** KNOWLEDGE MANAGEMENT SYSTEM FOR IMPROVEMENT OF QUALITY OF RAILWAY TRANSPORT SERVICE 

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**Abstract:** In the past, the railway industry has been faced with simple technical and technological systems which included a small number of defined inputs and outputs, comprising only simple subsystems and components. Thus, a single manager could understand them almost completely and could predict failure conditions and the consequences thereof. These days, railway technical and technological systems are complex. System complexity is continuously increasing, pushing managers to better understand of how the system behaves and what its influence over transport service quality is. It should be admitted that without having a well designed, properly organized and effectively working knowledge management system with respect to factors influencing railway service quality, even the best intentions would probably be in vain. The present paper discusses the need to establish, the essence and key features of a knowledge management system in the area of the quality of transport service in railways.

**Keywords:** KNOWLEDGE MANAGEMENT, RAILWAY TRANSPORT SERVICE, QUALITY, OPERATIONAL RELIABILITY AND SAFETY

1. Introduction

Nowadays, due to the impact of many factors (e.g. competition in rail industry, growing demand from customers, etc.), the importance of the quality of the railway transport service is increasing rapidly. Railway companies with well-organized and properly functioning quality management systems add benefits to their performance that not only satisfy customers but also make their operations more effective and competitive. Although quality is of indisputable importance, there is a little research being done to explore this specific issue.

Researches into the field of service quality involve identification and evaluation of the significance of some particular indicators, the essence of which is characterized by the nature of the definition of quality. There are many meanings of the term “quality” but two of them have a crucial importance regarding quality management:

- Quality stands for those features of a given product (or service) which meet client needs and as a result provide satisfaction. This meaning of quality is oriented to a company's income (a greater satisfaction of clients leads to their increased number and as a result – increased income).
- Quality means absence of deficiencies (technical failures, human errors, imperfection of exploitation process design, etc.) in a company’s functioning. In this case, there is no need for additional measures: higher quality stands for less cost.

In the past, the railway industry has been faced with simple technical and technological systems which included a small number of defined inputs and outputs, comprising only simple subsystems and components. Thus, a single manager could understand them almost completely and could predict failure conditions and the consequences thereof.

These days, railway technical and technological systems are complex. System complexity is continuously increasing, pushing managers to better understand of how the system behaves and what its influence over transport service quality is. It should be admitted that without having a well designed, properly organized and effectively working knowledge management system with respect to factors influencing railway service quality, even the best intentions would probably be in vain.

This paper discusses the need to establish, the essence and key features of a knowledge management system in the area of the quality of transport service in railways.

2. Essence of transport service quality and need for its management

Today in modern society, the daily lives and schedules of many people are more dependent on the transport service of railways than ever before. As a result, the importance of service quality is increasing rapidly.

There are a large number of definitions for quality currently being used in many industrial areas but few in the field of railway transport services, although this term is broadly used in papers, researches and regulations. In the light of the characteristics of railway operations and with adaptation of the definition of quality stated in [2], the quality of transport service could be indicated as: a complex property of a given railway technological system (e.g. railway undertaking) to perform its functions connected with the transportation of passengers and goods properly and in accordance with certain pre-determined performance (service) standards, designed in compliance with specific criteria and operational indicators (characteristic of the system).

On the basis of such a definition, the next five basic properties of service quality in respect of a railway undertaking functioning can be defined:

- Duration of transportation (goods or passengers) - determined by the speed of transport means moving from the initial to the end point of a given transportation route.
- Convenience - creating normal and ergonomic travel conditions for passengers in transport means, facilities for loading and unloading freights, etc.
- Cultural services - ethical and polite relation to customers of a railway undertaking (passengers or shippers), high level of sanitary and hygiene conditions in transport means, etc.
- Protection of cargo - creating conditions to prevent damage to the cargo during the transport process.
- Reliability - ability of a railway technological system (undertaking) to perform its required functions under stated conditions within a specified period of time. Reliability has three basic properties:
  - Punctuality - associated with the timely arrival/departure of trains at/from stations, i.e. train delays are both qualitative and quantitative criteria to assess the reliable implementation of requirements. Punctuality is an important indicator for the accuracy of implementation of the planned timetable and usually is defined as a percentage of trains arriving on time (of total number of trains realized) within a sufficiently significant period of time.
  - Regularity - characterized by reliable implementation of each single train route. Due to many causes a given train route
could not be entirely fulfilled (for example: an accident occurring during a train movement between initial and final stations).

-Safety - ability of a railway technological system to prevent hazards to the life and health of people (passengers, local population, operational staff, etc.), material damage, threat to the ecological balance of the environment, due to the influence of objective or subjective, internal or external destabilizing factors affecting the system. Occurring accidents are a measure of safety. But as the intensity of their occurrence is significantly less than the intensity of train delays, the last are key indicator of the reliability level of rail transport service.

Recently, railway transport in Bulgaria is facing tangible competition from road transport (both passenger and freight). In order to assess the situation and improve its competitiveness, railway transport as a whole should implement urgent measures. The correct understanding and evaluation of the nature of service quality and its properties is the only and correct way to identify shortcomings and improve service quality and competitiveness thereof. The above refers not only to infrastructure managers but also to all railway undertakings (operators).

In the area of railway transportation service, reference [3] proposes some minimum service quality standards. They do not cover all aspects (properties) of service quality stated above but this document gives the freedom to railway undertakings to define service equality standards and implement a quality management system to maintain service quality. The basis of such a system is a knowledge management system regarding all unwanted and unintended events, conditions and processes that impact negatively thereof. The above refers not only to infrastructure managers but also to all railway undertakings (operators).

The information about \( Q_j \) and \( Q_{SA,j} \) is more useful than the raw data \( n_{SA,j} \), \( n_{A,j} \) and \( n_{I,j} \) but it does not directly help the decision-maker to make the best choice. Using the knowledge of how to compute, use further and interpret probabilities, this information can be converted into more useful information, e.g. unconditional probability of occurrence of serious accident due to all possible causes: \( Q_{SA} = \sum_{j=1}^{n} Q_j Q_{SA,j} \) (\( n - \) total number of causes). In other words, knowledge involves appropriate combination of concepts, judgments, methodologies and know-how to get and process proper raw data, obtain and analyze information from them and use it for decision-making (Fig.1).

Having answered the question of knowledge attributes (data and information) another very important question arises: what must be done to get the most out of those very valuable resources? The answer here is connected with the possibility to design, organize and run appropriate knowledge management process. Virtually, the knowledge management in the field of transport service quality can be defined as implementation of appropriate intentional activities.
Continuous improvement is an organizational belief (culture) that effectiveness of its processes could and should always be to the attention of company’s management in order to meet customers’ demand. Continuous improvement relies on employees’ positive involvement in finding and fixing all problems of a company’s performance. Such an involvement happens only when employees are informed about company’s performance deficiencies and possible ways to correct them. Only then they can improve their functioning by applying their creative faculties to their work related problems.

Continuous improvement of a given process is usually interpreted as an iterative four-step management strategy namedPDCA cycle (Plan–Do–Check–Act) [1] [4]. It is also known as the Deming Cycle (named after Dr W. Edwards Deming, considered to be the father of modern science of quality). Figure 4 shows the basic details of PDCA cycle.

4.2. Railway undertaking – business and risk system

To understand the role of knowledge management system within an improvement cycle in a railway undertaking it is necessary to define the basic features of its performance, and no doubt that reliability and safety (as its property) are the most important of them. Therefore, it is of great use to specify railway undertaking as a risk system. This is a business system that is designed and organized to generate useful and intended outputs (conveyance of goods and people) which are realized within a specific and changeable operational environment characterized by substantial potential for the occurrence of adverse (risky) outputs (accidents and incidents). The definition above means that just as we would apply some quality management approaches and tools (e.g. organizational acquisition of knowledge) to control the quality of services from the business system, so we should apply similar tools to control the influence of incidents (as an output of the risk system) over the quality. To prevent incidents (and accidents) from occurring and to improve service quality it is necessary to have enough information regarding their characteristics, called incident learning. Incident learning is an important part of overall knowledge management system of railway undertaking. Virtually, railway staff and sometimes railway undertakings as a whole tend to hide (when possible) incidents because they are connected with liability for compensation and/or deterioration of their image to the society and state. As a result, whatever “gap” in information regarding causal factors of incidents, leads to a “gap” in knowledge management and decision-making. This is an extremely unwanted and intolerable state in a business system involved in transport service which is performed in an environment characterized by the presence of a great variety of harmful influencing factors.

4.3. Knowledge management as a powerful tool for balancing business and safety goals in railway undertaking

Principally, railway undertaking is a generic business system that is designed, organized and run to achieve a profitable output
(qualitative transport services that satisfy customers’ demand). In case of not achieving the designed output due to system failures (e.g. incidents), a railway undertaking is facing some losses – system failures require time and resources for their recovery. In other words, system failures (and losses connected with them) lead to transport service gaps and performance losses.

There are many different causes for system failures but what unifies them is the fact that they are principally avoidable. The avoidance of system failures is possible only when there is enough knowledge about causal factors to prevent them from occurring in the future. All this means that knowledge management is a very important tool for balancing transport service (business) and safety purposes. The relationship between the two main parts of a railway undertaking performance – system of transport process management and system of risk (safety) management, and also the role of knowledge management as a unifier of business and safety purposes are depicted in figure 5.

5. Conclusion

Railway transport service is characterized by complexity not only on the stage of design but also within its real implementation. Moreover, the functioning of a railway undertaking is realized in an environment with uncertain conditions – accidental influence of internal or external (for the organization) causal factors. Sometimes, the negative influences could fatally harm undertaking performance. This is why the knowledge about potential system failures and causal factors connected with them is a very important and powerful tool not only to support but also improve quality of transport services.

The possession of knowledge regarding potential system failures (leading to poor service quality) is quite insufficient. Knowledge should be enriched, shared and implemented for decision-making. All this is the foundation of knowledge management. The importance, structure and specifics of this foundation are discussed in this paper.

References


CONTRIBUTION OF GEAR BODY TO TOOTH DEFORMATION

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Abstract: Through applying the 3D finite element method (FEM), the investigation into a spur thin-rimmed gear tooth deformation was performed. The developed geometrical and FEM models without manufacturing errors of the engaged solid pinion and thin-rimmed wheel, enabled the torque transmission and the tooth load distribution corresponding to actual wheel structure and its deformation as a whole. For the wheel body with thin rim supported by middle web, the chosen geometrical parameters of interest were the rim and web thickness, while the value of tooth face width was kept constant. A spur tooth deformations were determined and analysed through the deformation modus of the loaded tooth mid plane along the tooth height and along the face width, for the certain gear body flexibility.

Keywords: TOOTH DEFORMATION, THIN-RIMMED GEAR, GEAR BODY, FINITE ELEMENT ANALYSIS

1. Introduction

The relation between actual gear structure and gear tooth deformation represents an important issue in gear drive design considering the desirable weight gains and reduction of noise originated from the gearbox. In order to determine the best combination of gear body geometrical parameters it is important to evaluate their contribution to the gear teeth rigidity. Preliminary design orientations are needed to successfully connect different tools [1].

A powerful method for the determination of gear tooth state of stress and strain has become the finite element method (FEM) that has been usually compared with the results of previous investigations by means of analytical and experimental methods. Consequently, this method has supplied with additional insight into and has become the basis for important advances in gear design. This has been especially true for thin-rimmed gears supported by complex body aggregated from a web that connects thin rim and hub. The gear body contributes to resultant gear tooth deformation and the load distribution along the tooth face width which has been considered by the development of various geometrical and numerical gear models. As thin-rimmed gear represents 3D structure more relevant investigation results have therefore been obtained by replacing 2D gear models with 3D ones. The 3D FEM gear models considerably differ on numerous aspects according to essential purpose they are built for.

A stress analysis of webbed gears has been mainly performed for the tooth root and adjacent area due to its importance for the estimation of gear strength [1, 2, 3].

An exhaustive 3D FEM analysis of thin-rimmed teeth stress and deflection can be found in [4, 5]. These investigations are characterized by the consideration of different structures of thin-rimmed gear (symmetric type single web gear, double web gear, thin-rimmed gears with and without ribs) and by the analysis of effects that the web, rib and rim thickness, and gear face width have mainly upon the stresses but on tooth deflection, too.

The problem of noise and vibration in the gear transmissions has been solved by use of dynamic models that evaluate the variations in mesh stiffness and transmission error [6, 7, 8].

As for the stress analysis of thin-rimmed gears, the modeling of gear deformation started with partial teeth models, until the advances in CAD systems have made possible to model whole gear deformations [9] and even entire gear transmission [10]. The issues of modeling proper load distribution over tooth face width, and the modeling of tooth contact zone have been solved differently by development of various methods [11, 12, 13].

The works worth to be mentioned regardless of different approaches to the gear modeling, but considering their generality and detailed elaboration of deformations and stresses arising at thin-rimmed webbed gears, are as follows [11, 9].

In [11] the subjects of investigation were the deformations and stresses at various locations at gear body with middle web. The attention was devoted to proper estimation of the load distribution along the tooth face width. Based on the known load distribution and the known reactions at the joint of teeth and rim, the stresses and deformations at the rim and web were determined by means of the developed software using the FEM. The results represent valuable information gathered after consideration of numerous gear geometrical parameters such as gear diameter, tooth face width, rim and web thickness. Furthermore, it was found that the decreasing rigidity of gear body considerably diminishes the influence of contact lines errors upon the load unequal distribution along the tooth face width which results with greater efficiency of transmission.

Owing to the available powerful tool more recent work [9] than previously mentioned, analysed the deformations and stresses of thin-rimmed gear with offset web by applying whole gear deformation model. The load distribution was again calculated through the loaded tooth contact analysis by the 3D FEM and mathematical programming method. Then the loads were used to determine deformations and stresses by means of FEM. Among gear geometrical parameters were included the rim thickness, pressure angle and module, and their influence on tooth root, rim and web stresses were investigated. The analysis of stress achieved at the joint of thin rim and web pointed to the necessity to regard the joint as critical stress point additionally to the tooth root.

Furthermore, the rim circle deformation and web deformation were analysed. The comparison of transmission errors for a solid and thin-rimmed gear showed that vibration-exciting force of thin-rimmed gear is greater than for a solid gear. It was concluded too, that in the total deformations of thin-rimmed gear the rim and web share about 70% and the gear teeth share only about 30%.

Fig. 1. 3D FEM model (one half) of a solid pinion and thin-rimmed wheel engaged at the outer point of single pair tooth contact; the points A, B, C along the tooth height.
In this paper a solid pinion is mating with thin-rimmed wheel with middle web. Based on the experience and suggestions of previous investigations, the load distribution along the tooth face width resulting from actual gear structure is accomplished and whole wheel deformations are taken into consideration.

2. 3D Geometrical and FEM Model

The deformation of thin-rimmed spur gear mid-plane is determined for the pinion-wheel system of the following constant geometrical parameters: number of teeth \( z_1 = z_2 = 20 \), modulus \( m_n = 10 \) mm, pressure angle \( \alpha_n = 20^\circ \), profile shift coefficient \( x_1 = x = 0 \), face width \( b = 100 \) mm.

For the gear body with thin rim supported by middle web, the chosen geometrical parameters of interest were the rim and web thickness. The backup ratio \( s_R / h_t \) (\( s_R \) - rim thickness, mm, \( h_t \) – tooth height, mm) is chosen from 0.44; 0.64; 0.89 to 1.33. These values overcome the backup ratio range proposed by the standard ISO [14] for thin-rimmed gear. The adopted web thickness is expressed by the ratio \( b_s / b \) (\( b_s \) – web thickness, mm): \( b_s / b = 0.1 \); 0.2; 0.3 and 0.4.

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The models of pinion and wheel differ as the pinion is partial gear model with three teeth and angular extension corresponding to four teeth, while the wheel is complete gear model with three teeth and other part of the rim made with increased rigidity that takes into account the excluded teeth (Fig. 1). The pinion and wheel are modeled in the outer point of single pair tooth contact. Due to the symmetry of geometry and load, the model with one half of the
actual face width is utilized.

The pinion-wheel system is subjected to constant torque and the imposed boundary conditions enable the simulation of torque transmission. The contact between the engaging teeth surfaces is accomplished by use of commercial software that detects frictionless contact. Due to non-linear contact problem and minute effect of Herzian local contact deformation on total tooth deformation, the tooth deformation is not followed at the point of contact but for the tooth mid-plane.

The tooth deformations were expressed by the magnitude of 3D displacements $\delta$ of tooth mid plane and were separated in the direction of tooth height and the tooth face width.

Fig. 1 shows the positions at the loaded tooth mid plane where the displacements are observed after the loading. The distribution of the displacements along the tooth height is followed for the points A (tooth tip), B (pitch point) and C (tooth root). Along the tooth face width five equally positioned points are chosen going from one to another tooth end.

### 3. Results and Discussion

The displacements were collected at the loaded tooth median surface. The distribution of displacements along the tooth height and face width is presented through the form of contour plot in Fig. 2, 3, 4, 5. Among the obtained results there were separated the combinations of rim and web thickness that represent extreme conditions of gear body flexibility. The direction of the tooth face width $b$ is expressed by no dimensional coordinate $x/b$.

![Fig. 6 The loaded tooth displacements $\delta$ along the tooth height and face width ($s_g/h_t=1.33; b/s=0.4$)](image)

![Fig. 7 The loaded tooth displacements $\delta$ along the tooth height and face width ($s_g/h_t=0.44; b/s=0.1$)](image)

3.1. The distribution of tooth displacements along the tooth height

Maximum displacements are always reached at the tooth tip and their magnitude considerably depends on the certain combination of rim and web thickness. In comparison with the combination of the greatest value of rim and web thickness under consideration ($s_g/h_t=1.33; b/s=0.4$), the diminishing of web thickness to minimum value ($b/s=0.1$) increases maximum displacements (reached at the face width) going from the tooth root C towards the tip A, for 85% and 34%, respectively (Fig. 2, 3).

As regards the thinnest rim supported by the thickest web ($s_g/h_t=0.44; b/s=0.4$) and going towards the thinnest web ($b/s=0.1$), the increment of maximum displacements is much more obvious and overcomes the initial values for twice and 54% when moving from the tooth root C towards the tip A (Fig. 4, 5).

The actual flexibility change of gear body affects mostly the variation of displacement $\delta$ at the tooth root and this influence diminishes going towards the tooth tip. The displacements for thin rim ($s_g/h_t=0.44$) generally increase more along the tooth height with the decrease of web thickness and for the combination of the thinnest rim and web severe displacement increment at the tooth root is evident.

In Fig. 6,7 the tooth displacements $\delta$ are shown along the tooth height and face width in the form of surface plot, for the gear body with the thickest rim and web ($s_g/h_t=1.33; b/t=0.4$) and with the thinnest rim and web ($s_g/h_t=0.44; b/t=0.1$). The variation of the displacements along the tooth height is evident for both combinations of rim and web thickness applied for the gear body, but the displacement for the thickest rim and web going from the tooth root C towards the tip A increases more.

![Fig. 8 The relationship between maximum tooth displacement $\delta_{\text{max}}$ at the tooth tip regardless of the position along the tooth face width, achieved for different web thickness and related to the rim thickness. As the web thickness increases from $b/s=0.1$ to 0.4, maximum tooth displacements diminish depending on the rim thickness, for 35% ($s_g/h_t=0.44$) and for 27% ($s_g/h_t=1.33$). The increment of rim thickness from $s_g/h_t=0.44$ to 1.33, results with the decrease of maximum displacements for 38% ($b/s=0.1$) and for 30% ($b/s=0.4$).](image)

3.2. The distribution of tooth displacements along the tooth face width

The displacement distribution that is followed along the face width for equally positioned points, shows significant differences in relation to the influence of both, the rim and web thickness. At the position of middle web the tooth deforms less in comparison to the tooth edges (Fig. 6, 7).

