, damping

1. Introduction

Safety and reliability in aircraft systems and performance are the main concern of rising importance, especially due to the sophisticated and modern maintenance and inspection technologies. Reliability comes through improving the quality or quality level of the components or products [1].

The main goals of aircraft maintenance and inspection technologies have been to efficiently correct defects and avert failures. NDT is the most useful technology for evaluating the soundness and acceptability of an actual component without spoiling functional properties of it. Non-destructive Testing is exactly what its name indicates for an instance, a procedure of testing without destroying. NDT is an analysis of an object or material in a way which will not spoil its future functionality. NDT is the use of technology for examining the materials according to known standards. For, Non-Destructive Testing do not in any way damaging the serviceability of the part or any component which is being inspected, therefore these can be applied, if desired, on all kinds of the units produced. Consequently, greater reliability in the production and the maintenance can be achieved. There are a number of NDT methods applicable for the maintenance of the aircrafts. In this project work, my major concerns are on the maintenance techniques and/or NDT techniques which are applicable for aircraft wheel overhaul and the factors affecting on the sensitivity of the crack detection and the solutions. During the operation of the Aircraft wheels are subject to vast stress and heat during take-off and landing, that generated some irregularities on its surface. The Aircraft wheels are made from a single piece of the materials such as aluminium, steel, magnesium and so on by the casting process, so we should have to focus on surface discontinuities on aircraft wheels. It is not necessary to focus on volumetric inspection, integrity or any welded part inspection. As the aircraft wheels are made by the casting process and there are not a weld on them, that mean we assume them as a single piece. Thus, we should focus on surface flaws only.

The techniques which are applicable for surface discontinuities on aircraft wheels are Liquid Penetrant Inspection, Magnetic Particle Inspection and Eddy Current Inspection.

2. Aircraft Maintenance

Aircraft maintenance is the overhaul, repair, inspection or modification of an aircraft or aircraft component [2]. It is the process of ensuring that a system regularly performs its deliberate function at its designed-in level of safety and reliability.
Aircraft Maintenance is purposive to be keeping the aircraft in a state which will or has enabled a certificate of release to service to be issued. Maintenance may incorporate such tasks as ensuring concurrence with Airworthiness prescriptions or Service reports. The maintenance of aircraft is highly synchronized, in order to ensure the precise and safe functioning during flight. National regulations are synchronized under international standards, maintained by bodies such as the International Civil Aviation Organization (ICAO). The maintenance tasks, personnel and inspections are all firmly regulated and staff must be licensed for the tasks they accomplish.

NDT is defined as or/and the part of scheduled maintenance. In addition, it is similar to the line maintenance and some similarities have been seen in shop maintenance, line Maintenance should be understood as “any maintenance that is carried out before the flight to ensure that the aircraft is fit for the intended flight.” [3]. This would typically include pre-flight checks, daily checks, failure rectification as well as minor, scheduled maintenance tasks as follows. The shop maintenance covers maintenance on components when removed from aircraft, e.g. engines, APU, wheels, brakes. Sometimes this is carried out within the same organization as the heavy maintenance, but sometimes special companies carry out this work separately.

3. Non-Destructive Testing

Non-destructive testing plays an important role in the quality control of a product [4]. Non-destructive testing (NDT) is the use of noninvasive techniques to determine the integrity of a material, component or structure or quantitatively measure some characteristics of an object. It is the testing of materials, for surface or internal flaws or metallurgical condition, without interfering in any way with the integrity of the material or its suitability for service. We can say that Nondestructive testing (NDT) is a wide group of analytical techniques used in science and technology industry to evaluate the properties of a material, component or system without causing damage. The terms nondestructive examination (NDE), nondestructive inspection (NDI), and nondestructive evaluation (NDE) are also commonly used to describe these technologies. It is a highly valuable technique that can save both money and time in product evaluation, troubleshooting, and research. NDT Surface Examination Techniques and Their Applications are shown in Table 1.

<table>
<thead>
<tr>
<th>NDT Techniques</th>
<th>Applications</th>
<th>Material that can be inspected</th>
<th>Flaws that can be inspected</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Liquid Penetrant</strong></td>
<td>Surface-breaking defects in all non-porous materials.</td>
<td>Metals (aluminum, copper, steel, titanium, etc.)</td>
<td>Fatigue cracks</td>
</tr>
<tr>
<td>Inspection</td>
<td></td>
<td></td>
<td>Porosity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Laps</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Glass</td>
<td>Quench cracks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Many ceramic materials</td>
<td>Grinding cracks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rubber</td>
<td>Seams</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plastics</td>
<td>Overload and impact fractures</td>
</tr>
<tr>
<td><strong>Magnetic Particle</strong></td>
<td>Surface and slightly subsurface discontinuities in ferromagnetic materials.</td>
<td><strong>Ferromagnetic materials:</strong></td>
<td>Fatigue Cracks</td>
</tr>
<tr>
<td><strong>Inspection</strong></td>
<td></td>
<td>Iron, Nickel, Cobalt alloys, Precipitation hardening steels.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Splits</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Diamagnetic materials:</strong></td>
<td>Seams</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Copper, silver, and gold</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>It is applicable for smaller components of the Aircraft wheel such as screws, nut, bolts, washers, bearings and so on.</td>
<td>Voids that forms when the metal ruptures</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Paramagnetic materials:</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oxygen, Magnesium, Lithium, Molybdenum.</td>
<td></td>
</tr>
<tr>
<td><strong>Eddy current</strong></td>
<td>Surface, Subsurface defects (depending on conductivity)</td>
<td></td>
<td>Fatigue Crack Corrosion</td>
</tr>
<tr>
<td><strong>Inspection</strong></td>
<td>Deepness of the crack</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Can able to detect without removing paint on Aircraft wheel</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Results, Comparisons and Conclusions From the Experiments

• Issue no.1: The nature of the defects and the factors affecting on the sensitivity of the Liquid Penetrant
Inspection method

- The sensitivity is defined as the smallest defect that can be detected with a high degree of reliability.

The different factors which affect on the sensitivity of the inspection by LPI method during Aircraft wheel maintenance are shown in the table as following.

<table>
<thead>
<tr>
<th>No.</th>
<th>Higher Sensitivity</th>
<th>Lower sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Small round defects</td>
<td>Small linear defects.</td>
</tr>
<tr>
<td>2</td>
<td>Deeper flaws</td>
<td>Shallow flaws.</td>
</tr>
<tr>
<td>3</td>
<td>Flaws with a narrow opening at the surface</td>
<td>wide open flaws at the surface</td>
</tr>
<tr>
<td>4</td>
<td>Flaws on smooth surfaces</td>
<td>Flaws on rough surfaces</td>
</tr>
<tr>
<td>5</td>
<td>Hydrophilic Surface</td>
<td>Hydrophobic Surface</td>
</tr>
<tr>
<td>6</td>
<td>The developers with good adhesiveness and wetability</td>
<td>The developers with poor adhesiveness and wetability</td>
</tr>
<tr>
<td>7</td>
<td>Inspection with removing the paint from the surface</td>
<td>Inspection without removing the paint from the surface</td>
</tr>
</tbody>
</table>

Solution.1: Choice of the developer with good wetting ability

- Hydrophobic Surface (Fig. 1)
  - High contact angle $\theta$.
  - Poor adhesiveness and wet-ability.
  - Low solid surface free energy.
- Hydrophilic Surface (Fig. 1)
  - Low contact angle $\theta$.
  - Good adhesiveness and wet-ability.
  - High solid surface free energy.

Solution.2: Choice of the good penetrants

- Fluorescent penetrant systems are more sensitive than visible penetrant systems because the eye is allured to the glow of the fluorescing indication. In contrast, visible penetrants do not require a darkened area and an ultraviolet light.

Solution.3: Choice of the good penetrant removers

Emulsifiers (Hydrophilic) represent the highest sensitivity level, and chemically interact with the oily penetrant to make it removable with a water spray. As a characteristic of hydrophilic surface of the emulsifies, they are more sensitive with the penetrants.

Issue no.2: The nature of the defects and the factors affecting on the sensitivity of the Eddy Current Inspection method (Fig. 2)

- As we discussed above the higher frequency range of an eddy current is familiar with the surface cracks
because the eddy current density is much higher at the surface of the test piece. But, eddy current density decreases exponentially with depth so, the higher frequency is no good to examine the subsurface cracks, it needs the lower frequency range.

- The equipment with single frequency is no essential to solve this problem even it has higher frequency range or lower.

**Solution.1: Multi Frequencies Equipment**

The best solution of the problem which mentioned above is to use multi frequencies equipment. Sweeping through multiple frequencies helps to optimize results, or utilizing multiple probes to obtain the best resolution and penetration required to detect all possible flaws.

**Solution.2: PEC (Pulsed Eddy Current) Instrument, as a multi frequencies equipment**

The most essential benefit of Pulsed Eddy Current is that, when it compared to single frequency Eddy Current Testing, it typically has a broadband of frequencies, which is advantageous for any eddy-current based NDT techniques due to the frequency-dependant skin effect.

The main benefit of Pulsed Eddy Current method over conventional eddy current method is that it holds a continuum of frequencies. Due to this, it is possible to estimate the electromagnetic response to several different frequencies can with just a single step. Information from a range of depths can be acquired all at once.

**Solution.3: Use HTS SQUID Gradiometer Sensor**

Superconducting Quantum Interference Device (SQUID) (Fig. 3) is the most sensitive magnetic field sensor well known nowadays. SQUID systems provide a high sensitivity at low excitation frequencies, allowing quantitative assessment of magnetic field maps from the investigated structure, allowing the detection of deeper flaws, and a high linearity.

![Fig. 3 Sketch of an Aircraft wheel, with typical crack positions and Automated aircraft wheel testing unit, with the SQUID mounted on a robot, during operation respectively](image)

- Today, the Aircraft wheels are inspected from the outside with a circumferential scan, measurement, after taking off the tires. Deep flaws are detected with the using of low frequency eddy current testing probe. However, the sensitivity is limited to large flaws: describe as flaws with 40% wall penetration from the inside and of length twice the wall thickness can be shown reliably. In order to safely detect small hidden defects, the Aircraft wheel has to be disassembled and be inspected from the inside. The prototype of the SQUID system for Aircraft wheel testing consists of an automated test stand with the wheel slowly rotating and a robot with the SQUID equipment scanning stepwise along the wheel axis. While the Aircraft wheel is turning, the robot moves the cryostat along its outer contour. Thus, a two-dimensional eddy current mapping of the outer surface of wheel is performed.

**Issue no.3: The nature of the defects and the factors affecting on the sensitivity of the Magnetic Particles** (Fig. 4 and 5)

**Inspection method**

**Discussion and Solutions:**

- The most conclusive in contrast and visibility is achieved by coating the magnetic particles with a fluorescent pigment (typically available in wet method materials only).

- The equipment used in wet testing can easily spray a uniform layer of particles over the entire surface of the component being inspected, even if the area is large.

- The liquid carrier offers mobility to the particles for an extended period, which permits sufficient particles to float to small leakage fields to form a visible indication.

![Fig. 4 Different magnetic particles cases](image)

- The dry powder is usually more sensitive for subsurface defects. The dry powder method is better for situating defects lying wholly below the surface because of the high permeability and the favorable elongated shape.
of the dry particles.

- The **wet method** is typically best for very fine and **shallow defects**.