Fig. 9 presents the ratio $\delta_s/\delta_{\text{max}}$ of displacement $\delta_s$ at the tooth

\[ s_g/h_t=1.33; b/s=0.4 \]
\[ s_g/h_t=0.44; b/s=0.1 \]
edge and the displacement $\delta_m$ in the middle of the tooth face, for the points A, B, C along the tooth height and related to the rim thickness $s_g/h_r$. For the sake of clarity, there are included the thinnest and thickest web.

Non uniform displacement distribution along the tooth face width varies along the tooth height: for the thinnest rim non uniformity diminishes going from the tooth tip A towards the root C, and for the thinnest rim the tooth root C distribution shows the greatest non uniformity. As the rim thickness diminishes displacement distribution becomes more non uniform, but much more for the thinnest web ($b_s/h_t=0.4$). Non uniformity of displacements along the tooth face width is maximum for the thinnest rim supported by the thickest web ($s_s/h_t=0.4, b_s/h_t=0.4$), and at the tooth root C the displacement at the tooth edge is about 40% greater than the corresponding one in the middle of face width (Fig. 4, 9).

For the thinnest rim and web ($s_s/h_t=0.44; b_s/h_t=0.1$) when the displacements take maximum values, non uniformity of distribution along the tooth face for certain tooth height, differs slightly (Fig. 7, 9).

### 4. Conclusions

The results about the loaded tooth deformation obtained at the tooth mid plane after loading, confirmed considerable impact of the actual combination of rim and web thickness of a spur gear with middle web.

Maximum displacements are always reached at the tooth tip. By the decrease of web thickness the displacements increase going from the tooth root towards the tooth tip, but more for the thinnest rim. The actual flexibility change of gear body affects mostly the variation of displacements at the tooth root and going towards the tooth tip this influence diminishes. For the combination of the thinnest rim and web a severe increment of tooth root displacements occurs.

As for the displacement distribution along the tooth height, the impact of rim and web thickness can be noticed through non uniform displacement distribution along the tooth face width, too.

In relation to the tooth height, non uniform displacement distribution along the face width for the thinnest rim supported by the thickest web is mostly expressed, while for the thinnest rim non uniformity of distribution is less obvious, regardless of the web thickness.

For the thinnest rim and web when the displacements take maximum values, non uniformity of distribution along the tooth face for certain tooth height, differs slightly.

### 5. Literature

THE ROLE OF LOGISTICS IN THE MARKET FOR TRANSPORTATION AND TOURIST SERVICES

Abstract: There is increasing interest in logistics, which is aimed at continuous optimization of material and information flows management, defining the any kind of peculiarities of these flows. The tourism logistics is the science of planning, control and management of operations carrying out during the process of preparing the travel offers, delivery of finished product to consumer in compliance with his/her interests and requirements, as well as during the process transfer, storage and processing of information concerned.

KEY WORDS: MARKET, TRANSPORT AND TOURIST SERVICES, LOGISTICS, CONVEYANCE OF TOURISTS, TOURIST FLOWS.

1. Introduction

There is increasing interest in logistics, which is aimed at continuous optimization of material and information flows management, defining the peculiarities of these flows [1]. Logistics is a corporate activity of different tourist companies aiming at integration of all processes concerning with attaining the objectives of their businesses. The tourism logistics is the science of planning, control and management of operations carrying out during the process of preparing the travel offers, delivery of finished product to customer in compliance with his/her interests and requirements, as well as during the process transfer, storage and processing of information concerned. It follows from this definition that logistics is a system containing the functional areas, each of which solves some problems [2]. Importance of tourism logistics, wherein are involved such major parties as customer- travel agent-supplier of transportation and tourist services, where it is important to properly plan, manage and operatively control the complex material and informational process of preparing and implementing the travel in compliance with interests and requirements of customer [1].

The important component elements of this system are the following ones:

1. Information – planning of travels, order processing and forecasting of demand;
2. Conveyance of tourists – means of transport and carrier company selection;
3. Tourist service staff;
4. Service supporting sector – logistics departments, which support the process of preparing the travel offers and provision of services to customer: production capacity and economic amativeness of tourist companies are of topical importance for functioning of logistics system.

2. Preconditions and means for resolving the problem

Integrated logistics structure of tourism covers its component, regional and functional structures.

The component structure includes the following elements:

1. Recreation and tourism resources (tourism resource base);
2. Tourism material and technical base logistics, including logistics of the spheres of tourists accommodation facilities (lodging establishment) and food catering (restaurant facilities) for tourists;
3. Logistics and information infrastructures (information logistics in tourism);
4. Logistics and transport infrastructure of tourism (tourist traffic logistics);
5. Sightseeing logistics;
6. Logistics of tourism related services;
7. Logistics of tourism products production and sales.

The regional structure of tourism logistics reflects its regional (geospatial) systems of six levels:

1. Local level (tour logistics);
2. Micro-level (tour operator logistics);
3. Mesoscale level (tourist and resort zones and tourist district logistics);
4. Macro-level (country’s tourism industry logistics);
5. Mega-level (world macro-regions logistics);


Fig.1. Tourist Flows in Tourism Logistics

Aims and tasks of tourism logistics are different on various regional levels. If the introduction of logistical principles in the management of the travel company (micro level) to reduce costs and thus increase the efficiency of tourist enterprise activities and increase its profits, the logistic approaches at higher taxonomic levels (macro, mesoscale) provides an opportunity to ensure the sustainable development of tourism business in the tourist-and-recreational zones, areas and country as a whole. On mega- and meta-level of the regional logistics systems there is considered the tourism sustainable development within the scales of world tourism macro-regions, and emphasized the World Tourism Organization, global issues of the balanced development of tourism industry.

Functional structure of tourism logistics includes such traditional elements as the procurement logistics; manufacturing and selling logistics. They relate to all the component and regional elements of tourism logistics.

Tourist flow is a main object of study in tourism logistics. Feature of tourism logistics as a service industry consist in defining the tourist flows as the main object of studies. This explained by fact that the travels pertain to those types of services, when the consumers move towards manufacturer, but not manufacturers with their products – to the consumer.

The latter situation is typical, in particular, of trade in consumer goods, when demand and consumption geographically drawn together, unlike the territorial localization of production. Thus, the aim of logistics system of tourist product in trade marketing consists in the delivery of products to the tourism production and consumption areas. Therefore, the tourism product
Foreign (incoming) tourist – non-resident visitor; this is a person, outside his/her country. i.e. a person, who travels outside the country during his/her way to the destination (duration of stay over 24 hours).

Foreign (outgoing) tourist – resident visitor, who makes travel in Georgia, but is nonresident of it; this person travels over Georgia or in other countries with the purpose not for recreation, entertainment or medical purposes, as well as for business purposes:

1. Regular tourist flows, in particular: tourist group and single tourist (so-called VIP-tourism) flows;
2. Irregular ‘wild’ tourist flows, which also apply a load to recreation-tourist resources in the recreation area.

For example, in Svaneti, mountainous region of Georgia, by some estimates, the share of “wild” tourists exceeds 1/3 of total number of holiday-makers (100 000 people in 2011-2012). Among the most popular destinations of “wild” holiday-makers in Georgia there are emphasized the Green Cape near Batumi (for family outing), mountainous regions Racha, Khevsureti, Mta-Tusheti, town-museum Mtskheta near Tbilisi, and Rabati Castle in Akhalatsikhe. Thus and so, the following objects must be studied in Tourism Logistics:

- Regular tourist flows;
- Irregular (“wild”) tourist flows (there are some difficulties with statistics).

Other citizens, who do not meet these requirements, but who are traveling, pertain to the category of travelers (they are not counted in Tourism logistics).

However, there are mentioned as well in the Law on Tourism the people traveling within 24 hours, and they are called one-day visitors [3]. One-day visitor is a person whose duration of stay in visiting area does not exceed 24 hours, and at the same time there is no envisaged overnight stop in visiting area. It consists of: holiday-makers; passengers who are in round trip (persons who enter the country on cruise ships spend the night on the ship, but they can make excursions ashore); vehicle crews whose members are foreigners and are located in a particular country during the day; transit visitors, they do not stay for the night and travel through the territory of a particular country to their destinations in another country. One-day visitor logistic flows are counted in tourism logistics in a main flow, since they effect on the recreational and tourist resources as well.

The following categories of tourists are highlighted in tourist flows:
1. Domestic tourism – visitor - resident, who travels within the territory of own country, but outside his/her usual environment. This person travels over Georgia and in inhabitancy areas;
2. Foreign (incoming) tourist – non-resident visitor; this is a person, who travels in Georgia, but is nonresident of it;
3. Foreign (outgoing) tourist – resident visitor, who makes travel outside his/her country. i.e. a person, who travels outside the customs territory of Georgia, but is a resident of it;
4. Transit visitor – a person, who stays in a particular area or country during his/her way to the destination (duration of stay over 24 hours).

The essence of the meaning of “tourist flow” is defined as a permanent arrival of tourists in the country or region. The following features are typical of this meaning:
- total number of tourists (including regular and irregular ones);
- number of tour days (number of overnight stops or bed-days);
- average duration of stay of tourists in the country or in the region.

The main indicators of tourist flows are the following ones: number of incoming (outgoing) tourists and duration of stay. The number of arrivals (departures) tourists means the number of registered visitors, who came from a certain country (or left it) for a certain period, typically, for the calendar year. Since a tourist during the year and even during one trip may visit different countries, and the number of arrivals exceed the actual number of tourists. In addition to absolute figures of tourist flows there are used the number of arrivals (departures) per thousand of population (relative index of tourist flow).

The duration of stay is determined in overnight stops for tourists and in hours for visitors. One overnight stop is made by tourist in a certain country or destination. The duration of stay of all tourists in the country for some period (i.e. total number of overnight stops) I calculated as a product of number of tourist arrivals and average duration of stay of each tourist in the country. The following formula is used for calculation:

\[ N = T \cdot M \]  

where, \(T\) – is a number of tour days; \(M\) – number of tourists.

Depending on the duration of stay (number of overnight stops) there are emphasized the following tours:
- short trips (1-3 overnight stops), made for recreation and entertainment purposes in week-ends and nonworking days and holidays (week-end tours), as well as for business purposes;
- short trips (4-7 overnight stops), envisaging trips with various purposes;
- medium trips (8-28 overnight stops) – long vacation, mostly for recreation purpose;
- long trips (29-91 bed and 92-365 overnight stops), which are used for recreation, entertainment or medical purposes, as well as for round trips, business and professional tourism.

Thus and so, from arrivals statistics, when the volume of tourist flows is determined, statistics of the duration of stays characterizes the tourist travels.

Tourist flow is characterized by irregularity, which is expressed by irregularity coefficient. The following expressions are used for its calculation:

\[ K_1 = \frac{T_{\text{max}}}{T_{\text{min}}} \cdot 100\% \]  

\[ K_2 = \frac{T_{\text{max}}}{T_{\text{dye}}} \cdot 100\% \]  

\[ K_3 = \frac{T_{\text{max}}}{T_{\text{id}}} \cdot 100\% \]  

\[ T_{\text{id}} = \frac{T_{\text{dye}}}{12} \]  

where, \(K_1, K_2, K_3\) – are the irregularity coefficients of tourist flow; \(T_{\text{max}}\) - number of tour days during the month with minimum tourist flow; \(T_{\text{dye}}, T_{\text{id}}\) - number of tour days during the month with minimum tourist flow, man-days;
\( T_{\text{tnk}} \) – yearly number of tour days, man-days;
\( T_{\text{cm}} \) – average monthly number of tour days, man-days.

3. Conclusion

1. Importance of tourism logistics in market of transportation and tourist services in Georgia is high, wherein are involved such major parties as customer - travel agent-supplier of transportation and tourist services, where it is important to properly plan, manage and operatively control the complex material and informational process of preparing and implementing the travel in compliance with interests and requirements of customer.

2. Tourist flow is a main object of study in tourism logistics. Tourist flow is characterized by irregularity, which is expressed by irregularity coefficient. Several equations were used for its calculation.

4. Literature

TECHNICAL AND ENVIROMENTAL CAPACITIES OF OIL TERMINALS IN GEORGIA

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Abstract: Transport-logistics system of the Southern Caucasus, which is used for the export of oil and gas resources from the Caspian region to global markets, includes the pipelines laid across the territory of Georgia, seaside oil terminals, tanker and ferry means of delivery and railways. The most important in technical and environmental terms, are the oil transshipment facilities in Batumi, Supsa, Poti and Kulevi.

Currently, the development of Georgian ports, including the oil transshipment facilities is carried out within the established infrastructure and defined water zones of ports.

KEY WORDS: TRANSPORT-LOGISTICS SYSTEM, OIL TERMINAL, ENVIROMENTAL SECURITY

1. Introduction

The creation of the seaside oil transshipment facilities is aimed to solve a whole number of technical, economic, environmental and navigational problems. One of the aspects of this process is the selection of a tonnage group of oil tankers for transportation of bulk oil cargoes. In general, however, economic considerations take precedence, although in some cases, you must take into account the navigational specific features of the regions and navigation and existing local conditions. World-wide trends in demand for the construction and purchase of oil tankers are known to everyone.

Unit costs for the transportation of 1 ton of oil by tankers with deadweight of 100-150 thousand tons are almost by 2 times smaller in comparison with tankers with deadweight of 40-65 thousand tons, so about 80% of the oil is transported by ships of such deadweight. The tankers of larger deadweight are not considered due to fact that the Turkish authorities have strengthened the control of passage through the Black Sea straits.

The use of high-capacity tankers for bulk oil transportation reduces the number of berths by about 2 times, and for the version with mooring berths, there is increasing their time of operation by meteorological factors that increases the throughput capacity of the berth.

Another aspect of the problem of creating the oil transfer complex (OTC) is to choose the type and location of the berthing facility. In recent years, generally, two types of bulk oil terminals are widely used: fixed moorings (inshore or protected areas moorings) and one-point inshore moorings. This is a multi-factor challenge, and its optimal solution depends on the location of the OTC and natural conditions, the availability of sufficient area protected harbors, volumes of overloads, planned the whole fleet. In each case, the choice is the priority requirements, conditions and source data.

Only with a view to the construction industry, this analysis makes sense, since the cost of construction of the fixed berth is approximately by 3 times higher in comparison with one-point inshore mooring, and the present costs (including the maintenance costs) – by 1,5-2 times accordingly.

In densely populated areas when selecting the location and type of berthing facility there are taking into account logically the criteria of operation safety, ensuring the required throughput capacity and construction costs.

The third aspect is an environmental one. Despite fact that the emergency oil tanker fleet losses are up to 10% of oil pollutants in the world-wide ocean, each accident with a considerable spill is considered as a serious environmental case.

Storage, transport and transfer of oil bear the risk of a negative impact on the environment:
- emissions of harmful substances from tankers, respiratory systems of tankers and tank batteries;
- oil pumping (spill);
- possible fires and explosions.

Since all sites of oil transfer are located near residential and recreation areas, the risk of their adverse effects is under the watchful eye of the public that attaches particular importance to safety of such objects.

Oil spills associated with its transportation by sea had always taken place in the world. After the 80-ies of the last century as a result of consecutive purposeful activities of the International Maritime Organization (IMO) and adequate measures taken by seafaring countries, the oil spill accidents has declined tenfold, but of times, but all the same that probability is conserved. of remain. This is due to the complex hydrometeorological conditions; the aging of tanker fleet; miscalculations in the actions of the ship’s crew; display of a human factor at all levels of the organization and performance of works on oil transportation by sea [4].

In the ports of Georgia, there has also been a downward trend in the oil spill. Special mention should be made of the creation and adoption during the last years of an entirely new of legislative-regulatory framework of Georgia in the domain of ensuring the safe operation of potentially hazardous facilities, to which the marine and oil and gas complexes are belonged largely, in particular, the marine oil transfer terminals [2].

Safety measures and equipment must be provided at all stages of the port installations (oil transfer terminals) – in the design, construction (reconstruction, modernization) and maintenance – and it must represent an integrated safety system.

2. Preconditions and means for resolving the problem

Currently, the development of Georgian ports, including the oil transshipment facilities is carried out within the established infrastructure and defined water zones of ports.

Thus and so, particular attention in the current develop schemes of ports is is received by security problems not only for new developing units, but for all units, including the “old” ones, which were built before adopting the modern security requirements: terrorist, environmental and fire protection.

The modern oil transshipment facilities existing in Georgia generally are well-organized and technically prepared for oil spill response in the defined water zones of ports, and they quite successfully solve the problems with liquidation of cosequences thereof. In formulating a project document on oil terminals and preparing proposals to investors regarding an integrated safety measures, the port management relies on real goods and services market, while actively participating in the creation of new technical means and technologies (ship fitters, boom-laying boats, firefighting equipment, and onshore activities).

Over past years, the efforts have been made in the world at different levels in order to ensure safe navigation and improve the reliability of large-tonnage tankers that resulted in both regarding the reduction of the number of incidents and minimizing the oil losses.

More accidents occur in areas with severe hydrometeorological and navigational conditions and a high density of traffic. The Black Sea does not pertain to such zones, and therefore there was no accident with the tanker fleet, but only in recent years through the main oil terminals (Batumi, Supsa, Poti and Kulevi) were transported more than 50 million tons of oil and oil products, and the number of ship entries amounted to several thousands.
The transfer of oil and oil products in Georgia is carried out via the sea specialized terminals in the ports of Batumi, Poti and Kulevi. Kulevi. Kulevi Oil Terminal. Due to traffic volume grow from Kaspi region, Batumi Sea Port became a bridge spanning the Eurasian transport corridor. Oil and oil products are loaded in Batumi Port’s 4 berths having an area of 8 ha and length of 755 meters. Throughput capacity of port is 15-18 million tons of oil products annually. The analogous indicator for dry cargo makes up 2.3-2.5 million tons over the year. The terminal’s planned cargo turn-over of the container shipping is 47-50 thousand containers annually.

The terminal provides consumers with loading, uploading and storing services. Oil is supplied to terminal by rail, and at the same time, it is capable of providing services for 260 rail cars. Total volume of terminal premises makes up 5700.000 tons, and is intended for 22 various sorts of oil products. Since 2008, the oil gas storages had been expanded as well, and their volume now is 5 000 cubic meters [1].

Oil in Batumi terminal is loaded in tankers from three berths by using the modern systems that allows loading of tankers with loading capacity over 130 000 tons.

At present, the throughput capacity of oil terminal is 15 million tons annually. The terminal is specialized on the processing of a crude oil and all sorts of oil products in practice, such as: diesel oil; petrol; oil slurry and so on. 5.4 million tons of oil products were transported via the oil terminal in 2011, and 6,115 million tons in 2010.

Oil in Batumi terminal is loaded in tankers from three berths by using the modern systems. The depth of berths in Batumi port is 25-30 meters that allows loading of tankers with loading capacity over 130 000 tons.

Over the last decade, cargo turnover of the Batumi Sea Port has been increased considerably. At present, about 90% of 80% total cargo turnover accounts for oil and oil products shipment. The Port actively participates in international associations, conferences and projects.

Till 2015, there is planned in the area of “Batumi Oil terminal Ltd.” the construction of oil reservoir with capacity 4X20000 m³ and facilities and engineering networks forming the tank battery complex, that should considerably increase the oil terminal’s throughput capacity.

Poti Port. Poti Port is located at the area of 49 ha and operates round-year. At present, the property that the Port owns is the cargo transportation complex, which comprises 14 berths and has length 2650 meters. 11 berths are equipped with portable elevator intended for 6-40 tons. The conditions required for shipping are fitted to transportation of any type of loads and liquid products. The infrastructure of Poti Port is designed so as to enable it to treat 10 000 tons of cargo. However, railway is no longer able to transport these loads, since there is only one rail-track on Poti-Senaki railway line that places a serious obstacle against railroad train turnover. It is necessary to construct one additional railroad on Poti-Senaki railway line in order that ingoing and outgoing trains in order that they might not interfere one to another.

At this time, Poti Port treats only 1,5 million tons of oil annually. Soon, the construction of a new oil terminal will be completed. This operation includes the construction of oil terminal with modern design in Poti port from the Caspian Sea towards the Black Sea for the purpose of opening the privileged export routethat in turn should strengthen the Georgian economy through expanding the railway traffic and increasing the oil transportation competitiveness, and actually, it should contribute to growing the volume of oil and oil products transportation in the region. This project is implemented under financial support of Black Sea bank (BSTDB).

ThePorti Port partially is connected with Ilychevsk Port (Ukraine), Varna (Bulgaria) and some Caucasian ports (Russia) by means of the direct ferry-boat-railway line, and with Novosibirsk (Russia), Burgas (Bulgaria) and Rize (Turkey) by means of the direct ferry-boat-automobile passages. Supsa Terminal. Supsa Oil Terminal is located on the left bank of Supsa River, and it was put into operation in April 1999. Annual throughput capacity of Baku-Supsa pipeline is 7 million tons.

Overall volume of Terminal’s storage tanks is 160 000 cubic meters. All four tanks have identical size. After the tanks are filled the oil transportation through the pipeline is carried out by means of tankers distanced from the coast [3].

In 2012, 3 922 306 tons of oil were transported through the Supsa Terminal that exceeds the data of 2011 by 2.8%. In 2011, the Socar Oil Company had transported .562 million tons of oil through the Supsa Terminal.

Kulevi Port. Kulevi Terminal is one of the most modern terminals among all Black Sea terminals. It is equipped with up-to-the-minute technology, as well as possesses the highest-level vast oil storage tank facilities located at the area of 320 thousand square meters. The terminal comprises two berths with capability of providing services for 100-ton ships. Kulevi Terminal is capable to receive high-tonnage ships, but the berth inlet area needs to be deepening down.

The Terminal possesses its own railroad line as well. The production control at the Terminal is carried out on the basis of modern SCM systems. Design capacity of Terminal is 10 million tons annually. At this time, it is only at 40%.

About 4 thousand tons of chemical products daily (50 thousand tons per year approximately) is transported through the Kulevi Oil Terminal. This could be accomplished due to a new complex for transportation of propylene existing in the Kulevi Terminal.

Kulevi Oil Terminal had successfully adopted the following standards: ISO 9001 (Quality Management Systems); ISO 14001 (Environmental Management Systems) and OHSAS 18001 (Occupational Health and safety Management Systems). Since 2007, the Kulevi Oil Terminal is a property of Socar Oil Company. The Terminal has started its functioning on may 16, 2008.
3. Conclusion

TRACECA is considered as a priority European project and in practice, it lays the European transportation service lines until the Caspian Sea, and then to Asia. Europe-Caucasus-Asia transport corridor or “New Silk Road” (TRACECA) begins from Ukraine, Bulgaria and Romania. Then crossing the Black Sea it is connected to Georgia, towards Batumi, Poti and Kulevi terminals. By involving the transportation networks of South Caucasus countries, the rout is directed to the Caspian Sea, and then passing through the ferry-boat passages (Baku-Turkmenbashi and Baku-Aktau) TRACECA has access to the railway network of Central Asia countries - Turkmenistan and Kazakhstan, whose transportation networks are connected to the directions of Uzbekistan, Kyrgyzstan and Tajikistan, and then they reach the borders China and Afghanistan.

Loading of terminals largely depends on transit oil cargoes, attraction of which is envisaged at the account of providing the services to an appropriate level, “adjusting” their nature to the market needs, improving the oil terminals infrastructure, which provides an appropriate volume of services to customers.

4. Literature

DETERMINATION OF VESSEL WEIGHT AND COORDINATES OF ITS CENTRE OF GRAVITY BY USING OF ELASTIC INFLATABLE TANKS

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Abstract: The methods of experimental determination of the vessel weight and the coordinates of its center of gravity without launching using inflatable elastic containers are shown in this article.

KEYWORDS: VESSEL, INCLINING, TEST, ELASTIC, TANKS

1. Introduction

The calculations of weight displacement of the empty vessel and coordinates of its centre of gravity are performed when the vessel is under project. But never the less there is an inclining test which is performed after the vessel launch for determinig the characteristics of the vessel.

The modernization and re-equipment often take place during vessel operations. These actions are accompanied with dismantling the existing equipment and designs and installation of the new ones. It leads to considerable changing of weight characteristics of a vessel. Calculations of changing of the specified characteristics of a vessel are carried out at performance of similar reconstructions to have a clear idea about its stability to vessel descent.

A new method of experimental determination of a vessel weight and coordinates of its center of gravity before ships launching by using of elastic inflatable cylindrical tanks (EICT) is presented in this article.

A method of transporting vessels on land with inflatab le elastic tanks is widely used in the countries of South-East Asia.

Elastic cylindrical tanks are made of rubber and are equipped with fitting for connection to compressed air system and pressure gauges to monitoring the internal pressure.

The tanks are stowed across vessels hull under the bottom between keelblocks. When the pressure is increased the tanks abut against the bottom and lift the vessel above the keelblocks. After that the keelblocks are removing (fig.1-2).

2. Weighing of the vessel

(Determination of vessel weight and abscissas of its centre of gravity)

The vessels are laid on keelblocks on the building ways (fig.8a). Inflatable tanks are lay down across vessels hull on building ways between keelblocks symmetrically about vessels centre line (fig.8b).

Then tanks are filled with compressed air until the vessel is not raised above the keelblocks till complete lack of them (fig.8c).

There are list of characteristics such as: internal pressure, contact area of bottom with tank, and abscissas of center of gravity of contact area in reference to chosen readout system (for example - the midship section plane) are measured for each tanks (fig.9).

Fig. 1 position of the vessel on cylindrical elastic c (side view): 1 – vessel hull; 2 – cylindrical elastic tank; 3 – building ways

Fig. 2 Position of the vessel on cylindrical elastic c (cross section): 1 – vessel hull; 2 – cylindrical elastic tank; 3 – building ways

Fig. 3 Position of the vessel on the platform, based on cylindrical elastic capacity (side view): 1 – vessel hull; 2 – keelblock; 3 – strength flat platform; 4 – cylindrical elastic tank?; 5 – building ways

Fig. 4 Position of the vessel on the platform, based on cylindrical elastic capacity (cross section): 1 – vessel hull; 2 – keelblock; 3 – strength flat platform; 4 – cylindrical elastic tank?; 5 – building ways

After that the vessel is towed in longitudinal direction. Herewith the cylindrical inflatable tanks act as rinks. Rinks that go out from the bottom in aft end are transported into the forepart.

Inflatable elastic tanks lay directly between bottom and building ways if the vessel has flat bottom (fig.1,2,5)

If the vessel has raise of floor or sharp curved contours then it is necessary to use special intermediate flat platform (fig.3,4,6,7).

Fig. 1

Fig. 2

Fig. 3

Fig. 4
Fig. 5. Preparation for transportation flat bottom vessel in inflatable elastic container placed directly between the bottom of the ship and berth platform

Fig. 6. The process of transporting the vessel with curved contours using intermediate flat platform

Fig. 7. Installation of the vessel with curved contours on intermediate flat platform (stern view)

Reaction force of each tank, acting on the bottom of the ship can be determined by the equation:

\[ Q = \rho F_i \]

Reaction action lines match with vessels center line if the tanks are located symmetrically about vessels center line. According to the condition of equilibrium can be written

\[ G = \Delta \]

where \( G \) – vessel weight, \( \Delta = \sum Q \) – maintaining force (equal the displacement). Then vessel weight can be determined by equation

\[ G = \sum \rho F_i \cdot \]  

(1)

Fig. 8. The sequence of operations during the installation vessel to inflatable elastic tanks: \( ? \) – vessel on keelblock; \( b \) – laying inflatable elastic containers between the keel blocks; \( c \) – supply pressure in tanks and lifting vessel from Keelblock; \( 1 \) vessel hull; \( 2 \) – keelblock; \( 3 \) – building ways; \( 4 \) – inflatable elastic tank without pressure; \( 5 \) – inflatable elastic tank with the pressure, sufficient to lift the vessel

Fig. 9. Determination of the weight of the vessel's center of gravity and the abscissa (weighing)

When the trim is missing abscissa of vessels center of gravity equal to abscissa of fulcrum support can be determined by the expression.

\[ x_q = \frac{\sum Q_i x_i}{\sum Q_i} \]

Or finally, after appropriate substitutions

\[ x_q = \frac{\sum \rho F_i x_i}{\sum \rho F_i} \cdot \]  

(2)

3. Inclining of vessel (Determination of vessel weight and applicates of its center of gravity)

The vessel is set on keelblocks on building ways as during weighing (fig 8a). The tanks are lay transverse under the bottom between keelblocks (fig 8b). When the pressure increases the tanks abut against the bottom and lift the vessel above the keelblocks. The lifting of vessel should be such to avoid contact of vessel with keelblocks while inclination to the required angles (fig 8c).

There is a fixed-ballast with weight lay on upper deck in midship section on height above principal plane with offset to one side from centre line on distance. As a result the heeling moment which lead to the ship heeled to the \( \theta \) angle appears (fig 10).

Because of it, deformation of an inflatable elastic tank asymmetrical about centre line.

There are list of characteristics such as: internal pressure, contact area of bottom with tank, and ordinate of center of gravity of contact area in reference to centre. (fig 11).

In the heeled condition (fig 10) the value of arm of heeling moment can be determined by equation

\[ e_i = e_i^0 \cos q + b \sin q \]
Rise of center of gravity of solid ballast above the center of gravity of the vessel

\[ b = H_{cp} - Z_g; \]

In the equilibrium heeled condition (fig.10, 12) at \( Q \) angle the heeling moment can be determined by equation

\[ M_{KP} = P \cdot \rho = P \left( \epsilon'_c \cos q + b \sin q \right) \]

Or finally, after appropriate substitutions

\[ M_{KP} = P \left[ \epsilon' \cos q + (H_{cp} - Z_g) \sin q \right] \]

\[ \Delta = \Delta' \cos q \]

\[ \Delta = \Delta' \cos q \]

\[ \Delta = \Delta' \cos q \]

Repeating moment in heeled condition of equilibrium in considering with \( \Delta = \Delta' \cos q \) (fig.12)

\[ M_B = 1' = 1' \Delta' \cos q \]

The ratio at equilibrium condition it’s necessary \( M_{KP} = M_B \) and \( G + P = \Delta \). After substitution values we get the equation

\[ P \left[ \epsilon' \cos q + (H_{cp} - Z_g) \sin q \right] = 1' \Delta' \cos q \]

Introduce notion of conditional metacentre, conditional arm of static stability and conditional metacentric height.

As it’s known the metacentre is a center of curvature the trajectory at which the center of buoyancy moves when vessel heeled. Characteristics of this trajectory depends on dimensions and form of the displacing part of the vessel.

If the vessel is set on the building ways on elastic tanks then hull form does not affect stability of the system. General principles of interaction of vessels hull and elastic foundation are basically equal.

The hull will get heel when the heeling moment is applied. As a result the reaction of elastic foundation appears. Resulting reactions of elastic foundation will move in the direction of that board in which the vessel heeled. It will lead to appearance of the restoring moment.

Point of intersection of action line of resulting reactions of elastic foundation with projection of centre line is a conditional metacentre. (Point M on fig.12).

Appropriate rise of conditional metacentre above the centre of gravity is a conditional metacentric height.

And distance along the normal between lines of action of forces of vessel weight \( G \) and maintained force \( \Delta \) - is a conditional arm of static stability.

It should be noted that the above characteristics have nothing to do either qualitatively or quantitatively with the same true parameters of the vessel afloat.

However, they enable us to determine the \( Z \) center of gravity of the vessel, which has nothing to do with hydrostatic characteristics of the vessel hull.

From the previous formula we get the value of the conditional shoulder static stability

\[ l' = \frac{P \left[ \epsilon' \cos q + (H_{cp} - Z_g) \sin q \right]}{\Delta' \cos q} \]

\[ l' = \frac{P \left[ \epsilon' \cos q + (H_{cp} - Z_g) \sin q \right]}{\Delta'} \]

whence

\[ l' = \frac{P}{\epsilon' + (H_{cp} - Z_g) \tan q} \]  \hspace{1cm} (3)

In a simplified version, taking into account the fact at low angles of \( \tan q = q \), we can write

\[ l' = \frac{P}{\Delta' \tan q} \left[ \epsilon' + (H_{cp} - Z_g) q \right] \]  \hspace{1cm} (37)

The conditional metacentric height(fig.12) can be determined by equation

\[ h' = \frac{l'}{\sin q} \]

\[ h' = \frac{P}{\Delta' \sin q} \left[ \epsilon' + (H_{cp} - Z_g) \tan q \right] \]  \hspace{1cm} (4)

In a simplified version, taking into account the fact at low angles of \( \tan q = \sin q = q \), we can write

\[ h' = \frac{P}{\Delta' q} \left[ \epsilon' + (H_{cp} - Z_g) q \right] \]  \hspace{1cm} (47)
Value of applicable of conditional metacentre comparatively principal plane (fig.12).

\[ H^* = \frac{e}{\tan q}. \]  

(5)

The applicable of centre of gravity vessel comparatively principal plane can be determined by using the (4) and (5) equation.

\[ z_g = H^* - H = \frac{e}{\tan q} = \frac{P}{\Delta' \sin q} \left[ e' + (H_{GP} - z_g) \tan q \right]. \]

\[ z_g = \frac{e}{\tan q} = \frac{P}{\Delta' \sin q} \left( e' + H_{GP} \tan q \right). \]

We solve the resulting equation for \( z_g \)

\[ z_g = \frac{e}{\tan q} - \frac{P}{\Delta' \sin q} \left[ e' + H_{GP} \tan q \right]. \]

whence

\[ z_g \left( \frac{1}{\Delta' \sin q} \right) = \frac{e \cos q}{\sin q} - \frac{P}{\Delta' \sin q} \left[ e' + H_{GP} \tan q \right]. \]

or finally

\[ z_g = \frac{e \cos q - \frac{P}{\Delta' \sin q} \left[ e' + H_{GP} \tan q \right]}{\sin q \left( \frac{1}{\Delta'} \right)}. \]  

(6)

In a simplified version, taking into account the fact that at low angles \( \tan q = \sin q = q \), and \( \cos q \approx 1 \), equation (6) becomes

\[ z_g = \frac{e - \frac{P}{\Delta'} \left[ e' + H_{GP} \tan q \right]}{q \left( 1 - \frac{P}{\Delta'} \right)}. \]  

(6?)

There is calculation result of \( Z_g \) using (6) and (6a) equations at various angles of heel presented in the table below.

Calculation errors when using a simplified formula are also defined in the table.

For the calculation used the following data \( \Delta' = 3000 \) t; \( P = 5 \) t; \( H_{GP} = 10 \) m; \( e' = 7 \) m; \( e = 0.3 \) m.

Calculations have shown that at heeled within \( 3^\circ \), the maximum error in the determination of the above approximate formula (6a) does not exceed 0.15%.

Given the fact that the metacentric height is usually order of magnitude smaller than , that is defined as a small difference of large values, the approximate version of the formula is quite applicable to an angle of heel of \( 3^\circ \).

in this case the error of determination of metacentric height associated with the calculation error will be no more than 1.5%.

The weight characteristics of the flat intermediate platform(fig. 3,4,6,7) must be determined earlier and then must be considered with calculations.

These methods of determining the vessel weight and the coordinates of its centre of gravity are the subject of invention, the application for which are sent in patent organizations of leading shipbuilding countries.

Table 1

<table>
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<th>( \frac{r}{\text{radian}} )</th>
<th>0.5</th>
<th>0.00873</th>
<th>1.0</th>
<th>0.01745</th>
<th>1.5</th>
<th>0.02618</th>
<th>2.0</th>
<th>0.03491</th>
<th>2.5</th>
<th>0.04363</th>
<th>3.0</th>
<th>0.05236</th>
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<td>33.08</td>
<td>16.53</td>
<td>11.01</td>
<td>8.251</td>
<td>6.596</td>
<td>5.491</td>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>( Z_g ) (6?)</td>
<td>33.07</td>
<td>16.53</td>
<td>11.02</td>
<td>8.256</td>
<td>6.603</td>
<td>5.499</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \Delta ), %</td>
<td>0.03</td>
<td>0</td>
<td>0.09</td>
<td>0.06</td>
<td>0.11</td>
<td>0.15</td>
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NEW TRENDS IN ENVIRONMENTAL SAFETY IN SERBIA

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Abstract: In the Republic of Serbia the air is the most polluted element of the environment. During the last five years in our country the concentration of sulphur-dioxide was increased. During 2011, the Ministry of Environment, Mining and Spatial Planning allowed the subvention for purchasing hybrid cars in our country. As the final result all cars with emission of carbon dioxide less than 100 g per kilometer ran will have certain privileges i.e. there will be additional benefits for all those who drive “green” cars. However, they are not exempted from customs duties, as it was announced. Investment of “Fiat” is the biggest investment in the sector of auto industry in Serbia. Before arrival the giant from Torino in Kragujevac the investments of producers of parts have already started.

By the new environmental regulations of the European Union all types of trucks and buses produced in 2013, will emit considerably less harmful exhaust gases. By these provisions so-called Euro 6 the reduction of 80% for nitrogen-oxide emission and 66% for particulates is predicted. It is interesting that in France Ministry of Ecology presented the number of measures directed on struggle against air pollution in large cities, among which is also the prohibition of entrance in the center of cities vehicles that are the biggest polluters. The question is how to provide for only “green” vehicles to enter in the center of cities? It is very important that the number of “green” vehicles constantly increases.

In March 2013 on the 83rd Geneva International Auto Show the public found out that still only every tenth car’s model exhibited can be lauded for its “green” qualities. It is necessary to stress in media and inform wider public on the importance of environmental aspects of traffic taking into consideration the well known fact that much cars reduce air quality by emission of harmful gases.

Key words: POLLUTION, ENVIRONMENT, SAFETY, HYBRID CAR, REGULATION, SERBIA

1. Introduction

Chaotic development of cities and industry was not followed by the corresponding measures of protection against pollution.

While every day in the world three to four plants disappear, experts claim that in our country the first to bear the brunt of climate changes will be conifer species with shallow root, like for example, spruce. Therefore......traffic, as the main air polluter throughout the world should be controlled. Transport emissions rose by 24% between 1990 and 2008, amounting to 19.5% of total EU greenhouse gas emissions, according to the Commission’s estimates. As a result, the transport sector will have to reduce missions by at least 45-60% below 1990 levels if the EU is to keep up with its climate change objectives for 2050.

In the past, environmental measures have cleared up much of the visible pollution in urban areas, but smog, soot and haze persist in many cities. Today we use market-based strategies to promote new, less-polluting technologies.