![Molecular bondings of different magnetic particles](image)

**Fig. 5 Molecular bondings of different magnetic particles**

<table>
<thead>
<tr>
<th>Sr.</th>
<th>Defect</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Porosity</td>
<td>Spherical surface signs</td>
</tr>
<tr>
<td>B</td>
<td>Casting Cold Shut</td>
<td>Dotted lines signs</td>
</tr>
<tr>
<td>C</td>
<td>Cracks</td>
<td>Straight continuous surface lines</td>
</tr>
<tr>
<td>D</td>
<td>Thermal cracks</td>
<td>Interconnecting lines</td>
</tr>
<tr>
<td>E</td>
<td>Heat treat Cracks</td>
<td>Multiple irregular lines signs</td>
</tr>
<tr>
<td>F</td>
<td>Fatigue cracks</td>
<td>Continues line in components</td>
</tr>
<tr>
<td>G</td>
<td>Grinding cracks</td>
<td>Signs with interconnecting X lines</td>
</tr>
<tr>
<td>H</td>
<td>Quench cracks</td>
<td>Continuous interconnecting surface lines</td>
</tr>
<tr>
<td>I</td>
<td>Seams</td>
<td>Straight line on edges</td>
</tr>
</tbody>
</table>

**Table 3**

Interpretation of Cracks (Fig. 6) and their descriptions presented in Table 3

![Interpretation of Cracks](image)

**Fig. 6 Interpretation of Cracks**

The analysis of considered Non-destructive testing methods

<table>
<thead>
<tr>
<th>Applications</th>
<th>Liquid Penetrant Inspection</th>
<th>Magnetic Particles Inspection</th>
<th>Eddy Current Inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective on Coatings/Paints</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Computerized record keeping</td>
<td>NO</td>
<td>NO</td>
<td>PARTIAL</td>
</tr>
<tr>
<td>3D/Advanced imaging</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Time require for periccular operation</td>
<td>HIGH</td>
<td>HIGH</td>
<td>LOW</td>
</tr>
<tr>
<td>User Dependence</td>
<td>HIGH</td>
<td>HIGH</td>
<td>HIGH</td>
</tr>
<tr>
<td>Cleaning</td>
<td>YES</td>
<td>YES</td>
<td>APPLICATION SPECIFIC</td>
</tr>
<tr>
<td>Post-inspection Analysis</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Chemicals/Consumables</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Size of the flaw/crack</td>
<td>Not assign</td>
<td>Not assign</td>
<td>Assign</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>Higher</td>
<td>Higher</td>
<td>Highest</td>
</tr>
<tr>
<td>Suitability for types of cracks</td>
<td>Only surface flaws</td>
<td>Both surface and sub-surface flaws</td>
<td>Both surface and sub-surface flaws</td>
</tr>
</tbody>
</table>

**Table 4**
5. Conclusions

The Aerospace industry is leading in the world for innovation in maintenance techniques and diagnostic techniques regularly to improve safety, reliability and reduce cost. Simultaneously, the inspection techniques (diagnostic techniques) are also being developed to monitor their integrity. The surface inspection techniques are being developed with great sensitivity. For instance, in the case of Liquid Penetrant Inspection technique, choice of good developers, penetrants and remover shows higher visibility and sensitivity, the prototype of the SQUID system for Aircraft wheel testing consists of an automated test with higher sensitivity (Eddy Current Inspection) and the wet magnetic particle testing method is more sensitive for detection of surface flaws such as fatigue cracks (Magnetic Particle Testing).

The following sentences depict conclusive results of this article.
- NDT improves and controls manufacturing processes.
- Inspect complex shapes and sizes of conductive materials.
- The defect indication has a high visual contrast.
- Equipments for inspection are very portable and the cost of the testing is very low.
- LPI method is most commonly use in the Aircraft wheel overhaul.
- Flaw detection, Leak detection, Location determination and orientation of the defects.
- Safety is required from UV rays and Chemical reaction from the penetrants materials.
- Minimum part preparation is required for all these NDT inspection techniques.
- Magnetic particle inspection is one of the fastest methods of inspection and an indication is visible directly on the specimen surface.
- For both surface flaws and sub-surface flaws, the Eddy Current Inspection and Magnetic Particle Inspection are more suitable than Liquid Penetrant inspection.
- Pulsed Eddy Current has a broad band of frequencies, which is advantageous for any eddy-current based NDT techniques due to the frequency-dependent skin effect. The Pulsed Eddy Current method can be done without the requirement of contact with the surface of the material.

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Prognose the Amount of Discount Tickets Before the Sale

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Abstract

This article is focused on simple estimation of the number of tickets that can be offered to passengers at discounted prices, so that it is still cost-effective for the airline considering operating costs. Using simple modeling calculations on sample examples, an estimate of ticket prices in the pricing process was calculated, useful especially for small airlines that need at least a brief overview of initial pricing options.

KEY WORDS: revenue management, pricing, marketing, sale, flight tickets

1. Introduction

We can simplify revenue management in the area of ticket sales defined as streamlined sales within dynamic pricing. It encompasses a number of activities that lead to dynamic pricing and the highest profitability of sales.

Some authors understand income management and yield management as identical concepts that we can define as managing pricing and plane ticket sales in an effort to offer potential passengers the right service for the right price at the right time. We could confuse these two terms as synonyms, but reputable authors see the difference between yield management and revenue management [1-5].

It is reported that yield management can be understood as managing the capacity of an aircraft, load factor - includes the effort to sell as many airplane tickets per flight as possible. Revenue Management is revenue of earnings- it focuses on profitability, pricing and sales efficiency.

This article discusses one of the ways how to determine the number of cheaper airplane tickets before they are put on sale based on a simple method using the Newsvendor model [6-12].

2. Applying of Revenue Management

The entire process of revenue management begins with data collection, and it is important to place emphasis on the accuracy and credibility of these data. In the internal airline system, these data collects, for example, ticket prices, competition, customer behavior and stores them. In addition to gathering data, we are getting to segment our customers, what is the other principle of applying revenue management in practice, and it is also one of the most complicated steps. At the beginning, airlines split customers into simple segments (for example, holiday and business travelers, business travelers with high price sensitivity and low price sensitive passengers, etc.). At present, however, passengers are segmented to the most relevant groups in order to better understand their buying behavior, and thus better tailor sales to the satisfaction of not only the airline, but also to the satisfaction of the passengers themselves.

Revenue management requires forecasting of various factors affecting on airplane ticket sales, such as forecasting demand or market share. Predicting is a critical role of revenue management and requires a lot of time and models to process these data. While we can predict forecasts as to how customer behavior evolves and we can estimate the market situation, optimization will tell us how the airline should react to change.

Optimization involves solving of two important issues in order to achieve the highest possible revenues. The first is determining which target function should be optimized. The airline must decide between price optimization, overall sales or other aspects. Secondly, it has to decide which optimization technique to use.

For airline companies, we must not forget about overbooking. By setting the level of overbooking correctly, airlines are better able to compensate seats cancelled at the last minute or just before departure, resulting in more efficient seats sales. On the other hand, bad decisions in overbooks can be expensive and costly. If the limits are set too low (more passengers will cancel the flight than expected), the airplane will fly out with empty seats, which is a huge loss for each airline company. An empty seat in an aircraft has no economic value, it is a loss. If the upper limit is incorrectly estimated, there may be a situation when more passengers arrive than was initially estimated, so the airline has to make offsets, which again is not an inexpensive matter. In this second situation, when more passengers arrive and
it is necessary to adapt the indemnities, there is another risk - the risk of leaving dissatisfied passengers. Loss of passenger’s favor means next additional losses, which need to be considered in overbooking models. If overbooking is to be successful, it is important to consider not only the additional revenue resulting from the offering of more flights, but also the probability of the number of canceled flights (based on historical data), the cost of passenger compensation and also on the recapture probability - that the passenger will again use the same airline (and not another, competitive). In the context of overbooking we can meet the term nesting. This approach simplifies the operation of ticket sales by automatic checking. When the seats begin to sell, the first is closed the lowest-priced airplane tickets (the lowest rated class). The highest ranked airplane tickets will be closed only when the overbooking is reached.

3. Principles of Flight Ticket Price Fluctuations

Flight ticket prices depend on many factors and each airline company has its own analysts.

The demand of passengers after the flight depends on the season, based on previous historical data, it is possible to predict the demand for the coming season. At the peak of the season, airline companies can increase their flight ticket prices, because more passengers are expected. A similar situation is repeated during public holidays and during the opening of vernissages, exhibitions and other social events. Out-of-season is an effort to increase profits at reduced prices for flight tickets, thus increasing the capacity of the airplane to fill up, and also thus increasing revenues or profits, so that the flight is ultimately not lost. Get extra ticket prices out of season can increase capacity utilization by offering lower prices for flight tickets on the same routes as those offered during the peak season. Data collected from past years then helps the manager estimate, when the peak of the season occurs. Demand for air travel is seasonal as well as time character. The peak of demand is during the summer months, the bottom of the season is in autumn, and demand also increases gradually and is more apparent until a few days before departure.

In addition to the aforementioned season, we also have to take into account the peak during the day, which we understand as the busiest hours on a given route for 24 hours. From previous statistics, the airline company could predict that the greatest demand for tickets will be in Monday's morning what we can justify that at this time of day starts working week and increase the number of business passengers for workshops. This is an opportunity for the airline company to plan higher airfares at this time, as it is a high assumption that they will be sold. A similar situation occurs on Fridays and Saturdays before noon, when a large number of travelers want to be at home during the weekend, so often have to pay interest for the ticket more. On Sunday around lunch time, the number of passengers is high because starts working weekend and some people need to be in the final destination early Monday morning.

Flight ticket fluctuations also depend on the time of their sale. Under this term, we mean the tactics of each airline company’s own, especially when the prices of airplane tickets are increasing or reducing, what is based on an estimate of customer behavior. This tactic results from long-term information gathering as well as from precise segmentation. In general, the price of the flight ticket will be higher, the closer the day of departure will be. Despite this, there are rules established airlines, they know customer behavior so well that at some point just before departure will offer a low price.

4. Sale of Cheaper Flight Tickets

During the flight tickets pricing, the airline company must pay particular attention to covering the cost of flights. Once covered, it is possible to work with all sort of variations to work with price. It is important to know how many flight tickets the airline company can sell for the full price, or also, for more expensive and how many tickets it can be offer cheaper.

At the very beginning of the ticket sales planning for a certain flight, a simple estimate based on the Newsvendor models could be enough, which is used when we need to estimate the lifecycle of products that are quickly subject to indifference or also to estimate long-term investments. The main idea is to estimate the quantity of goods offered in the case of unknown or hardly predictable demand. We can also apply this model when selling tickets.

Newsvendor model:

\[
P(f < x) \leq \frac{C_u}{C_u + C_o},
\]

where \(f\) - number of tickets for full amount; \(x\) - the number of seats reserved for the full amount; \(C_o\) - price of the ticket in the discount; \(C_u\) - lost opportunity for profit.

For example: The airline company has determined that the maximum flight ticket price will be 400 €, but six months before departure it wants to reduce the price to 250 €. Based on previous statistics, we can estimate the demand for 60 flights with a standard deviation of 10 flights. It is clear from the calculation that the airline company can offer 54 full-fare tickets if it wants to cover the costs. There are only 6 tickets that can be cheaper.

In this example, we can see how to work with the limit of the maximum flight ticket price and the lowest price of flight ticket. The advantage of applying this method in practice is the simplicity and speed of the calculation in preliminary analyzes when it is advantageous form practical form of view to first find out the possible effects of changes in the price of tickets on the profitability of the airline. This is, therefore, a rough calculation on which base a
more accurate estimation of the movement of ticket prices is then easier in the context of complex pricing issues.