2. Perspectives of Serbia

Between 1972 and 1977 several studies confirmed the hypothesis that air pollutants could travel several thousands of kilometers before deposition and damage occurred. The 1979 Geneva Convention on Long-range Trans-boundary Air Pollution, entered into force in 1983, has created the essential framework for controlling and reducing the damage to human health and the environment caused by trans-boundary air pollution.

In the Republic of Serbia the air is the most polluted element of the environment. During traffic jams the concentration of harmful substances is increased for 20%. Nitrogen dioxide is regularly growing, as well as polycyclic aromatic carbon hydrogens, whose level is raising during winter.

During the last few years in our country the concentration of sulphur-dioxide was increased. It is well known that in Serbia inhabitants in the city of Belgrade have the worst air quality because of sulfur dioxide presence.

On the list of the biggest polluters in Europe, Serbia is on the 5th place with around 6.2 tons of carbon dioxide per capita, and one of the largest emitters of harmful gases is just transport sector.

By the new environmental regulations of the European Union all types of trucks and buses produced in 2013, will emit considerably less harmful exhaust gases. By these provisions so-called Euro 6 the reduction of 80% for nitrogen-oxide emission and 66% for particulates is predicted. New EU provisions are in accordance with limitations of harmful gases emissions that are already in force in USA.

During 2011, the Ministry of Environment, Mining and Space Planning allowed the subvention for purchasing hybrid in our country. As the final result all cars with emission of carbon dioxide less than 100 g per kilometer ran will have certain privileges i.e. there will be additional benefits for all those who drive “green” cars. Owners of the ecologically “suitable” cars get ECO Friendly licence in the form of certificate on the occasion of vehicle purchasing. In Serbia all owners of cars with CO2 emission less than 0 g per kilometer will enjoy certain privileges, like more favorable insurance package, provision of free parking, more favorable conditions of financing. However, they are not exempted from customs duties, as it was announced. Investment of “Fiat” is the biggest investment in the sector of auto industry in Serbia. Before arrival of the giant from Torino in Kragujevac the investments of producers of parts have already started.

Our capital for 51-st Auto Show1 and 7th exhibition of motorcycles “Motopassion” with the most modern offer (from 22nd to 31st March 2013) for the first time presented 37 car bra and the host of the Show in Belgrade was „Fiat 500L” from Kragujevac, so called „umadina”, whose tracking version has already been presented on the Show in Geneve. Remainin models from „Fiat” (model 500, “punto” “bravo”,“panda”, “freemont”) were also presented, as well as the third generation of „Skoda octavia” for the first time presented at the Show in Belgrade. It is well known that „Renault” is one of the favorite brands among our drivers, and on the Show this year was presented with mini SUV, “Clio grandtour” and “Xenic X mod”.

In our country, it is clear that nautica - sailing is the chance for tourism development too, and especially after constructions of small marines and pier for charter ships. Today, in the season on the passenger dock in Karadžorđeva str. in the capital Belgrade, up to 300 yachts, passenger ships and smaller ships for excursions put ashore. Economic crisis is the reason why during 2008, there where 120, and now not even 15 new ships. However, there is a fleet of charter ships for renting mainly for weekend sailing.

Although noise can significantly pollute environment, American Governmental Agency for Road Traffic Safety requested at electrical and hybrid vehicles make more noise when go g with smaller gears so that pedestrians might hear them coming and trucks on electrical drive are considerably more quiet from vehicles.

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1 On the Belgrade Car Show 28 manufacturers presented their models. From the world premiere in Geneve on the Serbian market “series 3”, i.e. “BMW series 3 GT” were presented. It is interesting that for each BMW car bought buyers got 4 benefits: a four-year guarantee, as well as four years of free regular checks, some more favourable conditions of financing and possibility of buying up vehicle old for new.
using oil products i.e. having internal combustion engine. National Administration for Road Traffic reported that conventional vehicles are not noisy enough when going slower, so there is a risk for pedestrians, bicyclists and persons having problems with sight. It was offered 60 days to the public to give comments on the proposed rules, and Agency will use them during formation of final solution.

We should mention here the Directive on the assessment and management of environmental noise, in effect from July 2002, applies to environmental noise in built-up areas and public parks, and near schools, hospitals and other noise-sensitive buildings and areas. It does not apply to noise from domestic activities, from neighbors, at work, inside means of transport or from military activities in military areas.

Our plan in Serbia is achieving the long term objective of not exceeding critical ceilings and of protecting human health from the risks associated with atmospheric pollution.

3. World trends

For the long time Europe was heart of the modern world, and according to some indicators it is also today.

For a moment in the European Union Euro 5 standards in connection with limitation of harmful gases emissions are in effect. Restrictions mainly refer to nitrogen-oxides and harmful particles. Although regulation in connection with harmful gases emission, as far as passenger cars in EU are concerned, exists back from 70-ies of the last century. From then it was constantly tightened from Euro 1 norms from 1992, to Euro 6 rules that will go into effect in 2014.

It is interesting that in France Ministry of ecology7 presented the number of measures directed on struggle against air pollution in large cities, among which is also the prohibition of entrance in the center of cities vehicles that are the biggest polluters. The question is how to provide for only “green” vehicles to enter in the center of cities?

According to data of the International Organization of Motor Vehicle Manufacturers (OICA) by indicators from year 20127 the biggest manufacturer in European region is Germany, afterwards on the second place Russia as producer of 11% of cars, then follows France. For “Folkswagen group” Russia is the most important developing market in Europe. Now, with new engines factory in Kaluga, “Folkswagen” will remain provider of the Russian auto industry in the future.

Simultaneously the famous jeep producers (“Land Rover”) on the Car Show in New York presented and promoted model “Range Rover Sport”8 made of aluminum.

It is interesting that “Volvo” car corporation increases production capacities for new “Volvo B60 plug-in hybrid”9 beginning series of 1000 copies for this year 2013, to even 4000-6000 for year 2014. This car owns sophisticated plug-in hybrid technology that includes two power options and strong which enables the autonomy of movement for 50 kilometers, exclusively using current.

And while there is intention and belief that group “Peugeot-Citroen” will launch on the market till 2016 first hybrid vehicle using air for propulsion (adapted transmission will have cylinders of compressed air that preserve and release energy), in Switzerland6 exactly do not accept vehicles with hybrid and electrical drive.

Last year “Tojota”7 sold over 1,2 million hybrid vehicles thanks to the success of its brand “Prius” in the world, as well as the new brand “Aqua” in Japan.

It has been known that in 2003, newly established company “Tesla motors” in Freemont in California joined also to the great American automobile companies “General motors”, “Ford” and “Craiser” from Detroit. The name Tesla was not taken accidentally, because the main electric engine on these cars was made on the principles of Nikola Tesla’s invention from 1882. Deliveries of model “Tesla S” for American market began in the summer of 2012. with expected 5000 orders. During Exibition of consumers’ electronics in Las Vegas in 2012. the special attention provoked the instrument board of this elegant electric car, with dominant touch sensitive screen on the right side of the steering wheel by which all car functions are regulated.

We still do not know if model “Tesla” succeeded in commercial sense, but it is interesting that this auto business started in the cradle of inventions that at the end of last and at beginning of this century have changed the civilization.

The newest reports on testing “Tesla “, i.e. polemic on advantages and faults of this electric car from the factory named by “the most underestimated inventor in American history”, show that injustice toward Nikola Tesla to a certain degree is corrected naming by him first electric car of the modern era. Along the strategic road corridors “Tesla motors” has started to open special charging stations where electricity is free. Till now this car model was reserved by 13 000 buyers and in December 2012 factory announced the production tempo of planned 400 cars/weekly. This company also got credit from American Government in amount of 465 million dollars.

From Croatia came information that for the first time in the car is exported and that is electric car from the company “Rimac automobiles”. First world electric supercar was bought by one Spanish auto company.9

Perfection is in simplicity. However, on this year’s Auto Show in Detroit 2013, vehicles on electricity, hybrids and small cars remained completely in the shade.

The parade of the car on the 83 rd International Auto Show10 the most economical car11, “the economical wonder” from Germany, the remarkable aerodynamic hybrid model XL1 was presented. This car following the principles of sport cars design with two seats can cover a distance up to 50 kilometers in electrical drive regime and with zero emission of exhaust gases. It is interesting that in Geneva there were no signs on crisis in the world auto industry. In the city on Leman lake during March 2013. the strength and beauty were shown, without talking on recession, problems and decrease of sale and expensive fuel.

During two weeks in September 2012. (from 8-th till 24-th) 15 cars and tracks were driving rally throughout the Europe. The parade rally of “Blue Corridor” was filled exclusively by natural gas, so in that way the availability of natural gas on transit ways between East and West was emphasized. The number of pumps with natural gas increased in the last 7 years and so around 4000 of

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7 Hybrid vehicles represented 14% of total sale in 2012 from 1997, when first hybrid car “Prius”, that much less pollutes environment was placed in market, they were sold in 80 countries in the world.

8 This company was established to promote exclusively cars on electric propulsion instead of the engines that have in it. First car was “Tesla roadster” that made commercially debut in 2008: as sportsmanike sedan with caracteristics no one of competitors had (body was borrowed from British “lotus”), but its production was anyway suspended in autumn 2011. Experience gained with production of this model was used for model “Tesla S” installed in engine room in Freemont (used before by “General motors” and “Toyota”) and there are 3 models differentiated by capacity of batteries (40, 60 and 85 kilowatt-hours). The weakest of these models with one charge covered distance of 160 kilometers, with average speed of 90 kilometers per hour. This is one futuristic product in which everything is chosen or adjusted by touch screen: music, navigation, ride indicators, air, charging, even permanent internet connection. The question is do these interventions turn away attention from the road? Manufacturers answer that divers get used to them fast.

9 This sale to Spaniards will provide for resources for months of work for innovator and owner of the company “Rimac automobiles” from Samobor.

10 Distant 1905. the first exhibition of cars was held which developed into Show, that is today real spectacle of strength and elegance of more 700 models exhibited (“Auto world”, 11-th of March 2013, “Politika”, Belgrade).

11 Car is 115 centimeters high, 3.5 meters long and 1.6 meters wide, with consumption of 0.91 liters per 100 kilometers.
them in Europe (only 900 pumps in Germany) point out an significant growth of this network of pumps. In that way it was made possible that more than 1,5 million vehicles in Europe use gas. In Russia the pumps with gas as the fuel are also rapidly built.  

4. Conclusion

Pollution of living environment is seen in different shapes. Undesirable consequences of human activities disrupt natural living frame, and air is most frequently under an impact of pollutants.

Emissions will be the main factor to consider in designing the transport system of the future. One solution would be to use market-based instruments in particular fuel taxes, kilometer charges and cap-and-trade systems to make transport users pay for emissions, air pollution or noise.

It is necessary to stress in media and inform wider public on the importance of environmental aspects of traffic taking into consideration the well known fact how much cars reduce air quality by emission of harmful gases.

Increase of vehicles using natural gas happened because of economic benefit for consumers, but they were certain urged also by ecological interests. Euro 6 Standard will be applied from year 2015 and in that way nitrogen-oxide emission will be limited and in such a way the quality of air we breathe improved.

It is very important that the number of “green” vehicles constantly increases. In March 2013 on the 83rd Geneve International Auto Show the public found out that still only every tenth car’s model exhibited can be lauded for its “green” qualities.

5. Literature:

3. „Kombeg” info, izdaje ovlašćena agencija Privredne komore Beograda za odnose sa javnošću, mart 2012. („Kombeg” info, issued by authorized Agency of Economic Chamber of Belgrade, for public relations, March 2012.)

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11 During 2012 the price of gas on pumps was for (one) third lower than of gasoline, and the technology of filling vehicles with gas is widely available for new cars, buses and tracks. It is predicted that till year 2020 there will be 20 million vehicles using natural gas.

Abstract: The hydraulic hybrid is an alternative powertrain that offers an efficient way to recover braking energy and designed to enable a boost effect that would normally be offered only by complex electric drives. All vehicle manufacturers, in the stages of vehicle development, apply Vehicle simulation software for calculation of driving performance, fuel consumption and emissions of toxic gases. In order to investigate the potential possibilities of application of hydraulic hybrid drive in passenger cars in the urban environment during standard cycle UDC, NEDC, a modeling of the potential hybrid vehicle based on the platform of Yugo Florida is performed. Results show that it can achieve significant savings in fuel consumption, especially in case of vehicle motion purely based on hydraulic drive.

Keywords: HYDRAULIC HYBRID, VEHICLE SIMULATION, FUEL ECONOMY

1. Introduction

Hydraulic hybrid drive has already found considerable use in utility vehicles (garbage truck), but that's not all the possibilities offered by this type of powertrain technology. Due to its simplicity and robustness, and proven effects in fuel consumption reducing, the use of hydraulic hybrid system is suitable for all vehicles used in urban areas with frequent start-stop driving regime [1,2].

The hydraulic hybrid is alternative powertrain that offers an efficient way to recover braking energy and designed to enable a boost effect that would normally be offered only by complex electric drives. Here, a conventional internal-combustion engine combines with hydraulic units and an accompanying nitrogen pressure accumulator to provide a brief boost to acceleration. The hybrid system is able to support gasoline and diesel engines in ranges where they do not work at optimum efficiency. The hybrid system makes use of energy that would normally go to waste. Braking, for instance, quickly fills up the hydraulic accumulator: the kinetic energy captured during braking is converted into hydraulic energy and stored in the pressure accumulator. Normally, this energy would go to waste, turning into heat in the friction linings of the brakes. The advantages of a hybrid powertrain are equally evident when the vehicle is travelling at a constant speed. Here, the engine can be run within an efficient range while also filling the hydraulic energy accumulator.

2. Current status of hydraulic hybrid technology

The hydraulic full-hybrid powertrain technology, which Bosch is developing in collaboration with PSA Peugeot Citroën (Fig.1), is clear in its aims: to supply a hydraulic hybrid powertrain that will significantly reduce fuel consumption and CO₂ emissions in compact cars [5].

The hydraulic hybrid is designed to enable a boost effect that would normally be offered only by complex electric drives. Here, a conventional internal-combustion engine (ICE) combines with hydraulic units and an accompanying nitrogen pressure accumulator to provide a brief boost to acceleration. The hybrid system is able to support gasoline and diesel engines in ranges where they do not work at optimum efficiency.

The power-split concept permits various drive options. For short journeys, stored energy can be used to run exclusively on hydraulically generated power, with the internal-combustion engine remaining inactive and the vehicle producing zero emissions (ZEV). For longer journeys, or when driving at higher speeds, acceleration force is provided by the internal-combustion engine. Alternatively, the two types of powertrain can also be combined. In this case, the energy stored in the hydraulic system and the fuel burned in the internal-combustion engine work together to drive the vehicle, which also provides a brief boost effect. The smart control system adapts the operating mode to the driver's command and optimises energy efficiency in three different modes.

According to the reports issued by manufacturers, in the New European Driving Cycle (NEDC), it has the capacity to reduce fuel consumption by up to 30% when compared to a conventional internal-combustion engine.

3. Modeling of vehicle

All vehicle manufacturers, in the stages of vehicle development, apply software for calculation of driving performance, fuel consumption and emissions of toxic gases. AVL CRUISE [4] is Vehicle simulation platform basically developed for optimization of vehicle and vehicle components (fuel economy, vehicle performance).

Its modular concept enables efficient and quick evaluation of new vehicle concepts (eg, hybrid electric vehicle, fuel cell). AVL CRUISE is used to perform vehicle simulation and powertrain analysis. It is designed to develop and optimize low emission engines, reliable powertrains, and sophisticated control systems of engines, cooling, and transmission systems. CRUISE supports the engineer during the whole engine and vehicle development process in standard applications, such as fuel economy and full load acceleration tests, hill climbing performance and traction diagrams, as well as computational concept studies including the mechanical, electrical, thermal, and control system. This integrated solution makes simultaneous engineering in the development process possible, which is the basis for reducing development times and costs. properties of selected powder materials.

In order to investigate the potential possibilities of application of hydraulic hybrid drive in passenger cars in the urban environment during standard cycle UDC, NEDC, a modeling of the potential hybrid vehicle based on the platform of Yugo Florida is performed. Basic features of the car are: engine displacement 1116 cm³, power rating 45 kW at 6000 rpm, curb vehicle weight 910 kg and gross vehicle weight 1310 kg.

Taking into account the fact that it is a subsequent installation of the hydraulic drive device for research purposes, a separate configuration of driving units was chosen, where the hydraulic system is attached to the rear axle of the vehicle. This solution, in
addition to the practical side, has the advantage of better front/rear axle load distribution, which is used in some hybrid vehicles (e.g. Volvo). It is also easier to solve management system when there is only one of the two drives (ICE, hydraulic unit). The downside of this solution is doubling the differential mechanism and driving shafts, although the measurements of these elements are considerably smaller due to the lower values of torque generated by hydromotor.

With the wide use of the opportunities provided by the CRUISE simulation software, an upgrade of the standard FWD model as applied to vehicle Florida is performed, with a powertrain consisting of a rear differential gear and the main gear, and a module which performs the function of variable hydraulic motor/pump. Of course, the vehicle model is supplemented with the control unit (hybrid switch) that performs actuation of the hydraulic system based on parameters obtained from the cockpit [3]. Input parameters for the hydraulic control unit are: acceleration pedal travel, brake pressure, vehicle velocity (speed pump/motor), accumulator SOC and vehicle acceleration during travel. Operating range of hydraulic drive is within the range of 1-50 km/h.

Dimensioning of the hydraulic system was based on the declared maximum acceleration, i.e. deceleration in the UDC cycle located within the limits + / - 1 m/s². These system performances can be achieved by using a variable axial motor with the nominal displacement of 10 cm³, with a rated speed 3600 rpm and maximum torque of 42 Nm at 250 bar. Mass of the motor is 8 kg. Accumulator capacity is a value directly relevant to the autonomous motion of the vehicle on hydraulic drive, and for this purpose the selected unit of 10 liters which enables autonomous motion within a UDC cycle. Accumulated energy of 0.25 MJ at nominal pressure is enough for the vehicle chosen for the simulation. Of course, with the increase of the capacity of accumulators (e.g. PSA), a better autonomy of the vehicle can be achieved without using the ICE, although it should be noted that this will be followed with the increase of the vehicle mass, which ultimately may compromise the energy efficiency of the whole project. In general, vehicle operating mode is dominant for the selection of optimal characteristics of the elements of the hydraulic system.

Figure 2 shows a simulation model of a car used to examine the effects of the application of hydraulic hybrid system with special emphasis on energy efficiency and emission of toxic gases. It is a standard FWD manual scheme, with the friction clutch and five-speed gearbox. The optional start-stop function is available, with which the effects of the hybrid would be undoubtedly higher, since it enables the acceleration of the vehicle up to a certain speed with the engine off. In this case it is possible to reduce the fuel consumption for a few extra percents.

4. Comparative analysis of fuel consumption

Figure 3 shows the distribution of the drive torque at UDC cycle, where it is evident that the departure of vehicle is supported with ICE, and the hydraulic drive is engaged when the hydro-motor speed exceeds 10 rpm. The reason for that is the reduced efficiency values at low engine revs. The same principle is applied when the hydraulic system works in the pump mode, i.e. decelerates the vehicle, where the vehicle may stop with the assistance of the service brake.

For the purpose of comparative analysis, Figure 5 shows a variation of the torque and the introduction of the service brake in case of the lack of hydraulic system assistance (motion of the base vehicle under UDC cycle) with the remarkable increase of energy used by ICE and longer braking.

Figure 4 describes a flow of volume variation in hydroaccumulator during the UDC cycle, where at the end there is the increase in volume of about 1l, as a result of somewhat greater use of ICE for vehicle acceleration, relative to the influence of regenerating braking in case of vehicle deceleration.
Table 1 Fuel consumption in UDC

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>standard FWD</th>
<th>hydraulic hybrid</th>
<th>reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>0.0489</td>
<td>0.0429</td>
<td>12.3%</td>
</tr>
<tr>
<td>Engine idle</td>
<td>0.0099</td>
<td>0.0099</td>
<td>-</td>
</tr>
<tr>
<td>Acceleration</td>
<td>0.0154</td>
<td>0.0091</td>
<td>40.9%</td>
</tr>
<tr>
<td>Const. drive</td>
<td>0.0170</td>
<td>0.0170</td>
<td>-</td>
</tr>
<tr>
<td>Deceleration</td>
<td>0.0066</td>
<td>0.0068</td>
<td>-</td>
</tr>
</tbody>
</table>

In any case, the control module (hybrid switch) is the unit which maintains the necessary power reserve in the accumulator, depending on the desired effect. If the goal is to perform the entire UDC drive cycle solely on hydraulic drive (for which it is necessary to have a fully recharged accumulator), it is possible to use ICE in optimal regime, to refill it to the required level. Figure 6 shows a variation of torque from the hydraulic in the process of refilling the accumulator up to the full capacity, which is performed during the vehicle at a constant speed. The control system is designed to fully charge the accumulator during the one UDC cycle, which is shown in the same Figure through the increase of the fluid volume in the accumulator.

Table 2 Fuel consumption in dual UDC cycle

<table>
<thead>
<tr>
<th>Operation mode of the system</th>
<th>2x Combined drive</th>
<th>Combined drive with restore function + Solely hydro-drive</th>
<th>reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>0.0858</td>
<td>0.0595</td>
<td>30.6%</td>
</tr>
<tr>
<td>Engine idle</td>
<td>0.0198</td>
<td>0.0099</td>
<td>50.0%</td>
</tr>
<tr>
<td>Acceleration</td>
<td>0.0182</td>
<td>0.0089</td>
<td>51.1%</td>
</tr>
<tr>
<td>Const. drive</td>
<td>0.0340</td>
<td>0.0332</td>
<td>2.3%</td>
</tr>
<tr>
<td>Deceleration</td>
<td>0.0136</td>
<td>0.0074</td>
<td>45.6%</td>
</tr>
</tbody>
</table>

Table 3 shows the comparative fuel consumption of the basic vehicle and hydraulic hybrid vehicle in the NEDC, which consists of four UDC and EUDC cycles. As expected, the effects of the application of hybrid drive are decreasing at speeds over 50 km /h due to the lack of the assistance of the hydraulic unit. Yet the cost savings achieved by the use of this kind of hybrid technology in passenger vehicles is evident.

Table 3 Fuel consumption in NEDC

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>standard FWD</th>
<th>hydraulic hybrid</th>
<th>reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>0.3885</td>
<td>0.3608</td>
<td>7.1%</td>
</tr>
<tr>
<td>Engine idle</td>
<td>0.0457</td>
<td>0.0460</td>
<td>-</td>
</tr>
<tr>
<td>Acceleration</td>
<td>0.1460</td>
<td>0.1153</td>
<td>21.0%</td>
</tr>
<tr>
<td>Const. drive</td>
<td>0.1615</td>
<td>0.1619</td>
<td>-</td>
</tr>
<tr>
<td>Deceleration</td>
<td>0.0353</td>
<td>0.0376</td>
<td>-</td>
</tr>
</tbody>
</table>

5. Conclusions

- This paper shows the potential benefits gained from the use of Hydraulic hybrid system for passenger car, on a NEDC and especially during the UDC cycle, where the reduction of fuel consumption of approximately 30% is expected.
- Engine can be run within an efficient range when the vehicle is travelling at a constant speed while refilling the hydraulic energy accumulator at the same time.
- Depending on the capacity of the accumulator, the stored energy can be used to run the vehicle exclusively on hydraulically generated power, thus providing the vehicle producing zero emissions (ZEV).
- Hybrid systems are highly beneficial in a frequent stop-start (urban) driving regimes.

References

[4] AVL CRUISE v2010


**APPROACH FOR GENERATION OF EXTENDED STRUCTURAL SCHEME FROM CAD MODEL OF ASSEMBLY**

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**Abstract:** After the creation of a CAD model there may be required to do an analysis of its applicability to solve specific tasks. The conducting of this analysis is simplified considerably if the full geometry of the components is not seen but only imposed geometric relationships between them, which are the content of the structural scheme of the assembly. This paper proposes an approach for an automatic generation of the structural scheme of a mechanical assembly from its CAD model. It should be noted that the structural scheme, considered in the conventional sense, does not contain the actual properties of geometric relationships – in the structural scheme the components are of the same type when in fact they are divided into basing and based. Therefore, there are generated the so-called extended structural scheme that contains all components and their basing patterns.

**Keywords:** CAD MODEL OF ASSEMBLY UNIT, STRUCTURAL SCHEME, BASING OF PARTS, CAD MODEL ANALYSIS, AUTOMATIC GENERATION OF STRUCTURAL SCHEME

1. **Introduction**

To create a model of an assembly today’s CAD systems provide geometric constraints with which the components are oriented in the space or relative to each other. The proposed geometric constraints are in fact mathematical constraints that have no direct connection with the actual geometric relations in the real product. For these reasons, when the designer models an assembly, it creates more or less formal geometrical relationships between the components. Because it is difficult to achieve the creation of a real model, the primarily goal is to achieve high efficiency, which means to reduce the time and effort required for the technical work associated with entering information into the computer.

Along with the above, after the creation of the geometrical model a number of engineering analyzes follow, proper or even the possibility of having their implementations depend on an adequate imposition of geometric constraints for orientation. There may be listed kinematic and dynamic analysis, and creation of various animations that require a geometric model that has necessary degrees of freedom and has adequate connections between its components.

From the above it follows that when a CAD model has been created there may be necessary to make an analysis of its applicability to solve certain tasks. Performing this analysis is significantly simplified if the complete geometry of its components is not considered but only the imposed geometric relationships between them, which are the content of the structural scheme of the assembly.

This work proposes an approach for an automatic generation of the structural scheme of a mechanical assembly from its CAD model. It should be noted that the structural scheme, at issue in the conventional sense, does not contain the actual properties of geometric relationships – in the structural scheme the components are of the same type when in fact they are divided into basing and based. Therefore, there are generated the so-called extended structural scheme that contains all components and patterns of their basing.

2. **Approach for generating the extended structural scheme**

The extended structural scheme of an assembly includes the following information [1]:

- the full list of the components;
- basing patterns of the components;
- primary and auxiliary bases of each of the components.

For the creation of an extended structural scheme there is developed an algorithm based on the Method of structural recursion [2].

The structure of the model of an assembly is represented as:

\[ S=(M, W), \]

where set \( M \) (holder) contains all components and set \( W \) (signature) – imposed geometric constraints for positioning.

There are introduced the terms:

- primitive \( P \) – a component that is currently being analyzed how it is orientated;
- macros \( M \) – a conditional assembly from a lower level that is formed at a certain stage of the analysis of the model.

By introducing the concept of primitives holder of structure \( M \) is defined as:

\[ M=M_1^r \ldots M_i^s \ldots M_n^r, \]

where \( M_i^s \) is a set of components of the stage “\( i \)” of the analysis of the model.

The transition to each stage of the analysis of the model is carried out by applying the formulated in [3] **Rule R**, by means of which the sets of primary and auxiliary bases are replaced with the corresponding sets of geometric constraints for positioning.

The structure of the assembly is formed in accordance with the following procedure:

On the level “\( 0 \)” the parts (called primitives) are divided into two sets:

- set of “Basing primitives” (that have sets of primary and auxiliary bases);
- set of “Based primitives” (that have only sets of primary bases).

To each basing primitive in accordance with its set of exported features of type “set of auxiliary bases” there are joined primitives with the “sets of primary bases.”

Linked by theirs complemented sets of bases, the based primitives are based in form of a new primitive, which are defined its own sets of primary and auxiliary bases (the set of primitives is updated).
On each higher level the available primitives are analyzed and the \textbf{Rule R} is performed for the formation of the structure.

On the highest level it is built the last primitive – the assembly that has only set of primary bases by which it is based in the environment (fundament, base, etc.).

The described procedure can be generalized as a structural recursion that is performed on the arbitrary level “$i$”, for which:

\begin{itemize}
  \item the sets of basing and based primitives are determined;
  \item the \textbf{Rule R} is performed.
\end{itemize}

In Figure 1 the graph of imposed geometric constraints in a model of an assembly is shown. If the imposed geometrical constraints meet the geometric relationship in the actual assembly, from the model can be generated its structural scheme.

Despite of the fact that the CAD system usually keeps the sequence by which the two components, which are involved in a geometric constraint, they are considered as equivalent. This means that from the CAD model cannot be made reliable conclusions about basing of parts.

For carrying out the engineering analysis of the structure of an assembly it is necessary to known how its components are based. For this purpose there must be known which geometric constraints fixate the component itself and which of them fixate other components to him. For example, on one component could have been imposed a number of geometric constraints for positioning, but it does not follow that the part is over constrained i.e. there are an availability of redundant geometric constraints.

The method of structural recursion is intended primarily for creation of the extended structural scheme of a mechanical product during the stage of the conceptual design. This work will illustrate an application of this method to recover the sequence of forming the structure of an assembly and the determination of the primary and auxiliary bases of the parts from the CAD model.

With assumption that the geometrical constraints for the positioning of parts in the CAD model are imposed on the basing surfaces of the primitives, the definition of the primary and auxiliary bases is performed by the following procedure:

\begin{itemize}
  \item from formal analysis of the CAD model for each primitive $P_j$ are determined basing surfaces (surfaces over which geometric constraints are imposed) – $P_j[b_1, \ldots, b_k]$;
  \item at the level “$i$” of the formation of the structure, the imposed geometric constraints between surfaces of the macro $M_{i-1}^j$, that is formed on level “$(i-1)$”, determine the basing surfaces of the primitives $P_k^i$ based on that level. So based surfaces of $P_k^i$ are divided into primary, marked with “$o$” and auxiliary marked with “$s$” – $P_k^i[o_1, \ldots, o_p, s_1, \ldots, s_r]$.
\end{itemize}

At level “$0$” the macro $M_0^j$ includes all fixed in the CAD model parts that have only main bases.

The proposed algorithm is illustrated in Figure 2.
3. **Practical implementation**

In order to verify the theoretical foundation it is made a practical implementation of the developed algorithm. A practical experiment was done with Autodesk Inventor, and for this purpose a VBA program is contrived, that performs the algorithm in Figure 2.

The created program has the following functionality:

- creates a list of all fixed components;
- creates a list of all pairs of parts over which geometric constraints for positioning are imposed;
- with extracted from the CAD model data performs the algorithm in Figure 2;
- the extended structural scheme is visualized using the package Graphviz [4].

As seen in Figure 1 on a pair of parts may be imposed more than one geometric constraint. This work does not take into account the type of restrictions, but the presence of geometric relationships between parts. Therefore, circumstances as this are ignored.

Experimental researches have been made with a random existing CAD model of an assembly, in this case the product “Impeller Pump” shown in Figure 3. Geometric constraints imposed in the model are illustrated in Figure 1. The structural scheme, automatically generated according to the proposed approach, is shown in Figure 4. On the structural scheme the arrows point from based to basing surfaces of parts.

4. **Outcomes**

An analysis of the automatically generated structural scheme in Figure 4 shows good consistency with the engineering meaning of the imposed relationships. Along with this there are also some exceptions.

It may be noted as an exception the relationship "Grooved Pilley" → "Washer" → "Bolted Connection", as the engineering logic suggests the opposite direction of the arrows. The reason for this is the imposed “cosmetic” relationship between "Bolted Connection" and "Housing" placed for the proper orientation of the screw head when a technical drawing is created. In the actual device such geometrical relationship does not exist.

Components “SKF 6203-Z:1”, “SKF 6203-Z:2” and "Bearing Spacer" are located on the same level of structural recursion so it cannot be identified which surfaces are basing and which are based. In this case it is necessary to be accomplished a further analysis of the imposed geometric constraints.

5. **Conclusion**

An approach for automatic generation of the extended structural scheme of an assembly from its CAD model is proposed. The preview of imposed geometric relationships allows easy to do an engineering analysis of both the structure of the CAD model and the actual product.

6. **Literature**


GENERATIVE GEOMETRICAL DESCRIPTION OF PART THROUGH SET OF ITS BASES

Ass. Prof. Dr. Eng. Stoev A., Ass. Prof. Dr. Eng. Goranov P.
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Abstract: In the modern CAD systems the geometry is described by geometric features. The features can be considered as engineering primitives that are adapted to perform some engineering tasks. By addressing the sets of bases as geometric features, in this work an analysis of the advantages of that geometric description of parts is done. Sets of bases are represented as a connective element between conceptual and geometrical models. On an abstract level the proposed description allows a generation of different geometric configurations that meet the functionality specified in the conceptual stage of the design process. A description of parts on the geometrical level in sets of bases allows the creation of a more realistic CAD model of an assembly. The description of a part through its sets of bases is called generative, because it can generate multiple geometric implementations which satisfy the imposed functional requirements.

Keywords: SETS OF BASES, GEOMETRICAL DESCRIPTION, INTEGRATED GEOMETRICAL MODEL, GEOMETRICAL FEATURES, CAD MODEL OF ASSEMBLY

1. Introduction

In the contemporary CAD systems geometry is described by geometric features. Features can be seen as engineering primitives that are adapted for the solution of any engineering problem. They can be used as building blocks, which what assemblies can be defined. In clear terms, the features are [3]:

– physical constituents of a part;
– allow geometry to be generated;
– have engineering meaning;
– have predictable properties.

The system must support at least the two main parts of the definition of the feature – geometry generation and engineering significance. The generation of the geometry can be formalized by using a generating set of parameters or geometrical elements and relationships between them. The engineering significance is difficult to formalize in a uniform way, because it includes the formalization of the functions of features and how they should be produced, what action should be taken in the presence of a feature in connection with any calculations, how features are held in different situations and etc. The engineering significance can be formalized in terms of generating attributes and properties.

By addressing sets of bases as geometrical features, this work analyzes the advantages of the geometrical description of a part through its sets of bases.

2. Sets of bases as geometrical features

Let’s look at the extent to which the term “set of bases” [1] corresponds to those requirements of the features:

1. To be physically components of parts.

The set of bases, depending on the basing scheme, is a combination of the following base surfaces:

– adjusting base – takes 3 degrees of freedom;
– guiding base – takes 2 degrees of freedom;
– double guiding base – takes 4 degrees of freedom;
– supporting base – takes 1 degree of freedom;
– centring base – takes 2 degrees of freedom.

The implementation of these bases is done by real surfaces (explicit bases) or abstract elements (implicit bases), represented by the reference surfaces, axes and points belonging to the part. In other words, the first requirement is satisfied completely.

2. To allow generation of geometry.

The set of bases is by nature a prerequisite for generating the geometrical shape of the part in the following aspects:

– determines the mutual arrangement of the elements of the part’s geometry;
– depending on the type of the base, the particular variant of its embodiment can be searched into a previously developed database of parameterized geometries.

3. To have engineering meaning.

Sets of bases as features are laden with engineering information relating to both the structure of the part and the structure of the assembly.

The introduced in the Theory of basing concept of “primary and auxiliary bases” allows identifying the topology of an assembly as a hierarchical structure. Such structural description carries the mutual arrangement of the parts which is necessary for solving engineering problems, analysing geometric accuracies (problems of dimensional analysis of assemblies) and performing tasks related to technology of assemblage (contriving schemes of assemblage).

4. To have predictable properties.

The properties of the sets of bases are discussed in the Theory of basing and limited to the following:

– by the properties “primary base” and “auxiliary base” the relation of “hierarchy” is realized (determined by the type of base – primary or auxiliary – of joining together parts) in the structure of the assembly;
– reconciliation of the primary and auxiliary bases realizes clearly the relation of “neighbourhood” (determined by the relation of one to other parts) between the parts and accuracy of their positioning.

3. Generative description of a part through its sets of bases

In Figure 1 it is shown the relationship between sets of bases of components of an assembly, and the stages of the design process:

– basing of a component depends on its function in the assembly – to ensure the proper functioning of the assembly basing of its components must be determined at the time of the transition from the functional scheme to the structure of the assembly;
– the structure of a product depends in the great extend from the basing of the components through relation primary bases – auxiliary bases;
– the embodiment design of parts has to secure an implementation of the chosen set of bases.

The description of a part through its sets of bases is called generative, because it can generate multiple geometrical realizations that satisfy the functional requirements. A variety of geometrical
implementations is dependent on the level of the description of sets of bases. With an abstract description of the sets of bases (via abstract geometry) the ability to generate a variety of geometrical forms is significantly larger in comparison with the particular description of the bases (such as the forehead, cylindrical surface, etc.).

Depending of the concrete design task the description of a part through its sets of bases can be observed as one of the several partial models of the part itself or as an addition to the existing model. For traditional geometric models of assemblies that are created during the design process, it is useful the information of sets of bases of parts to be included on the following levels:

- abstract level – structural schemes with a description of the sets of bases of parts (extended structural schemes);
- geometrical level – CAD models of parts and assemblies with preservation of the information about sets of bases of parts.

4. Application of the generative description of a part through sets of bases

In terms of CAD systems the description of a part by sets of bases offers advantages in the following areas:

- integration of conceptual and geometric models of a technical product;
- creation of a more realistic model of an assembly.

The use of means for automation of the design may be connected with problems when changes in logically linked models are made. The main reason for this is that the modern software tools typically automate only partial tasks. In practice this means the presence of many partial descriptions of the product, which correspond to different stages of the design process or of the various subtask [2].

The elimination of the need to convert the partial descriptions can be achieved by creating an integrated description. The possibility sets of bases to be considered from two perspectives – conceptual and geometrical – make them an adequate basis for the creation of an integrated geometrical model. Figure 2 shows the structure of an integrated geometric model produced by this principle.

From the viewpoint of the CAD system, a description of sets of bases allows to overcome certain limitations of a model of an assembly.

A creating a model of an assembly is illustrated in Figure 3. In Figure 3a there are imposed two constrains – mate of flat surfaces on both parts and mate of their cylindrical surfaces. The analysis of the removal of the degrees of freedom shows as follow:

- mate of the two flat surfaces takes 3 degrees of freedom;
- mate of the axes of the two cylinders takes 4 degrees of freedom.

Taking into account that the solid body in the space has 6 degrees of freedom (and there is 1 untaken degree of freedom), it is seen that the model is over constrained. In actual assembly of parts, however, there are taken exactly five degrees of freedom, which indicates the limits of the model of an assembly.

Similarly, if is looked at the assembly on the Figure 3b it is shown that in the CAD model the three flat surfaces are equivalent. In the real construction each of the three flat surfaces fulfils a different role and therefore takes 3, 2 or 1 degrees of freedom.

The addition of a description of the part through its sets of bases allows overcoming that restriction of the CAD model of an assembly. In Figure 3a the sets of bases can be double guiding and supporting bases (4-1) or adjusting and centring bases (3-2). For
5. Conclusion

Sets of bases characterize parts of an assembly and have been a proven from engineering practice tool for determination of the layout. Neighbourhood relations and hierarchy generated by the sets of bases uniquely determine the structure of an assembly. Their use offers several advantages, both at the conceptual design of the product, and at the time of its embodiment.