5. Conclusion

Revenue management means more than just streamlining flight ticket sales. It includes an analysis of passengers thinking, comprehension of competing airlines companies, an effort to move forward in marketing, streamline the tool for price discrimination in flight ticket sales and many other aspects. It is therefore a whole set of aspects that we can uniquely call "revenue management."

When an airline company decides to actively take advantage of revenue management, it is always a long-term decision that analysts are gradually acquiring - it is necessary not only to learn basic principles and to understand the context, but also to learn to work with variables, to know the algorithms used in modeling simulations and able to read the correct outputs. The evolution of revenue management is continually advancing thanks to the capabilities of computing and the ability to connect more and more connections into a whole - decisions about pricing. Successful airline companies are constantly looking for new incentives to streamline not only revenue management but also yield management. Taking into account the complexity of ticket sales, we will get an insight into the simplicity of the simulation models.

Third-generation Revenue Management (current) evaluates historical with real-time information several times per hour to generate a prediction of total demand for a given travel class at a given time. These forecasts are then evaluated in optimization models that can calculate the recommended booking limits for the particular flight. Moreover, these optimization models also take account of historical overbooking data, so we see an optimal level of overbooking. The results are then presented as recommendations for analysts for revenue management department. These forecasts are regularly reviewed, updated automatically, and if changes are made (new flight reservations, flight cancellations, etc.), the system itself re-optimizes recommendations for analysts. So, there is a question: how can we process these processes even further?

The future could bring more sophisticated quick decision support tools that would increase the efficiency of flight ticket sales by taking even more input variables into account, in real time. American Airlines prepares a passenger decision model that works with variables such as time of departure, type of service, departure time, time between departure and arrival, ticket price and limitations. This is an attempt to automate passenger decision-making, therefore to create a simulation model of a change in demand estimate based on the above-mentioned variables when analysts will be able to better understand how demand will change when a fine for cancellation is increased or an extra baggage fee is increased. American Airlines also pays great attention to incorporating passenger choice into revenue management decision-making. Research provides estimates of how the demand will change when the passenger responds to a change in price or a new charge, or a new way of selling tickets.

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Options of Measuring the Work Performance of the Air Traffic Controller

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Abstract

In air traffic control there must be a lot of electronic systems included in one complex system, that in final helps air traffic controller to provide air navigation services at previously selected level of safety. All electronic devices used in air traffic control is highly responsible. Working with all these automatized systems is not easy and makes this job even harder. There is lot of rules and requirements that need to be apply by air traffic controller in real time to secure the air traffic flow. In last decades there was a lot of accidents, that occurred because of the human error. It means that human factor is the field where the research would be always needed. Work of the air traffic controllers is psychologically demanding and because of that, it is very important to point on possibilities of the overwork of the critical part in the transport process.

KEY WORD: air traffic control, human factor, air traffic controller, work performance, work environment, overwork

1. Introduction

This article deals with the measuring of the work performance of the air traffic controllers. Even when the technical support of the automatized systems is still developing, it is necessary to point at the possibilities of the human factor failure. Permanent growth of the air traffic is causing the regulations and requirements to be more specific. This fact could be possible risk in the case of overwork of the air traffic controllers. This article shows up the possible impact of human factor failure on the level of safety in air traffic control. In the article there is an analysis of the outer and inner factors, which effect the work performance of the air traffic controllers. The measurement was done by measuring device.

2. Performance of the Air Traffic Controllers

Human performance can be defined in several ways, and it can be also defined from many different angles. Performance is divided to physical and mental, but also to short-term and long-term. The performance of a person is mostly associated with an activity he/she performs. Extreme performance is exceptional and the reserve ability of selected individuals to reach the limit of human bio-adaptability limits. Throughout the aviation, performance is evaluated in terms of human factor, in two fundamental aspects. These are conditional upon either individual or group assumptions, or the quality of human resource management. The mentioned aspects are:

1. Efficiency and economy of the security system;
2. Satisfaction of employees.

If we want to define the performance of the workers in general, we could say, that it is a set of their features and dispositions that affects the quality of performance. In other hand, this can be explained by the workers readiness to perform as best as possible. Optimal performance means consistency between the demands of the work performed and the individual prerequisites of the workers, which is expressed by their employability, qualification, competence and positive motivation. The criteria of professionalism and competence are assessed by:

1. Results of theoretical knowledge and practical experience achieved through formal education and training;
2. The result of the verification of the actual capabilities by accredited authority;
3. Professional (security) code of conduct.

Performance of the air traffic controllers depend on whole range of circumstances, which may be short-term or long-term, subjective or objective. In case of short-term impacts, it depends on number and difficulty of each task assigned to the employee during the shift, the 24-hour day period during which they perform their work, health
conditions, specific climatic abilities, and many other factors. Long-term factors include technical, economic, organizational and social working conditions [1].

If we want to solve any of the problem of the ATC system capacity, we need to focus on the most critical part of it, air traffic controller. In the 1963 first mathematical model was assembled, that deal with load. It divides the load of air traffic controller to retail load, constant load and conflict one. Constant load relates to obligation of air traffic controller to stay at the workplace and perform activity that do not depend on the number of the controlled flights. Retail load is for usual obligation and tasks that directly depends on the on the number of the controlled aircrafts. Conflict load I sa search and a deal of conflicts. The load in this case represents squared of the number of the controlled aircrafts [2].

3. Stress in ATC

Fatigue and stress are the natural accompanying phenomena of human activity. A specific amount of stress is needed and represents even a certain level, which is an important presumption for a successful life-saving solution. Therefore, stress is divided into “favourable” stress – “eustress”, which causes the body to adapt and increase performance and “distress” that disturbs the body and reduces performance [3].

For fatigue we regard the state of the organism caused by effort, especially increased strain, which results in a relative attenuation, a negative state, which fulfils the function of protecting the organism from its damage [4]

Fatigue can take various forms. Physical (muscle) fatigue is felt because of physical effort. It manifests with reduced movement coordination, stiffness of the body, blunt pain. General fatigue arises as a result of the transfer of fatigue from one muscle group to the entire organism. Mental fatigue originates because of sensory nervous or mental overload predominantly in the mental type of work [4].

The nature of work and the organization of the work of the air traffic controller is an environment in which stress is an ongoing component. The asked demands on the controller are not small at all. They are required from them a high level of knowledge, a professional self-access and a continuous responsibility for the lives of many people and material values in the air and on the ground. Compared with other professions that we can also include in the stressful category, it is advisable to emphasize that the controller is often very time-limited. He/she is expected to make his/her decision quickly but correctly. Hundreds of human lives depend on his/her decision. Unlike pilots, the controllers are not in direct danger of life in the case of a bad decision. A pilot has the same chances as any passenger who is with him on board only with the difference that all responsibility lies on the commander of the aircraft. Controllers can be helpful in this case by preventing disaster [5].

General Adaptation Syndrome (GAS) is a mechanism which helps people to react on outer real, perceived and expected stimulus. Syndrome start excited mechanism which is controlled by autonomous nervous system (ANS) [6].

4. Analysis of Factors Affecting the Operational Performance of the Air Traffic Controllers

Air traffic controller is one of the key elements of safe flight realization. In the performance of work activities, it is influenced by many factors that directly or indirectly affect his/her work performance. We consider safe, regular, fluent and economical provision of the air traffic control services for the quality of air traffic control. The quality of work is affected by the working environment, the number of the scheduled flights, the state of health, the technical equipment of the workplace and, finally, the meteorological situation in the area of responsibility.

1. Human factor

The health status of the air traffic controller may affect work performance. In such a demanding work as air traffic control must consider not only the physical state but also the psychological state. The work of a controller is not physically active, but mentally. In this type of work, active rest is important, which is necessary to perform regularly in psych-hygiene. Any problems, whether physical or mental, play a significant role. The nature of work and the organization of the work of the air traffic controller is an environment in which stress is a natural accompanying phenomenon of human activity. A specific amount of stress is needed and represents even a certain level, which is an important presumption for a successful life-saving solution. Therefore, stress is divided into “favourable” stress – “eustress”, which causes the body to adapt and increase performance and “distress” that disturbs the body and reduces performance [3].

Fatigue can take various forms. Physical (muscle) fatigue is felt because of physical effort. It manifests with reduced movement coordination, stiffness of the body, blunt pain. General fatigue arises as a result of the transfer of fatigue from one muscle group to the entire organism. Mental fatigue originates because of sensory nervous or mental overload predominantly in the mental type of work [4].

The nature of work and the organization of the work of the air traffic controller is an environment in which stress is an ongoing component. The asked demands on the controller are not small at all. They are required from them a high level of knowledge, a professional self-access and a continuous responsibility for the lives of many people and material values in the air and on the ground. Compared with other professions that we can also include in the stressful category, it is advisable to emphasize that the controller is often very time-limited. He/she is expected to make his/her decision quickly but correctly. Hundreds of human lives depend on his/her decision. Unlike pilots, the controllers are not in direct danger of life in the case of a bad decision. A pilot has the same chances as any passenger who is with him on board only with the difference that all responsibility lies on the commander of the aircraft. Controllers can be helpful in this case by preventing disaster [5].

General Adaptation Syndrome (GAS) is a mechanism which helps people to react on outer real, perceived and expected stimulus. Syndrome start excited mechanism which is controlled by autonomous nervous system (ANS) [6].
not. An abortive attenuation affects every organism. After eating, the blood is collected in the stomach where it helps to break up food and absorb the necessary nutrients. This may result in insufficient cerebral blood flow and may lead to a late identification of a potential conflict [8, 11, 12].

2. Number of scheduled flights

The number of scheduled flights is directly proportional to the workload that is subject of the air traffic controllers. With the increasing number of scheduled flights, the workload of air traffic controllers is also increasing. However, in case of a low utilization of the airspace of the Slovak Republic, there may also be a possible failure of the human factor, due to lack of focus and inattention. Such a situation may occur in the case of a night shift where traffic is not as high as during the day. Air traffic controllers incline to overestimate their capabilities in such a situation, which may lead to potential failure. During non-standard and emergency situations, an air traffic controller is assigned under enormous pressure, when it is the first place to maintain a level of safety. Any such a situation can cause a potential disaster. All air traffic controllers must be ready to an emergency. They must have learned practices that need to be done in such situations. As such situations are rarely encountered in real-time operation, it is important that air traffic controllers periodically perform emergency training in simulators. It is necessary to react promptly to current situation. Understand the non-standard or emergency situation, we can imagine fuel leakage, engine failure or fire, chassis problem, strong frost, response failure, unlawful interference on board or loss of connection.

3. Meteorological conditions and distribution of airspace

Another important factor that needs to be discuss in analysing the operational performance of an air traffic controller is the meteorological conditions within the given area of responsibility. A bad meteorological situation can cause serious complications in air traffic control. In the airspace of the Slovak Republic there is not much space for manoeuvring and avoiding an area with storm clouds, turbulence or volcanic ash clouds. Ensuring a comfortable and still economically most advantageous way to avoid the storm clouds is a complete art. Especially when taking into account the fact that an average airplane passes our territory at a cruising level from east to west in less than 15 minutes. Decisions must be taken promptly in the light of all current circumstances. A valid list of active areas with precise conditions is available on the Internet. All controllers must be familiar with the current area of responsibility. This fact sells to each other on taking up duty [9].