6. Literature


*Figure 3 Assembly constraints in a CAD model*

Figure 3b – accordingly adjusting, guiding and supporting bases (3-2-1).
APPLICATION OF METHOD FUZZY LOGIC FOR CARRIER SELECTION

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Abstract: The one of the key strategic considerations in transport process is carrier selection problem. This problem is a multi objective problem involving both qualitative and quantitative factors. These factors and their interdependencies make the problem highly complex one. From the managerial perspectives, it is always convenient to express the variables and weights through linguistic values. An analytic hierarchy process (AHP) like procedure based on Eigen value has been proposed to derive the weightages of decision makers. This paper uses a fuzzy approach to deal with the carrier selection problem in transport process. A numerical example presented illustrates the different selection criteria to select the best carrier.

KEYWORDS: FUZZY LOGIC, SUPPLIER, CARRIER SELECTION, MULTI CRITERIA DECISION MAKING, TRANSPORT

1. Introduction

There are various transport companies/carriers/offering shipping services at the appropriate tariff policy, delivery time of goods and quality of the service in practice. In this sense, the optimal choice of transport services in a competitive market environment, is essential for cost management in manufacturing enterprises, in the realization of their material flows with their respective mode of transport and vehicle fleet.

The need for proper choice of carrier comes from the fact that transport costs are subject to change in the direction of increasing or decreasing, so manufacturing enterprises must periodically select the best transportation options for optimum compatibility between the parameters, the objectives of the manufacturing process, physical characteristics and specificity of the production and technical performance of the transport processes. In this regard, the decision to select the carrier is a complex multifactor problem, the core of which are set out various quantitative and qualitative criteria the evaluation of choice. Often, however, some of the criteria may conflict with each other, which could lead to inconsistent decision-making expertise inappropriate choice of transport variant, and hence, affecting the final financial performance of the companies, using transport services. Therefore, when choosing a carrier, along with methods of the expertise, have to apply modern methods of artificial intelligence in an experimental setting.

In this study, feasibility of the application of Analytical hierarchy process (AHP) is considered, based on fuzzy sets theory to estimate the significance and relationship of the criteria for selecting a suitable carrier.

The possible artificial intelligence methods [6], suitable for the problem under consideration, are Artificial neural network (ANN) and Fuzzy logic (FL).

Fuzzy logic (FL) - Fuzzy systems emulate the inaccuracy of human knowledge. They resemble the approximate conclusions of the people, using fuzzy terms, but in a quantitative manner. This allows computers to use fuzzy logic, which is much closer to the real world, as opposed to crisp logic.

Artificial neural network (ANN) are one of the major learning methods in computational intelligence. Acquired knowledge in neural networks is presented with numerical weights in structural connections.

With respect to the problem, the use of the ANN is less effective alternative, because it is difficult to change the trained ANN model when the decision makers change their evaluation rules.

Fuzzy sets theory was developed by Lotfi Zadeh in 1965 [5]. Fuzzy sets are defined versus crisp sets. For crisp sets, the element (x) either belongs to or not belongs to a set (S) totally.

By contrast, fuzzy set theory permits the gradual assessment of the membership of elements in a set. This is described with the aid of a membership function valued in the real unit interval [0, 1].

2. Theoretical formulation of the method

With AHP method performs the following basic steps:

- Define the problem and precise formulation of objectives and results;
- Decomposition of the problem in a hierarchical structure by conditional elements (criteria, sub-criteria and alternatives);
- Sequentially (for each level of the hierarchy) assessing the importance of the alternatives using pair-wise comparisons;
- Consistent evaluation of local priorities comparison items (for each level of the hierarchy);
- Check for consistency of local priorities;
- Aggregate the relative weights of decision elements to obtain an overall rating for the alternatives.

Based on a literature review is given a combination of FL x AHP, Fuzzy AHP [1,2,3,4]. Characteristic feature is that it keeps the logic of AHP and its basic steps, and implementation of some of them, become using FL.

Algorithm analysis by triangular fuzzy numbers are listed below.

Triangular fuzzy numbers

The number $M\in F(R)$ is called a fuzzy number if there exist $x_0\in R$, such that $\mu_M(x)=1$. For any $a \in [0,1]$, $A_a=(x,\mu_{A_a}(x),\mu_{A_a}(x))\geq a$ is a closed interval. Here $F(R)$ represents all fuzzy numbers, and $R$ - the set of real numbers.

We define a fuzzy number, $M$ on $R$ to be a triangular fuzzy number if its membership function $\mu_M(x):R\rightarrow [0,1]$ is equal to

$$\mu_M(x) = \begin{cases} x & x \in [l,m] \\ \frac{m-l}{u-l} x + \frac{l}{u-l} & x \in [m,u] \\ 0 & \text{otherwise} \end{cases}$$

Here $l \leq m \leq u$, and $l$ and $u$ stand for the lower and upper value of $M$ respectively, and $m$ for the model value. The triangular number is denoted by $(l, m, u)$. If $l = m = u$, it is non-fuzzy number. The $M$ is the set \{x $\in R$ | $l \leq x \leq u$\}

Extent Analysis Method

The extent analysis method is the technique that is widely used in the literature for fuzzy AHP problems. In this method, the "extent" is quantified by using a fuzzy number. The value of fuzzy synthetic extent can be obtained:

Let $X = \{x_1, \ldots, x_n\}$ be an object set, and $G = \{g_1, \ldots, g_t\}$ be a goal set. According to the method of extent analysis, we now take each object and perform extent analysis for each goal respectively. Therefore, we can get m extent analysis values for each object, with the following signs:

$$\tilde{\mu}_{g_i}^1, \tilde{\mu}_{g_i}^2, \ldots, \tilde{\mu}_{g_i}^m, \quad i = 1, \ldots, n$$
where all the $\tilde{M}_{i}^{j}$ ($j = 1, \ldots, m$) are triangular fuzzy numbers.

The concerned method by described below mathematical tools is being displayed.

The value of fuzzy synthetic extent with respect to the $i$-th object is defined as:

$$S_{i} = \frac{m}{\sum_{j=1}^{m} M_{j}^{i} \otimes \left( \sum_{j=1}^{m} m_{j} \right)^{-1}}$$

where:

$M_{i}$ - triangular fuzzy number;

We can obtain $\sum_{j=1}^{m} M_{i}^{j}$ by the fuzzy addition of $m$-th extent analysis values for a particular matrix such that:

$$\sum_{j=1}^{m} M_{i}^{j} = \left( \sum_{j=1}^{m} l_{j}, \sum_{j=1}^{m} m_{j}, \sum_{j=1}^{m} u_{j} \right)$$

where $l$, $m$, $u$ are real numbers for $M_{i}$ = $(l_{i}, m_{i}, u_{i})$.

To obtain $\left( \sum_{j=1}^{m} \sum_{j=i}^{m} M_{i}^{j} \right)^{-1}$, perform the fuzzy addition operation on values of $M_{i}^{j}$ ($j = 1, \ldots, m$) such that:

$$\sum_{j=1}^{m} M_{i}^{j} = \left( \sum_{j=1}^{m} l_{j}, \sum_{j=1}^{m} m_{j}, \sum_{j=1}^{m} u_{j} \right)$$

and then compute the inverse of the vector above, such that:

$$\left[ \sum_{j=1}^{m} \sum_{i=1}^{m} M_{i}^{j} \right]^{-1} = \left( \frac{1}{\sum_{j=1}^{m} m_{j}}, \frac{1}{\sum_{j=1}^{m} m_{j}}, \frac{1}{\sum_{j=1}^{m} u_{j}} \right)$$

As $\tilde{M}_{1} = (l_{1}, m_{1}, u_{1})$ and $\tilde{M}_{2} = (l_{2}, m_{2}, u_{2})$ are two triangular fuzzy numbers, the degree of possibility of $M_{2} = (l_{2}, m_{2}, u_{2}) \geq M_{1} = (l_{1}, m_{1}, u_{1})$ defined as:

$$V(M_{2} \geq M_{1}) = \sup_{y \geq x} \min \left( \mu_{M_{1}}(x), \mu_{M_{2}}(y) \right)$$

and can be equivalently expressed as follows:

$$V(M_{2} \geq M_{1}) = \inf \left[ \frac{1}{l_{2} - u_{2}} \frac{1}{l_{1} - u_{1}} \right]$$

$$\mu_{M_{2}}(d) = \begin{cases} 1, & \text{if } m_{2} \geq m_{1} \\ 0, & \text{if } l_{1} \geq u_{2} \\ l_{1} - u_{2}, & \text{otherwise} \\ (m_{2} - u_{2}) - (m_{1} - l_{1}) \end{cases}$$

According to fuzzy sets theory [5], the representation of a fuzzy triangular number is given in figure 1.

According to Figure 1, $D$ is the ordinate of the highest intersection point $d$ between $\mu_{M_{1}}$ and $\mu_{M_{2}}$.

To compare $M_{1}$ and $M_{2}$, both the values of $V(M_{1} \geq M_{1})$ and $V(M_{2} \geq M_{1})$.

The degree possibility for a convex fuzzy number to be greater than $k$ convex fuzzy $M_{i}$ ($i = 1,2,\ldots,k$), numbers can be defined by:

$$V(M_{2} \geq M_{1}, \ldots, M_{k}) = V(\left( M_{2} \geq M_{1} \right) \cap \left( M_{2} \geq M_{2} \right) \ldots \cap \left( M_{2} \geq M_{k} \right)) = \min V(M_{2} \geq M_{i}), i = 1,2,\ldots,k$$

Assume that $d(A_{i}) = \min V(S \geq S_{i})$ for $k = 1,2,\ldots,n; k \neq i$, Then the weight vector $W$ is given by:

$$W = (d(A_{1}), d(A_{2}),\ldots,d(A_{n}))^{T}$$

where $A_{i}$ ($i = 1,2,\ldots,n$) are $n$ elements.

Via normalization, the normalized weight vectors $W$ (a non-fuzzy number) are:

$$W = (d(A_{1}), d(A_{2}),\ldots,d(A_{n}))^{T}$$

### 3. Application of the Fuzzy AHP model in carrier selection

In the following section, we suggest a solution to the above mentioned problem by considering a situation involving three carriers $\Pi_{1},\Pi_{2},\Pi_{3}$, evaluated on four main criteria’s $K_{1},K_{2},K_{3},K_{4}$. To simplify the presentation of the methodology do not consider the sub-criteria of the main criteria.

The proposed criteria in this report are as follows:

- The cost of transport-$K_{1}$;
- Time delivery of consignments-$K_{2}$;
- Reliability and quality of service-$K_{3}$;
- Financial stability of carrier-$K_{4}$.

The relative degree of importance of each criterion is systematized in Table 1.

<table>
<thead>
<tr>
<th>Table 1: The fuzzy scale</th>
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<tbody>
<tr>
<td>Triangular alternatives</td>
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<tr>
<td>Fuzzy Scale</td>
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<tr>
<td>(1,1,1) poor(P)</td>
</tr>
<tr>
<td>(1,3,5) Medium poor(MP)</td>
</tr>
<tr>
<td>(3,5,7) Medium good(MG)</td>
</tr>
<tr>
<td>(5,7,9) good(G)</td>
</tr>
<tr>
<td>(7,9,9) Very good(VG)</td>
</tr>
</tbody>
</table>

The hierarchical structure of the problem is given in Figure 2. The problem is selecting the best supplier among 3 alternative carriers which are $\Pi_{1},\Pi_{2}$, and $\Pi_{3}$.

![Figure 1. The intersection between M1 and M2](image)

![Figure 2. Proposed hierarchical structure of the problem](image)
We assume that we have expert judgments offered by experts. We do not consider the problem of assessing the experts and obtain the weights of their evaluations on different criteria for different carriers. And start from the moment we get the final scores for each one of the criteria for individual carriers in Linguistic scale, summarized in Table 1.

Now as the linguistic assessments simply approximate the subjective judgment of decision-makers, we consider the linear triangular membership functions to capture the vagueness of linguistic assessment. The linguistic variables are expressed as positive triangular fuzzy numbers. The decision makers are asked to use the linguistic variables as shown in Tables 2 and 3, to evaluate the importance of the criteria and the ratings of alternatives with respect to qualitative criteria.

<table>
<thead>
<tr>
<th>Table 2: Evaluation criteria of importance</th>
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<td>rating</td>
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<tr>
<th>Table 3: Rating of carriers by decision makers under various criteria</th>
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<tr>
<td>carrier</td>
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<tr>
<td>HI</td>
</tr>
<tr>
<td>II</td>
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<tr>
<td>III</td>
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</table>

The Tables 1, 2 and 3 are used for rating the criteria by the decision-makers and the rating of carriers on various criteria. The ratings are represented using fuzzy values in Table 4.

<table>
<thead>
<tr>
<th>Table 4: The rating of carriers in fuzzy numbers</th>
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<tr>
<td>carrier</td>
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<td>HI</td>
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<td>II</td>
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<td>III</td>
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</table>

In order to find the priority characteristics of main criteria, the fuzzy synthetic extent values were calculated using equation (3). The different values of fuzzy synthetic extent values with respect to the different criteria are denoted by $K_1, K_2, K_3$, and $K_4$, respectively.

\[
K_1 = (10.16, 22.3) \otimes (47.2, 33.4) = (0.09, 0.19, 0.45)
\]

With the help of equations (7) and (8), obtain:

\[
V(K_1 \geq K_2) = 1; V(K_1 \geq K_3) = 1; V(K_1 \geq K_4) = 1;
\]

\[
V(K_2 \leq K_3) = 1; V(K_2 \leq K_4) = 1; V(K_2 \leq K_1) = 1;
\]

\[
V(K_3 \geq K_1) = (0.21 - 0.45)/(0.19 - 0.45) = 0.45.
\]

Similarly calculations are made for the other degree of possibility.

\[
V(K_3 \geq K_2) = 0.45; V(K_4 \geq K_1) = 0.26;
\]

\[
V(K_4 \geq K_3, K_2) = 0.97.
\]

With the help of equation (9), the minimum degree of possibility of superiority of each criterion over another is obtained:

\[
\min(K_1) = \min(1, 1.1); \min(K_2) = \min(0.45, 1.1)
\]

\[
\min(K_3) = \min(0.45, 1.1); \min(K_4) = \min(0.26, 0.97, 0.97).
\]

With the resulting values, the weight vector is given as:

\[
W = (1, 0.45, 0.45, 0.26).
\]

Via normalization on $W$, the normalized weight vectors (with respect to $K_1, K_2, K_3$ and $K_4$) are:

\[
W_K = (0.464, 0.208, 0.208, 0.120)T.
\]

The comparison matrices of each alternative according to each criteria are given in Table 6, 7 and 9 respectively. For the preparation of the weights, using that approach, and mathematical tools, applied to the Table 5.

<table>
<thead>
<tr>
<th>Table 5: The comparison matrix of criteria</th>
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<tbody>
<tr>
<td>criteria</td>
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<tr>
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<tr>
<td>$K_1$</td>
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<td>$K_2$</td>
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<td>$K_3$</td>
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<td>$K_4$</td>
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<table>
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<tr>
<th>Table 6: The comparison of alternatives with respect to $K_1$</th>
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<td>alternative</td>
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<tr>
<td>HI</td>
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<tr>
<td>H2</td>
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<tr>
<td>H3</td>
</tr>
</tbody>
</table>

With the following values, the weight vector is given as:

\[
W_{HI} = (0.052, 0.373, 0.575)T.
\]

<table>
<thead>
<tr>
<th>Table 7: The comparison of alternatives with respect to $K_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>alternative</td>
</tr>
<tr>
<td>HI</td>
</tr>
<tr>
<td>H2</td>
</tr>
<tr>
<td>H3</td>
</tr>
</tbody>
</table>

With the following values, the weight vector is given as:

\[
W_{HI} = (0.060, 0.103, 0.273); W_{H2} = (0.098, 0.291, 0.819);
\]

<table>
<thead>
<tr>
<th>Table 8: The comparison of alternatives with respect to $K_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>alternative</td>
</tr>
<tr>
<td>HI</td>
</tr>
<tr>
<td>H2</td>
</tr>
<tr>
<td>H3</td>
</tr>
</tbody>
</table>

With the following values, the weight vector is given as:

\[
W_{HI} = (0.105, 0.333, 1.061); W_{H2} = (0.143, 0.534, 1.667);
\]

<table>
<thead>
<tr>
<th>Table 9: The comparison of alternatives with respect to $K_4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>alternative</td>
</tr>
<tr>
<td>HI</td>
</tr>
<tr>
<td>H2</td>
</tr>
<tr>
<td>H3</td>
</tr>
</tbody>
</table>

With the following values, the weight vector is given as:

\[
W_{HI} = (0.188, 0.426, 1.054); W_{H2} = (0.134, 0.471, 1.288);
\]

\[
W_{HI} = (0.95, 1, 0.21);
\]

\[
W_{H2} = (0.35, 0.19, 0.52).
\]
4. Results

Based on the methodology applied and the calculations are given weights considered carriers indicated in Table 10. Figure 4 illustrated their distribution.

<table>
<thead>
<tr>
<th>criteria</th>
<th>К1</th>
<th>К2</th>
<th>К3</th>
<th>К4</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>II1</td>
<td>0,574</td>
<td>0,052</td>
<td>0,364</td>
<td>0,440</td>
<td>0,406</td>
</tr>
<tr>
<td>II2</td>
<td>0,374</td>
<td>0,373</td>
<td>0,445</td>
<td>0,463</td>
<td>0,399</td>
</tr>
<tr>
<td>II3</td>
<td>0,052</td>
<td>0,575</td>
<td>0,191</td>
<td>0,097</td>
<td>0,195</td>
</tr>
<tr>
<td>weight</td>
<td>0,464</td>
<td>0,208</td>
<td>0,208</td>
<td>0,120</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 3 shows the sensitivity of each decision alternatives with respect to the criteria.

5. Conclusions

The choice of criteria and their hierarchical structure should as far as possible to reflect the strategic business goals of the company, using transport services.

By the help of the extent fuzzy approach, the ambiguities involved in the data could be effectively represented and processed to make a more effective decision. As a result of the calculations made, it was seen that Carrier II2 ranked first as carrier.

Input data are averages for the implementation of the key indicators of the activity of companies, using transport services in the past few years.

This approach can lead to useful results to other sectors or in other areas of application. Appropriate comparison of results, obtained with that discussed methods, with those obtained from the model of expertise, which is subject to further development.

References:

NEW DESIGN OF OFF-ROAD MOBILE PLATFORM FOR SERVICE ROBOT

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DAIDO AD Kotor, Montenegro

Abstract: Service mobile robots have not become market products so far, as their development emerges from the ideas of manufacturers, research centers and the institutes. The existing solutions and mechanics, sensorimotorics and controlling are various. The work presents a new concept of a mobile robot platform having multiple purposes to be applied in open space on uneven terrain. The Platform has four drive wheels each having independent drive. In order to turn the drive wheels, an original spatial leverage mechanism has been designed in order to transmit motion from the motor worm gearing to the system of the drive wheels suspension. This robot has been created mainly for service and development-research purposes, but it is also intended for the educational purposes.

KEYWORDS: mobile robot, mobile platform, 4-wheel-drive/steer robot, off-road robot.

1. Introduction

Mobile robotics represents a growth of an engineering field which has achieved an incredible progress in the last decade. Today, almost every significant Faculty of Engineering has an institute researching mobile robots. In the world research institutes, different types of service robot capable of performing versatile tasks such as, transportation, searching for and saving people, investigating critical or unreachable terrains, setting the scientific instruments, exploring planets, providing assistance to old or disabled persons, assisting in the house works, for military and defense purposes, etc. The new trends in the robotics field researches, other than traditional industrial applications, are getting more focused to robots for providing multi-functional services in unstructured environment and interaction between people and robots.

Mobile robots stand for an ideal field for researching, education and creation of values as being multi-disciplinary field which requires knowledge of different fields, such as: engineering and mechanics (design of vehicles, motion mechanism, stability), electronics (supply system, energy converters, drive wheels), computer science (programming techniques in real time, process control, knowledge presentation, image processing, speech processing and planning algorithms), electronics (controlling and communication electronics), mathematics, psychology, perception and science on neurons (understanding how biological organisms solve similar problems).

Terrain or off-road robotics is a very active research domain where a significant progress has been achieved in the last years. Improvement of classic sensors and development of completely new systems, such as, 3D cameras or 3D laser scanners provide all detailed information on the robot’s surroundings. However, a large number of data generated by the sensors of high technology can be used only if sophisticated algorithms are available.

Unlike the robots that operate in closed, predefined environment, the vehicles intended to perform tasks in open environment must deal with rough, less structured environment which means much more complex world. This is particularly important when the robots leave an urban area and start moving off the roads. Lack of terrain structure, which can be easily recognized, can be: taking samples (water, gas, soil) from contaminated zone, recording critical terrain, detecting and marking mine-explosive appliance, etc.

3. Description of mobile platform for service robots

Project task demands to design and make a mobile service robot. Design of a mobile platform on which a manipulator could be placed is required to be made. A robot is intended to move within an open area and not only along a flat road but along an uneven road as well, performing certain task. A task assigned to a robot could be: taking samples (water, gas, soil) from contaminated zone, recording critical terrain, detecting and marking mine-explosive appliance, etc.

3.1. Mobile platform design

Service robot consists of a mobile platform and a manipulator. Mobile platform is a special vehicle with four-wheel drive; motion of the vehicle is controlled having all four wheels turned. Furthermore, mobile platform is designed to have a high clearance (distance from the base), independent suspension of each wheel and wheel turns at ±45º, which ensures good performances for off-road driving. It is important to emphasis that sizes, distance between
wheels axis, and a frame construction allow high angle of clearance which is very important for overcoming the obstacles.

3.2. Drive and controlling the mobile platform

Four servomotors with a gearbox and an encoder controlled by a central controller are designed to drive a mobile platform. Executive modules and user interface will be made particularly for this vehicle. The vehicle is turned, i.e., all four wheels are controlled by a servomotor with a gearbox which turns the wheels using the system of leverage connected by the sphere joints.

3.3. Mobile platform controlling

The mobile platform and a manipulator will be controlled by a PC (laptop) through a WIFI connection with a central processing unit – a module, which will be made particularly for this service robot. CPU will be placed in the frame of the platform. PZT IP WIFI camera will be installed on the service robot so that the operator could observe on the screen space in front of the robot and to control its motion. Similar model used when driving the platform will control a manipulator (robot hand) which will be installed on the platform.

3.4. Supply

Service robot will be supplied by batteries through a module supplier 24 VDC, which will be also placed in the platform frame.

4. Construction of the mobile platform

Mobile robot platform (shown in the Figure 2) is similar to terrain vehicles. It needs to have a system for supporting a mobile platform like the vehicles. Supporting system includes mechanism and elements intended to transmit to the frame (chassis) all reactive forces and moments appearing between the wheels and the base, during different motions. It is necessary to absorb bump load as much as possible, and to enable required stability of the platform, particularly when moving in curves. The supporting system is generally a very complex system consisting of four separate systems or mechanisms, as follows: mechanism for controlling the wheel, elastic supports, elements for absorbing oscillation and stabilizer.

![Figure 2: Mobile platform appearance](image)

Mechanism for controlling the wheels (elements for controlling) has been designed to ensure their relative motion as much as suitable against the frame (chassis). Elements for controlling also must provide transmission of horizontal reactive forces and reactive moments from the wheel to the frame. Elastic supports (elastic elements) basically have task to transmit vertical reactive forces to the frame. Actually, their task is to absorb vertical forces during their transmission, that is, to reduce bump load as much as possible.

Basic task of the elements for silencing is to silence oscillation of the elastic supports, i.e., the suspension system and the vehicle as a whole, and to reduce bump load.

![Figure 3: Basic dimensions of mobile platform](image)

The road vehicles, in addition to the above defined mechanisms and elements of the supporting system, sometimes have special elements, stabilizers, aiming to provide high stability of the vehicle, i.e., the mobile platform when moving in the curve. Design of the mobile platform made in Autodesk Inventor Professional 2012 is shown in Figure 3. The wheels diameter is 255 mm, and the wheels width is 20 mm. Basic dimensions of the platform are given in the Figure 3.
**Mobile platform frame** generally consists of a system of mechanical elements whose basic task is to ensure rigidity of the platform (the vehicle) and to allow attachment of other assemblies of the vehicle chassis (control servo motor, wheels supporting system, manipulator, battery (accumulator), control system, camera, sensor, car body, etc.). The frame should be light (small mass), to prevent shape deformation under force pressure generated when driving in extremely difficult, but anticipated conditions, following the purpose of the mobile platform. For the stated reasons, the frame has been designed by principles of a light steel construction. The frame of the mobile platform is shown in Figure 4.

![Figure 4: The mobile platform frame](image)

A mode of the wheels suspension is shown in Figure 5. Independent wheels suspension is provided by a double frame (upper and lower) in the vertical plane. Both frames are installed over the center of each wheel aiming to enable the wheel turning at the angle of ±45º around the axis inclined for the angle $\beta$ against the vertical axis. The frames have been installed so high for the following reasons:
- To provide high clearance i.e., distance between the frame and the base which allows mobile platform to move along uneven terrain (off-road)
- Possibility to overcome obstacles along uneven terrain
- Wheels turning freely (the wheel drive is set-up in the wheel axis).

![Figure 5: The wheels suspension](image)

5. **Mechanism for turning the mobile platform**

The biggest challenge for the driving mechanism of the road vehicles is to realize complete rolling with good traction of wheels in the curve. This requirement is met only if the turning center of each wheel is placed in one point - rotation center, that is, if the axes of all wheels are crossed in one point (Figure 6).

In addition to a basic function - turning the platform, driving wheels need to be able to keep a neutral position when the platform moves, i.e., turned wheels (intentionally or accidentally) tend to return to neutral position. Such ability is called - stability of the driving wheels.

![Figure 6: Rotation center of the mobile platform wheels](image)

Additionally, the wheels get stable by having a sleeve shaft installed at certain angles against the vertical axis. These angles are, as shown in Figure 7.a), in cross section, the angle $\beta$ - the angle of supporting the wheel, and in horizontal section the angle $\gamma$.

![Figure 7: a) Position of the wheels against the vertical axis; b) Drawing of a wheel with motor and suspension](image)

The angle $\beta$ has a double function, as follows:
- To make the shaft axis penetrate the base not too far from the center of the wheel print (as if the shaft was installed vertically), but as near as possible. Using this mode, a certain distance $a$, so-called, radius of the wheel turning is provided.
- To keep the wheel in neutral position. When the wheel is turned from neutral position around the shaft which is vertically tilted, the wheel of the vehicle placed in inner side of the curve is lifted, while the wheel being on the outer side of the curve is slightly descended (as if the wheel sank into the base), for the reason that the contact point of the wheel and the road is moved in the plane $b-b$ which is normal against the sleeve shaft axis.

The angle $\alpha$ (figure 7.a) is called the side angle of incline or the wheel inclination. The basic purpose of the side angle of incline of the wheel, in addition to impact to have the turning...
radius a reduced, is also to annul influence of side clearances in the wheels bearings which must be there for the constructive reasons.

Turning, i.e., controlling the mobile platform will be performed through a servo motor with an encoder that will be placed on a frame of the mobile platform and the system of leverage with spherical joints (figure 8). Such constructive solution of the leverage system enables the wheels turning at ±45° against the vertical axis of the vehicle. Such big angle at which the wheels turn will allow extremely high mobility of the platform.

The work provides short description of the drives and mode of the platform moving control. An original solution of the drives and mode of the platform moving control. The work provides short description of the drives and mode of the platform moving control. The work provides short description of the drives and mode of the platform moving control. The work provides short description of the drives and mode of the platform moving control. The work provides short description of the drives and mode of the platform moving control. The work contains a study of basic assumptions and requirements for the mobile robot platform. An original solution of mechanics of the mobile platform has been presented with original spatial leverage mechanism which turns all four wheels simultaneously, it is clear that the position of wheels is interdependent. The analysis of the wheels position has been done for general case when inner wheels are directed at the angle α against the vertical axis of the vehicle, and outer wheels at the angle β against the same axis (figure 9).

Figure 8: Connection of the spatial leverage mechanism for controlling direction of the mobile platform and the wheels

Considering that the position, i.e., the wheels direction is controlled by the same spatial leverage mechanism which turns all four wheels simultaneously, it is clear that the position of wheels is interdependent. The analysis of the wheels position has been done for general case when inner wheels are directed at the angle α against the vertical axis of the vehicle, and outer wheels at the angle β against the same axis (figure 9).

Figure 9: Wheels position when turning

For the mobile platform with four driving wheels, the analysis results with the following dependence:

\[ \text{ctg}\beta - \text{ctg}\alpha = 2e/l = \text{const} \]

6. Conclusion

The work contains a study of basic assumptions and requirements for the mobile robot platform. An original solution of mechanics of the mobile platform has been presented with original spatial leverage mechanism for controlling the wheels turning. Advantages of the proposed mode of the wheels suspension have also been highlighted. The turning angle of ±45° will ensure extremely high mobility of the platform. The work provides short description of the drives and mode of the platform moving control.

The next step in designing the mobile platform for the service robot will be to select a motor, define a controlling mode, input information, sensors, etc.

The following factors are important for the mobile terrain robots: mechanical robustness, easy maintenance, low purchase costs and good usability. From the mechanical point of view, a proposed concept of mechanics of the robot platform meets these requirements in complete.

6. Literature:

EQUIPMENT CB-1 FOR RENDERING THE PERFORMANCE OF THE ICE WORKING WITH GASOLINE INJECTION FOR RESEARCH AND EDUCATIVE-APPLIED AIM

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Technical College Smolian – University of Plovdiv¹, Faculty of Transport – Technical University of Sofia², Bulgaria

Abstract: In this paper are described the results about designing of set CB-1 for rendering the work of the injection ICE with aim to scientific research and application of the results, as well introducing the student with their features during the labs.

KEYWORDS: AUTOMOBILE, ENGINE, EQUIPMENT, RESEARCH, RESULT, STUDENTS

1. Introduction

The article concerns the results during the developing of equipment CB-1 for rendering the performance of ICE, working with gasoline injection. The main objective of CB-1 is ensuring the possibility for visualization, measuring and diagnostics the engine parameters for researching and educative-applied aim.

One method to improving the fuel consumption and ecology of ICE is optimizing the fuel dosage and distribution according to the work mode and work condition of the engine [1]. Moreover the significant influence of the exploitation factors is observed, such as quality and type of the fuel, technical condition of the engine and its system elements, specific moments during the technical servicing and using the elements with ill-matched characteristics and etc. This determines the researching of the influence of these factors upon the optimal performance of the engine and specifying the relevant dependences, which to be used as base point to control and evaluate its technical condition.

2. Description and principle of work of the equipment CB-1 for rendering the performance of ICE, working with gasoline injection

The common view of the developed equipment is presented on the fig.1. The equipment elements are mounted on the base 1, which ensures uniformly load distribution by six supports with vibrate-isolating rubber pads.

The starting of the engine 5 of the equipment is realizing by the ignition key placed in the control panel 7, which is containing the electronic control unit (ECU), the dashboard and the diagnostic socket.

The fuel is storing in the fuel tank 2, placed in the lower part of the base.

The controlling and changing the ICE revolution is doing by the lever 6, linked with the engine throttle. To the throttle housing by the stand is mounted the mass airflow meter together with the air filter 4.

The exhaust system 8 of the equipment is considered according to the modification and type of the engine.

The accepted layout of the equipment ensures the necessity visualness of the working process of the separate engine systems and its elements at keeping the requirements of safety and access for measuring and diagnosing.

3. Specification of the measuring and diagnostic tools

During the process of visualization and researching the performance of the equipment CB-1 are using standard and specialized tools for measuring and diagnostics. The main aim is to receive live data and graphics, which can be observed, processed, memorized and reopened for analyze and evaluating.

The measuring and observing the alternative signals is realizing by the specialized automobile digital oscilloscope, which have the following technical data [2]:
- Number of channels: 2;
- Number of outer synchronization: 1;
- Input impedance: 1MΩ / 25 pF;
- Input voltage range: ±1V; ±2V; ±5V; ±10V; ±15V;
- Maximum input voltage: ±400V;
- Computer connection: USB 2.0;
- Power for the adapter: from the USB;
- ADC: 8 bits;
- Frequency band: DC up to 100 kHz (up to 10 µs/mark);
- ADC frequency: 200000 per 1 s;
- Synchronization: automatic; single; outer; AC/DC; by increasing and by decreasing frontage;
- Record mode.
The measuring of the current signals to the actuators (injectors, electromagnetic valves, coils, relays etc) is done by current clamps type CA-60 with the following data:
- Measuring current: DC/AC from 10mA up to 60A;
- Frequency: up to 20kHz;
- Measuring accuracy: 1mV/10mA (100mV=1A) DC/AC from 10mA up to 20A; 1mV/100mA (10mV=1A) DC/AC from 20A up to 60A;
- Temperature accuracy: 0.1x(measuring accuracy) per degree °C.

The measuring of the high currents (starting the engine) is realized by the current clamps type CA-600 with the following data:
- Measuring current: DC/AC up to 600A;
- Frequency: up to 400Hz;
- Measuring accuracy DC signals: 1mV/1A ±(2%+2A) from 0 up to 600A;
- Measuring accuracy AC signals (from 50 up to 400Hz): 1mV/1A ±(2%+2A) 0~400Hz; ±(3%+2A) 400~500Hz; ±(6%+2A) 500~600A;
- Temperature accuracy: 0.1x(measuring accuracy) per degree °C.

The pressure pulsations are converted to the suitable signal to the automobile oscilloscope by the pulse sensor.

The primary voltage of the ignition system, as well as the control signals to the injectors (or actuators) is measured by the transformer 20:1.

The secondary high voltage produced from the ignition system is measured by the capacitive sensor. These pointed above tools are referred to the specialized tools of the equipment CB-1.

The engine compression is measured by the specialized arrow compression-meter with relevant adapter.

To perform the diagnostic pressure test is used the specialized vacuum pump, which produce pressure to 4,0 bar and vacuum to 40 in Hg.

The measuring of the temperature (oil, coolant etc) is performed by the Hg thermometer range 0-200°C with suitable connector.

The connection to the ECU is done by the diagnostic socket, to which is plugged the specialized diagnostic interface with specific software according to the equipment engine. By this way are observed live data, as the revolution, temperature, pressure, fuel consumption, air consumption, ignition advance etc, as well as is performed the diagnostics of the engine and its systems.

4. Some results from the equipment CB-1

At the initially developing of the equipment CB-1 are received the experimental results and characteristics, which represents the technological possibilities of the CB-1 as well as the applied tools for measuring and diagnostics.

On the fig.2 is presented the waveform of pressure in the engine manifold (curve 1) and of the signal from the crankshaft position sensor (curve 2). The vertical a means TDC of crankshaft determined by the signal from crankshaft position sensor, and vertical b – by the moment of shutting of the inlet valves. The difference between them can be used to evaluate the technical condition of the valve-train.

From the fig.3 to fig.6 is presented the starting process of the engine, which is consisted from the following stages: turning on the ignition key (fig.3), turning on and putting in motion of the starter (fig.4), putting in motion of the crankshaft and exciting of the alternator (fig.5) and actuating of the voltage regulator when the engine has already started (fig.6).

Thus can be made evaluation about the very starting process as well as about the performance of the alternator and voltage regulator. The curves 1 describe the voltage, and the curves 2 – the current.

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current of cold engine is \( I_{st}=170 \text{A} \), and of warmed engine – \( I_{st}=195 \text{A} \).

By the value of the starter current in starting mode can be made evaluation about the engine compression and worn-out of its piston-cylinder group. The measured values can be written in the database for relevant engine (automobile) and to be used during the next measuring as the base for comparison and evaluation.

From the fig.9 to fig.11 are presented the work processes of the ignition system of three different revolution modes of the engine (without applied load), as following: \( n=850 \text{ min}^{-1} \) – idle mode (fig.9), \( n=2000 \text{ min}^{-1} \) (fig.10) и \( n=3000 \text{ min}^{-1} \) (fig.11). The curve 1 presents the signal from the crankshaft position sensor, and curve 2 – the high voltage signal to the ignition plug.

The retrieved waveforms can be used for analyze the spark parameters (breakthrough voltage, sparking continuance), as well as for determine the ignition advance during the different working modes. Thus is realized the marks for analyze and diagnostics of ignition system and its elements.

The more closely researching of the spark create processes is presented on the fig.12, which describes the primary voltage (curve 1) and the secondary voltage (curve 2) of the ignition system. On the fig.13 is shown the waveform of the spark components – capacitive spark with sharp pike and voltage \( U_{\text{breakthrough}}=10,2 \text{ kV} \) and inductive spark with sloping section and smooth pike and \( U_{\text{breakthrough}}=1,8 \text{ kV} \).

A possibility for measuring, analyze and diagnostics the engine condition is presented on the fig.14 by the waveform from the oil pressure sensor. A definite interest has the section 3 (pulsations at the engine starting) and section 6 (pulsations at the engine stopping).

The pressure pulsations in these transitional sections can be used as marks for relative evaluation about the windage between rubbing couples. The recording of these data in a database can be used as mark for comparison at the next control and service of the same engine (automobile) after the certain mileage.
Fig. 14. Waveform from the oil pressure sensor:
1-engine stopped; 2-engine starting; 3-pulsations at the start; 4-engine work; 5-engine stopping; 6-pulsations at the stop; 7-engine stopped

5. Conclusion

1. The developed laboratory equipment CB-1 for rendering the performance of ICE, working with gasoline injection ensures possibility for observing, measuring and diagnostics of the running working processes.
2. The initially retrieved experimental results of CB-1 working are the mark for comparative analyze and evaluation of the engine technical condition and its system, as well as for the continuing of these researching with aim to retrieving the specific and interesting results relevant to determine working modes.

Literature

DETERMINATION OF CYCLIC CORROSION CRACK RESISTANCE CHARACTERISTICS OF AN OIL TRUNK LINE PIPE MATERIAL

Associate Professor, Dr. Eng. Luzhetskyy V.
Department of Machine Engineering & Material Study – Ivan Franko Drohobych State Pedagogical University, Ukraine

Annotation. Engineering estimations of the corrosion fracture velocity of oil pipelines have been given, which include both mechanical and physical-chemical interaction operation factors of strained material with workspace. Characteristics of cyclic corrosion crack resistance of a pipe metal of the exploited oil-trunk pipeline with the regard for operating production factors have been defined. New data about corrosive and fatigue failure of pipes in dependence on the initial sizes and forms of their detected defects have been obtained. Cyclic used and unused pipe 10I2BT103 steel crack resistance charts have been compiled. Also, it has been established, that aqueous corrosive environments (soil and distilled water) essentially influence the fatigue failure propagation process in the investigated steel.