4. Working environment and technical equipment

With the continuous increase in air traffic, it was necessary to improve the systems used for air traffic control. Air traffic control has moved away from its very birth by great technological advances. From the tables on which the position of the aircraft was indicated, to the most up-to-date Eurocat2000 ATC system. Eurocat provides the highest level of automation in air traffic control. Where the flights are color-coded, whether they are taken over and therefore managed or are in the pre-take-off phase. The E2000 system facilitates air traffic control. For each air object there is a label that contains the information of the target. After the implementation of secondary responders, this option has been improved. Once the relevant label is opened, it is possible to read out all important data that is automatically sent from the deck of the aircraft to the system.

The set-out of the individual systems must not affect the level control. The location of the controls should be at his/her fingertips. The control room could be customized. Every controller will adjust his/her work environment during his/her service according to his/her requirements. From the height adjustment of the seat backrest to the setting of radar information display, everything is variable. Air traffic control is a very responsible job in which no errors are acceptable and therefore it is important for the air traffic controller to feel as comfortable as possible during the service.

5. Training of air traffic controllers

Potential tenderers must be personally skilled and, of course, must be able to cope with the stresses that may occur during work, particularly regarding safety. Only a small percentage of candidates will pass to the successful end of the competition and even after being successful in the competition of air traffic controllers, there is no assurance of successful completion the training. It is precisely because of the high number of air traffic controllers-trainees, who have not completed the training despite the fulfilment of all the initial conditions that the question of the correctness of the tender procedure or the setting up of the training plan of the air traffic controllers in the Air Traffic Services of Slovak Republic is needed.

The quality of the air traffic controller's performance is of course also influenced by the quality of the training he/she has undergone. Air Traffic Control Training consists of a theoretical training that ends with tests. Subsequently, proceed to training on simulators. Beginning with exercises that instruct the controllers to learn the basis of aviation phraseology, apply the basis of flying rules and thereby ensure the safe conduct of air traffic. Subsequently, with the increasing number of exercises, the load of individual exercises extends. There are several aircraft that the controller must communicate with, as well as the number of conflicting situations in individual exercises. Subsequently passes through the emergency procedures that each trainee must learn to apply them, if necessary. Emergency situations do not occur regularly in real life, and it is therefore important for the controllers to regularly train in the application of their solution. These regular trainings must be completed by every full-time air traffic controller several times a year.

5. Measuring Equipment

For the measuring the work performance of the air traffic controller was used measuring equipment, which was developed on Department of Flight Preparation in partnership with Department of Aviation Engineering. This device was created to measure speed and correctness of the reaction. Device is fully compatible with any notebook that
provides installed measuring programme. Measuring equipment consist of main board, numeric board and feet’s buttons (in the case of need, it is possible to add in headphones).

Main window of the measuring programme is divided to three vertical parts. Each part has one attributable button on main board. In each part there is a few cubes of different colours (blue, yellow, green, red), their location on a screen is randomly generated.

Main task of the examined person is to find in one of the parts of the screen a red cube. The red cube is only cube that shows up on screen independently. All other coloured cubes show up in pair. In case, that the red cube shows up in left part of the screen, it is considered as right answer to push a right foot button. In case, that the red cube appears in the right part of the screen, there is a push of the left foot button considered as correct answer to the task. There can be also case, that the red cube shows up in a middle part of the screen. In this case, correct answer is to push a numeric button, which reply for the number of the beeps in headphones. There can be also situation when there is red cube in none of the parts of the screen. The correct answer is to find the part of the screen where there are two cubes of the same colour the nearest to each other and press the corresponding button on the main board [10].

In the Fig. 1 there is example situation that could occur during the measurement. In this case there need to be pushed the middle button on main board, because there are no red cube appears and in the middle part of the screen there are two yellow cubes the nearest to each other. On the Fig. 2 there is scheme of the measuring device.

![Fig. 1 Example of the measuring programme](image1)

![Fig. 2 Scheme of the measuring device](image2)

6. Analysis of the Results Obtained by the Measurement

Measurements were performed during simulator training. Every participant in training classified on the area control centre was subjected to testing on the measuring equipment before practicing on the simulator and then after performing the exercise in the initial phase of training (Phase A). Together, the initial training phase of air traffic controllers included 30 exercises on the simulator.

The first exercises on the simulator were aimed at correctly issuing permissions for turn and to train heading estimates. On Slovak airspace map, the instructor of the training had set out the round obstacles in one line, which had to be flown by the aircraft based on the instructions of air traffic controller to the pilot. In the form of slalom, he/she tried to navigate the aircraft in the right direction, which was assigned to each aircraft at the beginning of the exercise on the simulator by instructor. In this form, the trainees learn to correctly estimate the headings. In these exercises, on coming controllers are also introduced to work in real-time. We must realize that in real life, sometimes elapses between the issue of the permit and the subsequent fulfilment of the permitted act by the crew of the aircraft takes a few moments. In the initial stages of the training the trainees learn to distract their attention, previse the traffic flow and search for potential aircraft conflicts.

At each stage of the initial training, the number of aircraft on radio connection increased to 110%. In the case of the next stage, the number of aircraft is reduced again only to 60%, because the new stage is focused mainly on the new conditions of the set of exercises, which had to be learned in the training at that stage. Once a trainee knows how to deal with new conditions, number of aircrafts start to increase again.

In the Fig. 3 is a complex graph one’s of the participants of the trainee. As is shown there is 30 grey rectangles in the background of the graph, which is for grade of each exercise given by instructor. The green colour symbolizes the total time of measurement, which was performed before the exercise on simulator. The blue colour shows the total time of measurement that was performed after the exercise on simulator. Both are connected to the right side’s numbers,
which represents time of the measurement in seconds. Orange color symbolized the number of errors committed during the measurement performed before exercise and yellow color stands for amount of the mistakes that occurs during the measurement performed after the exercise on simulator. Both are connected to the left side’s numbers, which represents total number of mistakes in measurement. In detail of Fig. 3 we can see few interesting facts. One of the first is a comparison of the number of errors in measurement performed before and after the exercise on the simulator. It is obvious that the controller has committed a greater number of errors before the exercise, than in the measurement made after the exercise performed on the simulator. It is considered, that this was done based on constant focusing. Air traffic controller in the training subconsciously set up to solve problems before exercises on the simulator. The controller’s brain has prepared for performance with increased load. Upon completion of the exercise the brain, nervous system and whole blood circulation are set up to perform as the best as they can. In this physical condition, the trainee underwent the measurement performed after exercise. We can testify the current psychological state of mind also reducing the total time of measurement. Trainees can perform their reactions faster during the measurement after completing the exercise on simulator, also with improvements in the field of error results. It is also necessary to highlight the comparison of the overall exercise assessment within the initial stages of training, especially considering the number of aircraft in the exercise. In Fig. 3 with the increasing requirements of the controllers training the overall assessment grade of the exercise is deteriorated. When moving to the next stage, we can observe a revolution increase as the volume of navigated aircrafts has dropped and the new requirements are already in place for the trainee to apply properly. However, it is clear from the overall analysis of the measured results of all participants that a benchmarking exercise is not possible. Since the assessment of instructors represents their subjective opinion on the performance of the trainees.

Fig. 3 Complex graph of the trainee

From the Fig. 3 I would like to point at exercise Nr.10. In this exercise there were no new requirements needed to apply despite of we can see significant change against the others results. During the thorough analysis of the result, there was surprised conclusion made. This exercise was done by trainee in lately afternoon as his first exercise that day, because of the lack of the instructors. It is obvious that the error rate had increase as in the measurement perform before the exercise, also in the measurement after the exercise. From this is evident, that in the case of low occupancy of the trainees there is increased probability of errors.

7. Conclusion

The most important factor which this article is dealing with is the human factor. It is affecting the level of safety of air traffic navigational services provided. It is closely connected to the mental state of the individual and may be affected by any external action. The air traffic controller has a high degree of psychological load in critical situations of air traffic control, which can cause health problems in the event of long-term exposure as the body exhaust. This may lead to a situation where there is an increased risk of a dangerous occurrence in air traffic control. Due to the character of the air traffic controllers’ duties, only a narrow selection of people who successfully undergo challenging psychological and physiological tests to reveal the ability of a potential controller to perform multiple tasks simultaneously with the correctness of the solution and the speed of decision – making is the only choice for the controller position. A complex analysis of the factors influenced the operation of air traffic controller was done. Analysis of the work performance of the air traffic controller was also made. We must recognize that the work of the controller is a set of tasks that the controller must logically solve in real time to maintain a level of safety while considering the most economical basis of international agreements which must be complied with all the air participants. Where necessary, it is possible to change the entry or exit conditions of the aircraft after coordination. To solve the airspace situation, the air traffic controller must consider the active areas in his/her area of responsibility, and he/she must optimally manage the air traffic based on the occurrence of any dangerous meteorological phenomena. In addition to external factors, internal factors that also influenced the controller. It is difficult to define how much it affects each person individually.

References


Project Proposal for the Introduction of Sleeping Boxes at the Istanbule Airport

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Abstract

The article deals with project management in terms of its practical implementation on a selected project, where it gradually analyzes its individual parts. The subject of the paper is the preparation of the project "Pilot introduction of sleeping boxes at the airport in Istanbul". The reason for the implementation of the project is the fact that Istanbul Airport is a crossroads of tours mainly led by Turkish Airlines, where there are relatively frequent transfers of more than 8 hours (especially travel from smaller countries where Turkish Airlines started flying in connection with their classical known routes to New York or Bangkok - examples are flights from Kosice to New York or Bangkok). Passengers say that sleeping at the airport in Istanbul is not primarily safe, secondly, there is not enough space for sitting for longer-lasting transfers, and for example at night it is relatively cold in these areas. The paper analyzes the parts of the project definition, the description of the project, it describes the reason and the way of the project implementation and its success criteria. Subsequently, it deals with project-related risks and feasibility studies to see if it is possible to implement the project in the way we think about it. The Gantt chart and network analysis will be designed mainly to describe the critical path and project schedule. Even based on a passenger rating, for example, Turkish Airlines, for which this airport is the base, they may lose interest from passengers and therefore have decided to provide such a service. First, it will increase the level of quality of service for passengers, and secondly, it is a project that can minimally return costs at a reasonable time and potentially generate a small profit in the future. What is more important, however, is that it will bring innovations as well as better flight service.

KEY WORDS: project, feasibility study, airport, sleeping box, planning

1. Introduction

Change and the need for change is a phenomenon closely related to the implementation of projects. The project is a means of change that will lead to planned or the intended consequence to improve the position and functioning of the system in the company, on the market. Project management represents planning and management of the organization's resources during the process of planning the implementation of the assigned task.

Project management brings a set of approaches and practices as effective and successful in managing projects. The contribution focuses mainly on the parts of project definition, project risks, feasibility studies, describing their activities as part of the decomposition of project work as well as the method of network evaluation PERT (Program Evaluation and Review Technique). The aim of the contribution is to demonstrate project management in its preparatory phase of project design. We chose the pilot project of sleeping boxes at the airport in Istanbul.

2. The Basic Process of Creating a Project Model

Process approach sees the external customer, and from its requirements arranges processes, sub-processes and activities. At the same time, it also focuses on internal customers, by trying to clearly define the parameters of each input which the project team will develop. Fig. 1 shows the basic types of processes and activities, as well as the relationships between them [1].

The phase of initialization of the project will start with initial formalization of the project charter, drawn up by the basic definition of the project and its goal. The second phase of the project is defined by the subject of the project, as well as a detailed project plan. The third phase of the project management course and coordination process shall include a summary of activities that are focused on performance and coordinating the planned tasks. In particular an effective management team, project communication, motivation and conflict resolution. Efforts to meet the project goals must lead to orientations on the subject of the project, and outputs by the required amount, scope and quality. Monitoring and
control over the project requires constant supervision of the project as well as achieving results implementing controls, in compliance with the plan. Inspections are focused on performance and coordinating the work according to the plan. Monitors must focus particularly on compliance with the schedule, cost, time, quality and deviations. The last phase of the project is to complete and transfer the project. This will focus on the successful completion of the project site for the material, financial and administrative. At this point the final results will be given to the customer [2, 4, 5, 8].

3. Characteristic of the Reason for the Project Realization

The reason for the introduction of the project is the fact that Istanbul Airport is a crossroads of tours led mainly by Turkish Airlines, where there are relatively frequent transfers of more than 8 hours (especially travel from smaller countries where Turkish Airlines started flying in connection with their classical known routes to New York or Bangkok - examples are flights from Kosice to New York or Bangkok). Passengers in the ratings on the website say that sleeping at the airport in Istanbul is not primarily safe, secondly, there is not enough space for sitting for longer-lasting transitions and, for example, at night it is relatively cold in these areas. Even based on these assessments, for example, Turkish Airlines, for which this airport is the base, may come to the passengers and therefore have decided to provide such a service. On the one hand, it will increase the level of quality of service to passengers, and secondly, it is a project that can minimally return companies at a reasonable time and potentially generate a small profit in the future. What is more important is that it will bring innovations as well as better flight service. The whole idea of the project is based on the creation of a service that will complement existing services and will provide a higher level of comfort for passengers on that basis. The project will take place at the airport in Istanbul and will be operated by Turkish Airlines and primarily for Turkish Airlines customers (they will receive discount vouchers if they are customers). Project funding will be provided by Turkish Airlines and the airport at preferential prices but will not have a profit share. The project will start in mid-May and the expected completion of the assembly will be September (15/05/2018 - 07/09/2018). We plan 20 sleeping boxes valued at $ 50,000. The sleeping cells must be located in places where they are under camera surveillance.

4. Description of Sleeping Boxes

Sleeping boxes (or sleeping boxes or sleeping capsules) are a futuristic phenomenon that is rooted in airports all over the world. For decades, passengers have been scattered about the stools and aisles they used to take as part of a travel experience, but we cannot talk about comfort and motivation to travel. Therefore, and for the very fact that it is a good business, sophisticated and entrepreneurial individuals are beginning to think about how to improve the quality of travel during transportation. From seat-ups to luxury beds, a whole range of functional solutions for long-distance travelers are created, with sleeping boxes being the most popular as they offer several positive features [6].

Creation of so-called "sleeping booths (sleeping cells or sleeping boxes), which at present exist at some exclusive airports, have many advantages. An example of how these sleeping cells look like we see in the picture below. These sleeping cells function on the principle of closing for a selected time into a silenced cell where a timer can be set. Sleeping cells can be used in case of long waiting for transfer flights. If the airport did not want to use these options directly as a free service, it would be possible to create something like a slot machine from these sleeping cells, where it is possible to pay by card or coins for a certain time. Another positive feature is the ability to implement storage space in sleeping boxes to take advantage of the deck underneath the deck.

The introduction of these sleeping cells should be based on an analysis of the airport environment and the factors that affect the number of sleepers [7]. Benefits to the airport are not only in the form of satisfied customers but also in the form of marketing as it is an innovative approach to airport services [6].

The introduction of sleeping boxes (Fig. 2) is almost without any additional staffing. The system is fully automatic, which means it can be applied without any extra high investment. The biggest benefits of this system for the user include:
- Relaxation at a good standard,
- Acceptable price,
- Possibility of charging equipment,
- Usually an internet connection, storage,
- Sound insulation, separation from the mass of people,
- Peaceful, undisturbed sleep without traveling to, for example, the hotel.
5. Feasibility Study

A feasibility study is being carried out in the project preparation and planning phase. It is a tool through which it is possible to assess the feasibility of the project from the financial point of view, to consider the various possible alternatives of the solution, to analyze the market potential, to analyze in detail the output requirements. The result of such a study is to recommend or implement a project or not [3].

The feasibility study of the sleeping box implementation project at Istanbul airport is shown in the following Fig. 3.

6. Project Risks and their Elimination

Given that design at airports is relatively demanding in terms of safety and high concentration of people, this relatively simple project also has risks. The main risks and possibilities of their solution include:

- inability to agree with the airport on sleeping box locations - elimination is possible by preparing a suitable presentation;
- late delivery of goods - Elimination may be possible with time reserve and penalty as compensation for non-delivery of goods in time;
- exceeding the installation of sleeping boxes for a limited time - elimination maybe by regular daily checks that we have implemented.

7. WBS – Work Breakdown Structure

Structure of the job description is a basic prerequisite for the preparation of the project plan. It contains a set of work, an activity that is also a powerful element of control. Decomposition of project activities uses the so- stage project model. By using the top-down principle, it is possible to systematically and in detail describe the individual project procedures. The stage model includes the entire lifecycle. The partial stages at the first decomposition level are bounded by miles. Milestones are the decision deadlines and locations of the project's life cycle, where it is decided whether to continue or to repeat the activity.

The project will consist of the following parts as shown in the following Table.
<table>
<thead>
<tr>
<th>ID</th>
<th>No.</th>
<th>Activity</th>
<th>Time (TA)</th>
<th>Previous activity</th>
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<tbody>
<tr>
<td>AB</td>
<td>1</td>
<td>Analytical work and decision making</td>
<td>20</td>
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<td>- consist of the works to be covered submission of the documents to the interested parties, namely the contracting authority and the airport in Istanbul.</td>
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<tr>
<td>A</td>
<td>1</td>
<td>Analysis of the impacts of introducing sleeping boxes to the airport</td>
<td>10</td>
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<td></td>
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<td>- will be particularly noticeable for the airport, but it is an essential component for the project promoter, as he will provide him with the reasons why he should want this service in his premises - how it affects the comfort of the passengers and why it will improve his position on the market. At this point, it is also necessary to find arguments that open the topic of profitability for other businesses within the airport, as the construction of sleeping boxes can significantly affect theirs, and that is negative - potentially they can reduce their income. In the second place, it is necessary to justify the introduction of these sleeping boxes also because there is a hotel with which the airport can have a contract at the airport, so it is necessary to defend it.</td>
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<td>B</td>
<td>1</td>
<td>Analysis of the impact of the introduction of sleeping boxes on Turkish Airlines</td>
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<td>- will be based on the fact that the prerequisite for the airline is that these sleeping boxes increase customer ratings and will be profitable over time. In this analysis, it is necessary to find the reasons why such a project is worthwhile to do.</td>
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<td>2</td>
<td>Selection of suitable spaces within the airport</td>
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<td>- these works are related to the selection of suitable premises that would not break the airport's infrastructure and safety while agreeing to the conditions with the airport.</td>
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<td>C</td>
<td>2</td>
<td>Airport lease negotiations with airport management</td>
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<td>1</td>
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<td>- It is necessary to agree on what price the airport is willing to rent space and what. In this case, it will be necessary to agree as much as the size of these spaces is to be counted as sleeping boxes that operate essentially autonomously and can be installed in several parts of the unused area of the airport.</td>
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<td>D</td>
<td>2</td>
<td>Defining Terms</td>
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<td>- it is necessary to do this work to define terms and conditions not only in terms of rental and price, but also in terms of camera system and security. In addition, it is necessary to define the operating conditions, service logistics and cleaning of sleeping boxes.</td>
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<td>E</td>
<td>2</td>
<td>Signing a space contract for defined conditions</td>
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<td>2.2</td>
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<td>- signature of the contract is a confirmation of the agreement between airport management and contractors, and is a prerequisite for dealing with a company that will manufacture sleeping boxes and then assemble them</td>
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<td>F</td>
<td>3</td>
<td>Requesting bids</td>
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<td>- at this point it is necessary to reach out to companies that provide sleeping boxes or sleeping pods. These are companies such as Podtime, GoSleep and the like, which offer a range of variations of sleeping boxes and different pricing options.</td>
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<td>G</td>
<td>3</td>
<td>Vendor Selection Process</td>
<td>14</td>
<td>3.1</td>
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<td></td>
<td></td>
<td>- Evaluation of bids and terms contractors</td>
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<td>H</td>
<td>3</td>
<td>Supplier selection</td>
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<td>- should be approved by the contracting authority. Project team will select the main candidates and will be the one to choose from</td>
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<td>I</td>
<td>3</td>
<td>Signing a contract with a contractor</td>
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<td>- the signature itself of the contract, which will be besides contractor to sign the contractor and other necessary persons depending on the contract</td>
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<td>J</td>
<td>4</td>
<td>Preparation of the implementation plan</td>
<td>7</td>
<td>3.4</td>
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<td>- These works are directly related to the implementation of the preparatory plan and assembly of sleeping boxes</td>
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<td>Preparation of the implementation plan</td>
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<td>- an organized program is required for installers, which will consist of instructions and timetables. The action plan should be built to address all issues related to security and smooth progress. It is important not to forget to inform interested parties about the course of implementation</td>
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<td>K</td>
<td>5</td>
<td>Installation by an external company - control activities</td>
<td>56</td>
<td>4.1</td>
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<td>- the installation will take place an external company, but must be under control</td>
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<td>L</td>
<td>5</td>
<td>Collared sleeping boxes</td>
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<td>5.1</td>
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<td></td>
<td></td>
<td>- Determine if mounted sleeping the boxes meet the defined conditions, whether they work and whether everything was delivered. The quality criteria are checked in the contract and the amount is paid to the contractor.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
8. Conclusion

The current time has also brought inflation into the use of the word "project", which is used to indicate many activities, let alone any type of project. Project management is very widespread, the project can be the foundation of a new firm, the design and realization of a research task, or the start of new customer service, which we have just addressed in this paper.

Evaluation of air transport services is very important, especially in the current economic climate, where air transport development affects the rise in service levels and thus competition. As part of improving the services provided by airlines, it is first and foremost to base what customers want and under what conditions they feel safe. In addition, it is necessary in some ways to ensure that the services offered are something innovative, not only because it will not only improve the quality of the customer but also help the marketing of the company.

The aim of the contribution was to give a practical example of project management in its preparatory phase of project design. We chose the pilot project of sleeping boxes at the airport in Istanbul.

References

The Acoustic Risk Factor for a Parachute Rescue Team Executing the Specific Activity – Parachute Jumps

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Abstract

This article discusses measuring the acoustics in the working environment of rescuers of the Parachute, Paratrooper and Rescue systems (PPRS). The aim is to determine the extent to which the members of the PPRS are exposed on noise in their work training and conducting. The investigation was focused on jumping and preparation for work connected with jumps. We executed practical noise measurements in various stages of jumps and compared with the permissible values. By regulation in the Slovak republic, the exposure action values are LAEX, 8h = 85 dB, measure values during 12 h working day of paratroopers was 95 dB. The regulated high frequency value at 20 000 Hz is 67 dB, measure values during 12 h working day of paratroopers was 96.8 dB. All measurements were performed at the air temperature of 20°C, pressure of 103.1kPa, and a humidity of 60%.

As we expected, rescuer’s work of Parachute, paratrooping and rescue services falls within the category of hazardous work. The assumption about the adverse effect of noise in special activities such as parachute jump has been fully confirmed. Rescue workers are exposed to noise that exceeds the permitted limits and have to be included in the Category III.

KEY WORDS: Jump, Health protection, Noise, Prachute, Paratroopers

1. Introduction

Noise and vibration have become an essential part of active safety measures because they are endangering the health of the employee as well as the public [8]. As a part of the career in aviation, we encounter the specific functional responsibilities and workloads in different workplaces. One of such demanding work is the one of the Parachute, paratrooper and rescue services. These specialists carry out a lot of activities that are not common in the civilian life [6]. Various activities in the private life or health problems may caused the person to come to work tired, although it can happen only sometimes [2]. Therefore, the problem of their work is difficult to apply in generally valid measurements and observations. This activity is the only one in Slovakia and exceptional abroad. They focus mainly on special military components. Because of the so far non-existent measurements, we decided to process and measure the risks that affect their health and safety in the performance of duties. It is mainly the analysis of risks in the workplace and at work on the aircraft. After specifying the risks we will focus on the risk of noise [1]. Our goal is to incorporate the results of investigation to the practical activities and to help protect human health in high risk activities. Rapid skydiving descent from high altitudes causes negative middle ear pressure changes [4].

The most recent meeting organised by the PDH programme at WHO, in the series on strategies for prevention, was on the prevention of noise-induced hearing loss, held in Geneva in October 1997. The participants concluded that exposure to excessive noise is the major avoidable cause of permanent hearing impairment worldwide. Noise-induced hearing loss is the most prevalent irreversible industrial disease, and the biggest compensatable occupational hazard [9].

The Parachute, paratrooper and rescue service of the Slovak Air Force (PPRS AF SR) is used for searching the lost crew and passengers of aircraft after aircraft accidents or in emergency abandonment of the aircraft in the air using parachute equipment. They also intervene in emergencies such as natural disasters, industrial accidents or provide any assistance to civilians. In case of aircraft accidents the service is deployed if terrestrial components of the Integral Rescue System (IRS) are not able to reach the place of event. This service is partially included in the IRS [7]. The issue of noise exposure that we have processed, has not been solved anywhere abroad, and if it was solved, so only in internal regulations of the armies to which we have no access.

2. Work Objective

The aim of this work is to determine whether a risk of noise during the parachute jump is possible to include in the III. category of hazardous work. We used the measurement for collecting information about workers exposed to noise and we monitored them in order to assess whether there are exceeded limits and action values laid down for noise in the workplace, and in the case of exceeded limits, to propose these activities to be included in the category III of hazardous work.
3. Metodology of Work

The specific measurement was the method we used to investigate the issue of noise exposure of the PPRS rescue team. PPRS members, in their rescue activities - parachute jumps are directly exposed to noise. We have chosen the following procedure for this measurement:

- measurements in the building where they operate;
- in areas around aircraft;
- on the aircraft board;
- in the actual jump.

In addition to aircraft noise, we conducted noise measurements in air flow around the paratroopers and measurement of the altimeter buzzer sound, which is located at the rescuer’s ear. The device for measuring the noise was placed close to the paratrooper’s ear. All data were obtained using measurement instruments. We used the program to evaluate the measured data. The output values of the program are protocols of noise measurements. Based on the protocols we evaluated the results and proposed the measures.

4. Work Description

We did the measurements at the Transport Air Force Wing of General M.R. Stefanik. The selection of the appropriate measurement strategy is influenced by several factors such as the complexity of the work situation, number of workers involved, effective duration of the working day, and amount of detailed information required [11–16]. Transport aircraft provide activities associated with training, search for aircraft, skydiving, photogrammetry, reconnaissance and transportation tasks for the benefit of the Ministry of Defence and state officials.

The actual measurements, we carried on the airplane L-410 Turbojet and An-26. They operate right in the tasks of PPRS and emergency services and their air training – paratrooping and parachute jumps. Members are bothered by noise, especially in summer and partly during the free fall with audible alarm device in the helmet that reports the heights.

At the time of flight operation during flight changes the stay in the aircraft lasts 4.5 hours. During a typical week of training the rescue workers are in the aircraft an average of eight hours of the 40 hour working week. By measurements we wanted to determine the exposure level at normal flying days, the normal working week and on days when they do not conduct air training.

The Parachute, paratrooping and rescue service employ some positions: a PPRS commander, senior chief instructor and junior assistant of PPRS. They all have the work shift of 12 hours during a normal flight day with the air training. The normal flight day, 12 hours is divided into three parts - pre-flight, post-flight and flight.

<table>
<thead>
<tr>
<th>Area</th>
<th>Place of work activity</th>
<th>Workplace</th>
<th>Activity</th>
<th>Hours worked 40 hours /week</th>
<th>Flight day 12 hours /work shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airport</td>
<td>Movement areas, airports, airport areas, air space</td>
<td>Pre-flight, post flight, between jumps – preparation and parachute and equipment check</td>
<td>6 h</td>
<td>2 h 45 min</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stay in An 26</td>
<td>3 h 30 min</td>
<td>1 h 45 min</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stay in L-410</td>
<td>4 h 30 min</td>
<td>2 h 45 min</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Freefall</td>
<td>15 min</td>
<td>5 min</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hang gliding</td>
<td>45 h</td>
<td>25 min</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>Station for parachute service, preparation, training</td>
<td></td>
<td>25 h</td>
<td>4 h 14 min</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>40 h</td>
<td>12 h</td>
<td></td>
</tr>
</tbody>
</table>

In the table 1 we can see a timetable of the individual workplaces designed for different activities in one work shift during flights and 40 working hours a week. Of course, every day and every week is different. Numbers of hours worked in the workplace are dependent on weather conditions, the level of preparedness and not least the financial resources.

5. Measuring Instruments Used and Ways of Measurement

For the noise measurement we used the following measuring instruments:

- ½ "microphone Nor 1225 with a preamplifier 1206;
– analyser Nor 118 (2 pieces);
– calibrator Nor 1251;

For measurement the evaluation program NORREVIEW and Nørreport were used. During the measurement the microphone was placed close to the ear of the evaluated rescuer. When it was not possible to place the microphone near the person’s ear (by reason of the operation), so we put it close to the ear of a technician measuring, and this one remained close to the person being assessed.

6. The Result of the Noise Measurement

The results of measuring the exposure we received at individual workplaces and in the various activities during jumps. The data acquisition was difficult. The weather, preparation and the actual rescue work of PPRS had direct impact on the data acquisition. The obtained values we want to use as a basis for including this activity into the Category III of hazardous work. Including the work of parachute rescuers in that category will help partially compensate harmful noise financially, and increase the length of holidays and possibility for recovery stays.

The detailed results of measurements (one-third octave spectra, timing) of individual work operations, for the evaluated profession – a rescuer, are introduced in the protocols of the noise measurement at activities performed.

Uncertainty of measurement for all types of measurements using a ½ "microphone is 2.3 dB [10].

Based on the results the noise load was determined in levels for a normal flying day (12-hour of work shift), a regular 40-hour week and the day when airborne training was executed.

The tables 3, 4 and 5 show the measured value parameters that are under Government Regulation [3] necessary for the evaluation of noise exposure in the workplace. According to the Government Decree [3] the determining variables for assessing noise exposure in the workplace are the normalized noise exposure levels and peak C of acoustic pressure. Normalized noise exposure at other than 8 hours of working time was recalculated to eight hour shift. If the working time during the week is unevenly distributed or if the noise exposure during the working week varies significantly, weekly averages of daily normalized noise exposure levels are calculated.

The evaluation by weekly average of daily values of normalized levels of noise exposure is possible only if the value does not exceed 87 dB [10].

Results of normalized noise exposure levels and weekly averages of daily noise exposure level normalized to a normal work week were calculated from the measured data at scheduled times.

All measurements were performed at the air temperature of 20°C, pressure of 103.1kPa, and a humidity of 60%

Table 2

Exposure to noise of a rescuer in 12 hour shifts with air training

<table>
<thead>
<tr>
<th>Positions: PPRS commander, senior instructor of PPRS, PPRS assistant</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of activity</strong></td>
</tr>
<tr>
<td>Flying</td>
</tr>
<tr>
<td>Pre flight/Post flight</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Frequency [Hz]</th>
<th>LEX,8h [dB]</th>
<th>Lmax [dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>95,0</td>
<td>117,4</td>
</tr>
<tr>
<td>25</td>
<td>99,2</td>
<td>126,7</td>
</tr>
<tr>
<td>31,5</td>
<td>96,8</td>
<td>120,3</td>
</tr>
<tr>
<td>40</td>
<td>96,8</td>
<td>116,1</td>
</tr>
<tr>
<td>8000</td>
<td>69,1</td>
<td>98,4</td>
</tr>
<tr>
<td>10000</td>
<td>71,2</td>
<td>103,3</td>
</tr>
<tr>
<td>12500</td>
<td>71,1</td>
<td>101,9</td>
</tr>
<tr>
<td>16000</td>
<td>69,4</td>
<td>100,1</td>
</tr>
<tr>
<td>20000</td>
<td>65,5</td>
<td>96,8</td>
</tr>
</tbody>
</table>

Expanded measurement uncertainty is 2.3 dB.

Uncertainty in estimation of the levels with the handset is 2.5 dB.

where $Tr$ – duration of activity; $L_{AEX,8h}$ – A level of noise exposure converted to 8-hour of working shift with tonal /pitch correction; $L_{AEX,8h}$ – A level of noise exposure converted to 8-hour of working shift without tonal/pitch correction; $L_{C,Pk}$ – C peak sound level; $L_{C,EX,8h}$ – C level of noise exposure recalculated to an 8-hour working shift; $L_{C,PK,S}$ – the estimated C peak sound level under the declared hearing protectors; $L_{AEX,8h,S}$ – the estimated A level of noise exposure below declared hearing protectors converted to an 8-hour work shift without tonal/pitch correction

Noise exposure levels were measured in the workplace at work activities:
- taxiing, take-off, to 4000 meters, L-410 landing without paratrooping;
- preparation before paratrooping;
- preparation of parachutes;
- flight to 4,000 m, L-410;
- flight to 4000 meters, airdrop, L-410 landing without paratrooping;
- flight preparation, taxiing, take off, flight to 4000 m L-410;
- airdrop An -26;
- take-off, flight An-26;
- taxiing An-26;
- indication of the height by an audible altimeter.

![High frequency noise [20000Hz]](image)

**Fig. 1** The results of exposure to noise of a rescuer in 12 hour shifts with air training

**Fig. 1** presents the results of exposure to noise of a rescuer in 12 hour shifts with air training (recalculated for 8h) compared with declared values by regulation.

### Table 3

<table>
<thead>
<tr>
<th>Exposition on noise for a 40 hour week (TD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positons: PPRS commander, senior instructor of PPRS, PPRS assistant</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Flying</td>
<td>15,0</td>
<td>96,4</td>
<td>91,4</td>
<td>132,4</td>
<td>100,7</td>
<td>105,4</td>
<td>77,7</td>
</tr>
<tr>
<td>Pre-flight/Post flight</td>
<td>25,0</td>
<td>52,2</td>
<td>52,2</td>
<td>90,6</td>
<td>57,2</td>
<td>63,6</td>
<td>34,2</td>
</tr>
<tr>
<td>Total</td>
<td>40,0</td>
<td>96,4</td>
<td>91,4</td>
<td>132,4</td>
<td>100,7</td>
<td>105,4</td>
<td>77,7</td>
</tr>
</tbody>
</table>

### Low and high frequency noise

<table>
<thead>
<tr>
<th>Frequency [Hz]</th>
<th>LEX,TD [dB]</th>
<th>Lmax [dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>90,4</td>
<td>117,4</td>
</tr>
<tr>
<td>25</td>
<td>94,3</td>
<td>126,7</td>
</tr>
<tr>
<td>31,5</td>
<td>92,0</td>
<td>120,3</td>
</tr>
<tr>
<td>40</td>
<td>91,9</td>
<td>116,1</td>
</tr>
<tr>
<td>8000</td>
<td>64,4</td>
<td>98,4</td>
</tr>
<tr>
<td>10000</td>
<td>66,5</td>
<td>103,3</td>
</tr>
<tr>
<td>12500</td>
<td>66,4</td>
<td>101,9</td>
</tr>
<tr>
<td>16000</td>
<td>64,5</td>
<td>100,1</td>
</tr>
<tr>
<td>20000</td>
<td>60,7</td>
<td>96,8</td>
</tr>
</tbody>
</table>

Expanded measurement uncertainty is 2.3 dB.
Uncertainty in estimation of levels with the headset is 2.5 dB.
The values shown in the Table 3 are introduced without taking into account the uncertainties mentioned.
Expanded measurement uncertainty is 2.3 dB.
Uncertainty in estimation of levels with the headset is 2.5 dB.
The values shown in the table 4 are introduced without taking into account the uncertainties mentioned.

7. Limit and Action Values of Noise Exposure

Exposure limit values are $L_{AEX,8h,L} = 87$ dB and $L_{CPL} = 140$ dB.
The upper exposure action values are $L_{AEX,8h,a} = 85$ dB and $L_{CPL} = 137$ dB.
Lower exposure action values are $L_{AEX,8h,a} = 80$ dB and $L_{CPL} = 135$ dB.
For various activities, included in various groups of work, action values of normalized noise exposure are determined [10].

The action levels of normalized noise exposure levels for each group of work [10]

<table>
<thead>
<tr>
<th>Group of work</th>
<th>Noise exposure at workplace $L_{AEX,8h}$ (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>40</td>
</tr>
<tr>
<td>II</td>
<td>50</td>
</tr>
<tr>
<td>III</td>
<td>65</td>
</tr>
<tr>
<td>IV</td>
<td>80</td>
</tr>
</tbody>
</table>

Table 5 shows the action levels of normalized noise exposure levels for each group of work.
In addition to the sound levels $A$ and peak acoustic levels $C$, the values of acoustic pressures are assessed in the third-octave bands for high-frequency and low-frequency sounds.
Action levels of low frequency sound values $L_t$ in the third octave bands from 20 Hz to 40 Hz are presented in Table 6. In these bands, the maximum sound pressure must not exceed, even for a short time, $L_{tmax} = 132$ dB.
The determining quantities of high-frequency sound are normalized levels of acoustic pressure in the third octave bands.
The obtained results show that the muscle is suitable for the application in a suspension based on the elements of real VW Golf car. The damping effect when the excitation frequency corresponds natural frequency of the vehicle body is obvious.
It was observed, that, due to small air flows and the damping functions of the muscle, when pneumatic muscle is at work, the system do not has a phenomena of auto-vibrations, it allow to investigate other field of fluid muscle utilization, for example in the stability control systems.
### Table 6

<table>
<thead>
<tr>
<th>Group of work</th>
<th>Infrasound LGEX,8h,p</th>
<th>Low-frequency noise LtEX,8h,p</th>
<th>Ultrasound LoEX,8h,p</th>
<th>High-frequency noise LtEX,8h,p [dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8kHz, 10kHz, 12.5 kHz, 16kHz, 20kHz</td>
</tr>
<tr>
<td>I.</td>
<td>90</td>
<td>80</td>
<td>75</td>
<td>35, 40, 52</td>
</tr>
<tr>
<td>II.</td>
<td>100</td>
<td>90</td>
<td>85</td>
<td>50, 55, 67</td>
</tr>
<tr>
<td>III.</td>
<td>105</td>
<td>95</td>
<td>90</td>
<td>60, 65, 77</td>
</tr>
<tr>
<td>IV.</td>
<td>116</td>
<td>106</td>
<td>105</td>
<td>70, 75, 87</td>
</tr>
</tbody>
</table>

### 8. Conclusions

Based on the acquired results we can state:

- during the normal 12-hour work shift, when airborne training was executed, the exceeded exposure occurs,
- during the normal 12-hour work shift, when airborne training was executed, the action level of normalized level of exposure for the group of works exceeded,
- during the normal 12-hour work shift, when executed airborne training action values are exceeded determining the values for high frequency noise,
- during the normal working week, when airborne training was executed, the limit value of exposure of weekly averages of daily values of normalized noise exposure levels exceeded,
- during the normal working week, when airborne training was executed, the action level of the weekly averages of daily exposure of normalized noise exposure levels for a group of works exceeded,
- during the normal working week, when airborne training was executed the action values exceeded of determining the values for high frequency noise.

It should be noted that during the normal working week, when airborne training was executed, the exposure to the weekly average of the daily values of normalized levels of noise exposure exceeded, it is therefore not possible to carry out an assessment using the weekly average of the values of determining variables. The evaluation by weekly average of daily values of normalized levels of noise exposure is possible only if the value does not exceed 87 dB.

During training and deployment we have encountered a variety of factors that negatively affect our health. Training takes place in day, night, summer and winter conditions. [17] The main objective of this study was to measure a risk factor of noise at parachute jumps, evaluate measured values, and on the base of the measured values, suggest this activity for category III of hazardous work. The actual measurement we did at workplace of PPRS members. That is a building that is away from the aircraft. There are ongoing preparatory work activities and pre-flight briefings. There, all measurements were satisfactory and none of the measurements exceeded the permitted values. As a further place for measurement we chose the landing area at the airport. This area is used by members for packing the parachutes after jumps and preparation for the next jump. This workplace we included for the group of flight activities. It is located near the aircraft stand. During packing the parachutes, aircraft are starting up, moving on the runway, returning from the runway and conducting engine tests. Especially engine tests according to the noise measurements, imposed on all persons in the area. The next step was the measurement of noise during take-off, flight and landing without a paratrooping team. The measurement results were worse. In one jump the noise exposure took at least 20 minutes and, at a jump from greater heights, even an hour.

The following measurements were associated with the jump. Jumping out of the aircraft L-410, airborne at speed 160 km/h and the An-26, airborne at speed 330 km/h started with measuring the free fall lasting up to five seconds. Since the jump to deploying the parachute, no increased noise levels were measured. The increased exposure to noise was measured during the free fall of 5-15 seconds. During this period the free fall speed was about 180 km/h. Measuring over 15 seconds already recoded overcame legal limits. Freefall speed exceeded 200 km/h. At the free fall of 60 seconds the measurement results were complicated. At free fall approaching to 300 km/h, the measured values of the noise exposure exceeded capabilities of a measuring device which could record them. We had to repeat the measurement. After several attempts and settings the instrument, we decided not to include them into documents for determining noise exposure.

Measurements were not objective, because not every attempt had been recorded. And if the recorded values were true, this activity would be included to the category IV. And there would be a risk that after one year in the position the trained rescuers should be reclassified to another position.

### 9. Recommendations for Public Health Practice

This work has fulfilled conditions to the full extend. As we expected, rescuer’s work of Parachute, paratrooping and rescue services falls within the category of hazardous work.

The assumption about the adverse effect of noise in special activities such as parachute jump has been fully confirmed. Exposure exceeded the permissible limits in free fall jumps. Workplace measurements were normal, without any influence. When measured near the aircraft stands, the noise was annoying, but within the standards. When flying
on a plane to airdrop the measured values were marginal.

During the free fall that lasts over 5" with bypass air intensity the noise increases and becomes harmful. When you jump from 4000 m it lasts 60" for skydivers to reach the speed of 200 km/h to 350 km/h. This diving rate lasts up to 50". In this activity the measured values significantly exceed the permitted levels. It has been confirmed that noise exposure is harmful and affects the health of paratroopers.

Special measurements of noise exposition we did when using an acoustic altimeter. The signal was so intense that in the overlapping noise during the freefall the beep sound of altimeter instrument could not record the exact value of the noise. In repeated measurements the situation was the same, nothing or high values were recorded.

The results of this work can be used as an aid in the assessment of the same or similar workplaces, not only in the Slovak Armed Forces, but also in the civilian sector. They support other measurements in the civilian sector, especially for Air Traffic Controllers. The values measured in this work cannot be authoritative and each must carry out own measurements.

In this work the military aviation regulations have been used and incorporated, the ordinary person does not have access to them because they are confidential.

References

Comparison of the Accuracy of Selected Forecasting Methods

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Abstract

Over the last three decades, the dynamic development of air transport has led to a great development and progress in the process of predicting and planning individual aviation activities. The final test of any forecast is whether or not it is able to predict future results with sufficient accuracy. For this reason, the most important step in the forecasting process is the selection of a suitable prognostic method. Aviation forecasters and planners have a wide choice of means and forecasting methods, starting with intuitive but also expert approaches, following highly structured and complex quantitative methods. The aim of the paper is to evaluate and compare the accuracy of selected forecasting methods used for planning further aviation activities.

KEY WORDS: forecasting, aviation, forecasting method, time series analysis, planning, accuracy

1. Introduction

Forecasting methods used for planning aviation activities should reflect causal relationships conditioning aviation activities. The levels of these activities are the result of the interaction of supply and demand factors. Demand for air travel is a function of demographic factors and economic activities of the state. Supply-side factors affecting the level of individual activities include costs, competition and regulations [1].

When planning and designing aviation activities, it is necessary to evaluate and correctly interpret the results resulting from the use of appropriate forecasting methods and relationships. It is the evaluation of the expected results that is a necessary part of the forecasting process.

Forecasts of future development, which begin with the collection of historical data and are created based on a set of rules, fall into the category of quantitative methods. If historical data is not readily available and usable, and experience and judgment must be used to prepare the forecast, the use of qualitative methods is most appropriate. It follows that the use of some methods may be limited by a lack of data or data sources. However, it can be concluded that a more reliable and accurate forecast can be obtained by using multiple approaches (methods) and then consolidating different results through the knowledge of relevant markets [2, 5-9].

2. The Accuracy of Forecasting Methods

An important step in preparing the forecast of the aviation development is to select a suitable forecasting method based on the accuracy of the forecast. The final test of any forecast is whether or not it is able to predict future results sufficiently accurately. A good prognostic method should exhibit a low predictive error value, i.e. an error that does not deviate significantly from its average, i.e., is constant [3].

Characteristics which serve to verify the accuracy of forecasting methods are based on residual deviation expressed by the formula:

\[ e_t = y_t - \hat{y}_t, \] (1)

where \( e_t \) is the residual deviation of the forecast at time \( t \), \( y_t \) is the empirical value of the dependent variable at time \( t \), \( \hat{y}_t \) is the predicted value of the variable at time \( t \).

We distinguish the following methods of assessing the accuracy of forecasting methods:

- Mean absolute error that uses the absolute residual deviation value. It is used to express the forecast error in the same units that are inherent values of the original statistical series.
- Mean absolute percentage error - the use of this methodology is justified by the need to highlight the size of
the predicted variable and the ratio between the error size and the size of the predicted variable, and when the value is high.

Mean percentage error - indicates the distortion of the predictive model. This methodology consists in calculating the mean of all relative errors calculated by dividing the forecast deviation in each period by the empirical value of the dependent variable from the given period [3, 4].

In addition to the forecasting accuracy characteristics listed above, it is possible to verify the predictive power of the prognostic method by means of a determination index that can obtain values from interval 0 to 1. The relation for calculating the determination index is as follows:

$$I^2 = 1 - \frac{\sum_{i=1}^{n} (y_i - \hat{y}_i)^2}{\sum_{i=1}^{n} (y_i - \bar{y})^2}. \tag{2}$$

Wherein, the more the value of the determination index is closer to zero, the smaller part of the total variability is explained by the model, on the other hand, the more the value of the determination index is close to 1, the greater part of the total variability of the model is explained.

The selected characteristics of the accuracy of the forecast were used in other parts of the work for:

a) comparison of the accuracy of the selected forecasting methods,

b) verifying the usability and reliability of the relevant methods,

c) finding an optimal forecasting method.

3. Comparison of the Accuracy of the Linear and Exponential Trend of Time Series Analysis

The time series analysis method is based on the assumption that historical patterns will continue in the future, relying on the availability of historical data. The individual time series values are called $y_t$. The index $t$ serves to express the individual time points in which the corresponding $y_t$ was measured, for $t = 1, 2, ..., n$. The letter $n$ serves to express the length of the time series in the time frame examined [4].

We have tracked the number of passengers transported during the period 1999-2017. We divided the data set into two parts, the first part, that is, the data from 1999-2007 we used to compile the equations on which we created the forecasts for 2008-2017. Consequently, our forecasts were compared to the actual data from these years and we calculated the errors of the individual forecasts. To determine the most appropriate prognostic method, we compared the mean percentage error, mean absolute percentage error, and the determination index of the individual methods.

We considered the values of the reference indicator $y_t$ for $t = 1, 2, 3, ..., n$.

**Linear Trend**

The actual course of the function $y_t = \beta_0 + \beta_1 \cdot t$ was not known, we just passed an estimate of this trend in the form [4]:

$$\hat{y}_t = \hat{\beta}_0 + \hat{\beta}_1 \cdot t. \tag{3}$$

To estimate the parameters we used the method of least squares, thus:

$$\varphi = \sum_{i=1}^{n} (y_i - \hat{y}_i)^2 = \sum_{i=1}^{n} (y_i - \hat{\beta}_0 - \hat{\beta}_1 \cdot t)^2 \rightarrow \min. \tag{4}$$

We set the partial derivation equal to zero and we received:

$$\sum_{i=1}^{n} y_i - nh\hat{\beta}_0 - h \sum_{i=1}^{n} t = 0; \tag{5}$$

$$\sum_{i=1}^{n} t \cdot y_i - nh\hat{\beta}_0 \sum_{i=1}^{n} t - \hat{\beta}_1 \sum_{i=1}^{n} t^2 = 0. \tag{6}$$

We simplified the relationships for calculating the estimation of model parameters by placing the time variable equal to one in the case of first observation from the chronological point of view.

We introduced the variable $t'$ for which the relationship applies:

$$\sum_{i}^{n} t' = 0. \tag{7}$$

For an even number of valid observations (Table 1):
Table 1

Even Number of Valid Observations

<table>
<thead>
<tr>
<th></th>
<th>January</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t )</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>( t' )</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

For an odd number of valid observations (Table 2):

Table 2

Odd Number of Valid Observations

<table>
<thead>
<tr>
<th></th>
<th>January</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
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</thead>
<tbody>
<tr>
<td>( t )</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>( t' )</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

We simplified the relationships to estimate the model parameters to the following form:

\[
\begin{align*}
    b_0 &= \bar{y}_t' \\
    b_1 &= \frac{\sum t' \cdot y_t'}{\sum (t')^2}
\end{align*}
\]

(8)

(9)

Table 3

Calculation of the parameters needed to compile the linear trend estimation equation

<table>
<thead>
<tr>
<th>Year</th>
<th>( t' )</th>
<th>( y_t' )</th>
<th>( t' \cdot y_t' )</th>
<th>( (t')^2 )</th>
</tr>
</thead>
<tbody>
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<td>1999</td>
<td>-4</td>
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<td>-6560</td>
<td>16</td>
</tr>
<tr>
<td>2000</td>
<td>-3</td>
<td>1756</td>
<td>-5268</td>
<td>9</td>
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<tr>
<td>2001</td>
<td>-2</td>
<td>1750</td>
<td>-3500</td>
<td>4</td>
</tr>
<tr>
<td>2002</td>
<td>-1</td>
<td>1748</td>
<td>-1748</td>
<td>1</td>
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<tr>
<td>2003</td>
<td>0</td>
<td>1805</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2004</td>
<td>1</td>
<td>2014</td>
<td>2014</td>
<td>1</td>
</tr>
<tr>
<td>2005</td>
<td>2</td>
<td>2157</td>
<td>4314</td>
<td>4</td>
</tr>
<tr>
<td>2006</td>
<td>3</td>
<td>2277</td>
<td>6831</td>
<td>9</td>
</tr>
<tr>
<td>2007</td>
<td>4</td>
<td>2478</td>
<td>9912</td>
<td>16</td>
</tr>
<tr>
<td>( \sum )</td>
<td>0</td>
<td>17625</td>
<td>6295</td>
<td>60</td>
</tr>
</tbody>
</table>

From the above relationship and data from the Table 3 we calculated:

\[
\begin{align*}
    b_0 &= \frac{17625}{9} = 1958.33 \\
    b_1 &= \frac{6295}{60} = 104.92
\end{align*}
\]

and then we calculated the equation of the linear trend estimation in the form:

\[
\hat{y}_t = 1958.33 + 104.92 \cdot t
\]

On the basis of the equation for the estimation of the linear trend we predicted the number of transported passengers for the next few years, so that we gradually set \( t \) equal to values 5-12.

![Time Series Analysis - Linear Trend](image)

Fig. 1 Comparison of the predicted and real number of carried passengers
It is clear from the above graph (Fig. 1) that the use of the linear trend estimation equation is warranted when short-term forecasts are compiled, as in the first years of the comparison it shows a relative correlation with the actual state. However, it does not take into account fluctuations caused by economic factors, i.e. accidental effects, such as the economic crisis, which caused a significant drop in demand for air transport in 2009.

For the mathematical expression of the accuracy of the used method we calculated the mean absolute percentage error MAPE, the mean percentage error MPE and the index of determination:

$$MAPE = \frac{1}{n} \sum_{i=1}^{n} \left| \frac{y_i - \hat{y}_i}{y_i} \right| = \frac{1}{9} \cdot 0.44 \pm 0.049;$$

$$MPE = \frac{1}{n} \sum_{i=1}^{n} \left| \frac{y_i - \hat{y}_i}{y_i} \right| = \frac{1}{9} \cdot 0.34 \pm 0.038;$$

$$I^2 = 1 - \frac{\sum_{i=1}^{n} (y_i - \hat{y}_i)^2}{\sum_{i=1}^{n} (y_i - \bar{y})^2} = 1 - \frac{47128.5}{1686267.37} = 0.23 \pm 0.77.$$  

**Exponential Trend**

We assumed an estimation of the trend in the form [4]:

$$\hat{y}_i = b_0 \cdot b_1^t \quad \text{for } b > 0$$  

(10)

This model is not linear in the parameters, so it was not possible to directly use the least squares method for the calculation. To estimate the model parameters, we used the linearization transformation methods, where we were working with the transformed variable $t'$:

$$\log \hat{y}_i = \log \left( b_0 \cdot b_1^t \right);$$  

(11)

$$\log \hat{y}_i = \log b_0 + t' \cdot \log b_1.$$  

(12)

We denoted $A = \log b_0$ and $B = \log b_1$ by which we could write the equation in a linear form:

$$\log \hat{y}_i = A + t' \cdot B.$$  

(13)

We proceed as in the case of a linear trend and to calculate the parameters of the model we used the method of least squares:

$$\sum \log y_i - n \cdot \log b_0 - \log b_1 \cdot \sum t' = 0 \Rightarrow \log b_0 = \frac{\sum \log y_i}{n};$$  

(14)

$$\sum t' \cdot \log y_i - \log b_0 \cdot \sum t' - \log b_1 \cdot \sum (t')^2 = 0 \Rightarrow \log b_1 = \frac{\sum t' \cdot \log y_i}{\sum (t')^2}.$$  

(15)

**Table 2**

<table>
<thead>
<tr>
<th>Year</th>
<th>$t'$</th>
<th>$y_i$</th>
<th>$\log y_i$</th>
<th>$t' \log y_i$</th>
<th>$(t')^2$</th>
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<tbody>
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<td>1640</td>
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<td>-12.88</td>
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<td>1765</td>
<td>3.25</td>
<td>-9.75</td>
<td>9</td>
</tr>
<tr>
<td>2001</td>
<td>- 2</td>
<td>1750</td>
<td>3.24</td>
<td>-6.48</td>
<td>4</td>
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<tr>
<td>2002</td>
<td>- 1</td>
<td>1748</td>
<td>3.23</td>
<td>-3.23</td>
<td>1</td>
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<tr>
<td>2003</td>
<td>0</td>
<td>1805</td>
<td>3.26</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2004</td>
<td>1</td>
<td>2014</td>
<td>3.31</td>
<td>3.31</td>
<td>1</td>
</tr>
<tr>
<td>2005</td>
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<td>3.33</td>
<td>6.66</td>
<td>4</td>
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<tr>
<td>2006</td>
<td>3</td>
<td>2277</td>
<td>3.36</td>
<td>10.08</td>
<td>9</td>
</tr>
<tr>
<td>2007</td>
<td>4</td>
<td>2478</td>
<td>3.40</td>
<td>13.6</td>
<td>16</td>
</tr>
<tr>
<td>$\Sigma$</td>
<td>0</td>
<td>17625</td>
<td>29.6</td>
<td>1.31</td>
<td>60</td>
</tr>
</tbody>
</table>

From the Table 4 data and the above relationships we received:
The equation for the estimation of the model parameters:

\[
\hat{y}_t = 1949.85 \cdot 1.05^t
\]

Fig. 2 Comparison of the real and predicted number of carried passengers

The chart (Fig. 2) and data from the Table 4 show a very similar development of the number of passengers carried during the years under review. More pronounced deviations are evident in 2008-2010, when air traffic has been shaken by the aforementioned economic crisis, so even in the case of this model, it can be said that it does not take into account any accidental impacts.

Following the graphical evaluation of the accuracy of the model, we reapplied to the calculation of the selected prediction accuracy characteristics:

\[
MAPE = \frac{0.18}{9} = 0.02
\]

\[
MPE = \frac{-0.06}{9} = 0.007
\]

\[
I^2 = 1 - \frac{5236.54}{1686267.37} = 1 - 0.003 = 0.997
\]

In the case of an exponential trend, the index of determination is very close to 1, which tells about the variability of this model, and similar to the graphical representation, there is a high degree of accuracy, that is to say, correspondence with the actual function, in our case the number of passengers carried.

4. Conclusion

Every day at all levels of air traffic management there are decisions made about the future development. Business measures and strategies adopted today must be based on yesterday’s results and tomorrow's (future) expectations, predictions. The term "air traffic forecasting" means, in particular, an attempt to quantify future demand, an estimate of future volumes of transport or the financial situation. The most important step in the process of compiling any forecast is the selection of the appropriate forecasting method, which has been devoted a substantial part of this work. Each type of prognosis serves a specific purpose, on which the selection of a suitable prognostic method also depends. We used quantitative forecasting methods to consider the development of air transport. After testing and comparing selected quantitative prognostic methods, we conclude that for the monitored dataset, the equation of estimation of the exponential trend appears to be the most appropriate for further forecasting.

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