KEYWORDS: TRUNK PIPELINE, CORROSIVE FISSURING DEFECT, CORROSIVE ENVIRONMENT, CYCLIC CORROSION CRACK RESISTANCE CHART, CRACK GROWTH RATE, THRESHOLD (K_th) AND CRITICAL (K_c) STRESS INTENSITY FACTOR

1. The Introduction. Research topicality

Technical diagnostics of responsible constructions exploited in the conditions of combined power load and corrosive aggressive media is an actual scientific and technical problem, particularly, for definition of long-term exploitation objects. Pipes, used for oil production and transportation, are in constant contact with corrosive and deleterious substances which cause intensive internal corrosion of pipes, whereas their abrasion is accompanied with great material losses and severe ecological consequences [1, 5 – 6].

As demonstrated by multiple researches, processes of wear-out failures of industrial constructions under the influence of combined action of mechanical loadings and corrosive workspaces are caused by a number of physical and chemical localised processes of formation and development of fissuring troubles in the material [2 – 4]. Besides, alongside with places of enhanced exertion concentration (openings, cuttings, cracks and other technological and constructive exertion raisers), these processes often arise on smooth distressed surfaces, which is due to heterogeneity of their physical and chemical condition. This has been affirmed by the recent statistical data [8 – 10], namely, that almost 80 % of all oil pipelines failures are caused by primary corrosion-mechanical damage and by progressing surface fissuring troubles in places of corrosive caverns and welding joints. In this connection, there appears an acute problem in development of effective methods of evaluation of these phenomena and adequate loading diagrams for engineering practice.

Thus, definition of features and evaluation criteria of technical state of oil pipelines and the interrelation between parameters of physical-mechanical state of their material and operating environment corrosion mechanisms is an actual scientific and applied engineering task.

2. Problem setting

It is possible to prolong durability and provide reliable exploitation of trunk pipelines by diagnosing the actual state of metal and characteristics of its resistance to fissuring troubles expansion, taking into consideration a number of exploitation factors (such as static, cyclic and dynamic loads, corrosive media) which influence probable development of the detected damages.

In order to carry out these engineering evaluations, today they use modern approaches to fracture mechanics [1, 5], which enables the definition of regularities of corrosion cracks expansion under the influence of fatigue failures that are represented in the form of cyclic corrosive crack resistance charts, which are dependences of fracture growth rate on stress intensity factor \( K \). Such charts are arranged between its two boundary values: bottom threshold value \( K_a \) corresponding to the value of \( K_I \) at which there occurs no corrosive fatigue failure growth, and upper \( K_c \) corresponding to the value of \( K_I \) at which there occurs spontaneous (catastrophic) growth of a fracture. The average amplitude part of such charts is analytically described by Paris power dependence [7]

\[
dc/dn = da/dN = C(\Delta K)^n,\]

wherein \( C \) and \( n \) are system “material – environment” constants, \( \Delta K \) is stress intensity factor \( (\Delta K = K_{\max} - K_{\min}) \), definable as a function of working pressure inside a pipe.

The four aforementioned chart parameters \( K_a, K_c, C \) and \( n \) are characteristics of cyclic corrosive crack resistance of the oil-trunk pipe material.

3. The purpose and object of research

Grounding on charts of cyclic corrosive crack resistance of the oil-trunk pipeline material to substantiate a comparative evaluation of the influence of corrosive media on corrosive fatigue failures developing in it for different “material – environment” systems.

Our research object, thus, is processes of formation and development of fissuring defects in pipe walls, and the influence of their forms and sizes on a pipe’s working capacity.

4. Methods of definition of cyclic crack resistance of a pipe material

The investigations have been carried out for both unused (new) metal (steel 10I2BT103, \( c_{\text{O}_{2}} = 423,7 \text{ mPa}, \delta = 26,9 \% \), \( d_{\text{O}_{2}} = 530 \text{ mm}, \tau = 8 \text{ mm} \) and used steel (metal 10I2BT103, \( c_{\text{O}_{2}} = 438,9 \text{ mPa}, \delta = 25,6 \%, \delta_{\text{O}_{2}} = 530 \text{ mm}, \tau = 7 \text{ mm} )) of oil pipeline “Druzhba". Mechanical characteristics of steel have been defined after a standard testing procedure of cylindrical samples for stretching.

In Table 1 chemistry of the investigated steel is presented.

<table>
<thead>
<tr>
<th>Mass content of elements, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
</tr>
<tr>
<td>0,11</td>
</tr>
</tbody>
</table>

All basic physico-mechanical investigations of corrosive fatigue failures' developments have been conducted on prismatic models, which geometry is shown in Figure 1. The intermediates for samples of 10 mm \( \times 10 \times 40 \text{ mm} \) in size have been cut out from fragments of real pipes. The total length of the sample add up to \( l = 200 \text{ mm} \). The diagrams of cyclic crack resistance of unused metal of the pipeline have been received by way of testing of approbation beam samples with rectangular section \( (8 \times 10 \text{ mm}) \) with the initial edge crack \( c = 1,5 \ldots 2,0 \text{ mm} \).

Also, investigations have been conducted of cyclic crack resistance of used metal of an 81 km long “Druzhba" oil-trunk...
pipeline segment, which have been in operation for 41 year. What should be underlined is, that as a result of metal abrasion during operation process the thickness of the pipe wall lessened from 8 mm to 7 mm, and the most typical operational defects are corrosion defects (Figure 2), caused by joint action on metal of working loadings and environments.

Fig. 1. The geometrical dimensions of the sample for developments fatigue failure investigation in pipeline steels

Fig. 2. Typical corrosion damages on “Druzhba” oil trunk pipeline internal surface

The investigations for cyclic crack resistance have been conducted on special experimental equipment in pure bend operation process the thickness of the pipe wall lessened from 8 mm should be underlined is, that as a result of metal abrasion during pipeline segment, which have been in operation for 41 year. What should be underlined is, that as a result of metal abrasion during operation process the thickness of the pipe wall lessened from 8 mm to 7 mm, and the most typical operational defects are corrosion defects (Figure 2), caused by joint action on metal of working loadings and environments.

The investigations for cyclic crack resistance have been conducted on special experimental equipment in pure bend conditions of the models with 1 Hz frequency at the sinusoidal form of loading cycle \((R \approx 0.8)\). They have been tested in laboratory air, in distilled water (pH 6.7), as well as in 0.1 % NaCl solution (pH 6.5), which served as a soil water model. Environment temperature \(T = 25^\circ\text{C}\).

The models have been tested to final fracture with the subsequent analysis of fracture surfaces. The computerized fracture surface images, that correspond to different stages of corrosive fatigue failures development, can be used as models at identification of fracture conditions of real elements of pipelines in operation.

For the aforementioned steel 10Г2БТЮ3 test conditions, there in Table 2 the values of constants in Paris power dependence \([7]\) are presented. Here, also, the corresponding values of threshold \((K_{th})\) and critical \((K_{fc})\) stress intensity factors are given.

### 5. Investigation results

Approbation results have been represented as diagrams of cyclic crack resistance. These diagrams for various testing media for new and used metal are shown in Figure 3.

The analysis of the final results testifies to the following. With the growth of test media corrosiveness (laboratory air – distilled water – soil water), cyclic crack resistance of both new and used metal declines.

For all analysed cases the cyclic crack resistance of used metal of “Druzhba” oil-trunk pipeline is lower, than for the metal of the new pipe. The exploited metal is more sensitive to the environmental influence.

In particular, during the tests of used steel in soil water, the value of exertion intensity factor \(K_{th}\) declines in 1,5 – 1,7 times, whereas critical value \(K_{fc}\) declines in 1,3 – 1,6 times in comparison with the analogical data for new metal in the air.

Thus, we have defined the degree of influence of aggressive corrosive media on propagation of fatigue failure in the indicated steel.

### Table 2. Characteristics of cyclic crack resistance of steel 10Г2БТЮ3

<table>
<thead>
<tr>
<th>System “material – environment”</th>
<th>(n)</th>
<th>(C, \text{m/cycle} \times (\text{MPa} \cdot \text{m}^{\frac{1}{2}}))</th>
<th>(\Delta K_{th}, \text{MPa} \cdot \text{m}^{\frac{1}{2}})</th>
<th>(K_{fc}, \text{MPa} \cdot \text{m}^{\frac{1}{2}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>New metal – air</td>
<td>3.55</td>
<td>(5.86 \times 10^{13})</td>
<td>11.57</td>
<td>43.75</td>
</tr>
<tr>
<td>New metal – distilled water</td>
<td>6.76</td>
<td>(1.03 \times 10^{14})</td>
<td>9.90</td>
<td>36.85</td>
</tr>
<tr>
<td>New metal – model soil water</td>
<td>7.53</td>
<td>(1.63 \times 10^{17})</td>
<td>9.47</td>
<td>35.51</td>
</tr>
<tr>
<td>Used metal – air</td>
<td>4.56</td>
<td>(2.61 \times 10^{14})</td>
<td>10.28</td>
<td>42.90</td>
</tr>
<tr>
<td>Used metal – distilled water</td>
<td>8.38</td>
<td>(3.00 \times 10^{18})</td>
<td>8.37</td>
<td>32.62</td>
</tr>
<tr>
<td>Used metal – model soil water</td>
<td>10.40</td>
<td>(7.36 \times 10^{21})</td>
<td>7.64</td>
<td>33.61</td>
</tr>
</tbody>
</table>

Fig. 3. Influence of operational medium on cycle crack resistance diagram for new (1) and used (2) metal (steel 10Г2БТЮ3) of “Druzhba” oil-trunk pipeline: a – laboratory air; b – distilled water; c – soil water.
6. Conclusion

New data on character and peculiarities of fatigue and corrosive fatigue failure of pipes in dependence on the initial size and form of the detected in the pipeline defects have been obtained. It has been established, that the exploited over 40 years (degraded) metal of “Druzhba” oil-trunk pipeline (steel 10Г2БТЮ3) in corrosion medium has smaller resistance to propagation of cracks in comparison with unused metal.

It has also been found out, that aquatic corrosive media (soil and distilled water) essentially influence the process of a fatigue failure propagation in steel 10Г2БТЮ3. The most dangerous corrosive medium is 0,1 % NaCl solution, that is, model soil water.

7. Practical importance of the results

With the purpose of determination of the mechanism of corrosive-mechanical damages and developing of the recommendations for their preventive maintenance, the data obtained on cyclic crack resistance a pipe material will further be used in computed estimations of durability and longevity of pipeline elements taking into account the subcritical development of corrosion fissuring defects.

8. References


The work has been carried out in research laboratory of mechanics of materials and durability of constructions of Study of Engineering and Materials Department.
Abstract: In the field of the mobile service robots, several different robot systems have been developed being able to perform versatile tasks, such as searching for and saving the people, investigating unreachable areas, different applications in dangerous environments, taking samples from unreachable or dangerous environments, searching for the mines, exploring the planets, reasearching the sea bed, taking records from the air, etc. The purpose of this work is to study the mobile robots intended to be used on uneven terrains. Before starting to design a new terrain robot, it is important to define the terrain or the environment the robot is supposed to move within, as well as the scope of its assignments. When these data are collected, a mode of moving and locomotive robot system will be defined. In this process a requirement to keep the robot price as lower as possible has been constantly imposed.

KEYWORDS: MOBILE ROBOT, ROVER, OFF-ROAD MOBILE ROBOT, ROBOT MOVING, ROBOT CONTROL.

1. Introduction

The robots that are able to function expertly, efficiently and completely autonomously on unknown and/or extreme terrain have not been made yet. The best results have been achieved with the robots for exploring the space and unreachable terrains on the earth. A number of American and Russian rovers successfully completed their mission on Mars, while the latest ones are currently performing their mission. Planetary rovers need to be adjusted to walk on unknown and uneven terrain. Development of a terrain (off-road) robot, whose task would also be to walk on uneven terrain being unknown by a rule, has certain similarities with development of the planetary rovers.

The question arising is what would be the best construction of the mobile robot? This problem is not simple to resolve. William Whitaker, the chief researcher for development of the mobile robot ‘‘Dante II’’ told: “One of the reasons why we did not solve the robot mobility in the best way is because there is not a unique solution. We can see diversity in the nature, from the moving of snakes and the insects to the people’s two legged moving. These are not minor variations.” A moving mode is very complex in the world of animals and contemporary robotics is tending to utilize diversified solutions given by the nature and existing in the world of animals.

For all the stated above, before starting a phase of the robot projecting, it is important to define the terrain and the environment the robot is supposed to move within. According to these data, a mode of moving and locomotive robot system will be defined. In this process a requirement to keep the robot price as lower as possible has been constantly imposed.

In the project for developing a mobile service robot - ROBECO, financed by the Ministry of Science, Montenegro, the following goals have been set:
1. Analyse the environment conditions the robot is intended to move in
2. Study the latest generations of robots;
3. Compare different and suitable constructions of rovers
4. Select the best design of the mobile robot platform
5. Create physical model of the mechanism for moving the robot
6. Dynamics testing and controlling the selected mode of the robot moving

2. Work environment

Based upon the research of available information on planetary and terrain robots, the following guidelines for development of the terrain (off-road) robot can be given:
• a robot should move in natural, unstructured and a-priori unknown environment; terrain mobile robot needs to have a moving mechanism adjusted to uneven terrains;
• Information on robot and the environment need to be received by the robot sensors; different types of sensors are required (for perception and moving control);
• Terrain robot is often required to be equipped with a robot arm for handling the object;
• Supplying the robot for activation, moving and handling is limited. Terrain mobile robot requires on-board power supply;
• Terrain robot should drive on uneven terrain with high stability and when carrying material;
• Mechanical structure and moving control must be robust and safe to ensure the robot is capable of completing the task.

The first four aspects make the research of unknown terrains a difficult issue for robotics. These limitations imply the robots with semi-autonomous or autonomous capacities.

Terrain (off-road) robot that should be designed will move on the roads and off the roads, that is, on uneven terrain, but without extreme bumps which would require development of a special mechanism for overcoming high slopes i.e., bumps on the road.

3. Concepts of the existing rovers

From the mechanical point of view, rover researches have included: stability of the vehicle, mobility of the vehicle (mobility of the vehicle with legs is often tested against the vehicle with the wheels), handling and skilfulness.

DANTE (Figure 1.a) is a robot that was developed to explore the Antarctic volcanoes. This robot type with six legs is moving up and down the sheer surface supported by the winch. NASA allocated $ 1.7 million to have a research of this robot type continued. This resulted with creation of Dante II (the year of 1994) which has eight legs.

ROBBY (in 1990, Figure 1.f) is a machine with six wheels; this vehicle whose body consists of three parts has high level of mobility. The vehicle is bent around the central shaft which makes the wheel (all four) adjusted to very complex terrain geometry. Rear and front cabins have a control stereo vision and a Puma manipulator.

BLUE ROVER (Figure 1.c) is a three-segment prototype of 1987.

A mobile robot Sojourner (Figure 1.d) was used in the mission Pathfinder to explore Mars in summer 1997. It was completely controlled from the Earth. However, some sensors on the robot were able to detect obstacles.

Nomad rover (Figure 1.e), the vehicle without a driver was designed (at a Carnegie Mellon University) for testing such vehicles driving on other planets. In 1997, a robot „Nomad“ with four wheels was exploring uneven terrain of the Atacama desert in Chile for 45 days. A special panospheric camera took over a million of panorama photos from a cold and dry desert at height of 2.000 m.
AZIMUT (Figure 1.h) is a modular robot platform with the wheels-legs-caterpillars. A multiple mechanism is suitable for locomotion of the same robot platform. Four independent articulators can be used for the wheels, the legs or the caterpillars, or combination of all. Having the direction of articulation changed, AZIMUT can move sideways without changing its orientation which makes it move in different directions.

Opportunity rover (Figure 1.f) has been used since 2004 for exploration of Mars. Its dimensions are 2.3m x 1.6m x 1.5m, and it weighs 180kg. It has 6 wheels with rocker-bogie suspension, each having its own motor. Moving direction of the vehicle is controlled through the front and the rear wheels and can be safely done at the angle of incline up to 30º. It is supplied by solar cells.

Curiosity rover (Figure 1.g), dimensions - 2.9m x 2.7m x 2.2m and weight - 899kg is supplied through a radioisotopic thermoelectric generator (RTG). It has 6 wheels of 50 cm in diameter with rocker-bogie suspension and independent supply systems. The vehicle is controlled through pairs of front and rear wheels. The Rover has an arm of 2.1 m with a cross-shaped cupola with five devices which can be turned at 350º. The arm has three segments that can be extended forward and can be reassembled. The arm weighs 30 kg, with diameter of 60 cm including the accessories attached to the arm.

4. The robot moving

Generally, there are three different tendencies of the rover moving: the robot rovers similar to the cars with wheels, robots with legs and robots with caterpillars. Their general characteristics are given in the table 1.

The robots that combine basic moving modes and supporting mechanisms enabling them moving on highly uneven terrains and stairs have been developed by the research centres, in recent years. Combination of the wheels and the legs for moving also makes the robot faster, enabled by the wheels, while its mobility on uneven terrain is enabled by the legs.

<table>
<thead>
<tr>
<th>Moving mode</th>
<th>speed</th>
<th>mobility</th>
<th>Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>With wheels</td>
<td>high</td>
<td>In dependance on the platform construction it can move on uneven terrain</td>
<td>Compact and robust</td>
</tr>
<tr>
<td>With legs</td>
<td>low</td>
<td>Able to move on every terrain</td>
<td>Supports artificial intelligence</td>
</tr>
<tr>
<td>With caterpillar</td>
<td>medium</td>
<td>Able to move on uneven and bumpy terrain</td>
<td>Compact and robust; possible slipping</td>
</tr>
</tbody>
</table>

There are usually four motors for the wheels driving and another four motors for the wheels control with the existing solution of the mobile platforms. For a large number of motors, the platform control is more complex. The mobile platform for the robot “ROBECO” will have each wheel equipped with its motor which will ensure the wheel speed to be controlled independently. Control of all wheels will be interdependent and one motor has been predicted for this purpose. Such concept allows existence of rotation centre which is required to enable manoeuvrability of the platform. The controlling concept by directing wheels through a motor requires designing of a special transmission mechanism which makes a mechanical construction of the platform complex. From the other side, lower number of motors (5 motors) compared to the existing solutions (8 motors) makes controlling demands more simple.
A remote-controlled robot *Tiburon* (Figure 3) is used for underwater archaeology. Such autonomous underwater vehicle (UAV) gives possibility of floating.

*Pioneer* (Figure 4) is a remote-controlled robot designed to explore the electric power plant in Chernobyl assigned to relocate the sensors and take samples.

It has:
- a mapper for creating photo-realistic 3D model of the building interior,
- drill for drilling and taking samples of structured material, as well as
- programme package for processing data on radiation and from other sensors for reading the environment data.

*Pulstech Corporation* developed the first industrial walking „forest“ robot (Figure 5). It was designed to take the cut timbers out from the forest. Coordination of legs is automated, but navigation is done by a human.

Mobile robot *Sojourner* (Figure 6) was used in a mission Pathfinder for exploring Mars in summer 1997. It was almost completely remote-controlled from the Earth. However, some sensors on the robot were able to detect obstacles.

*HÄCHER* robots for inspection and reparation of the sewer pipes (Figure 7) are completely the remote-controlled systems.

6. Instead of a conclusion

This work is a part of an introductory research for the development project of a multi-functional service robot „MNE-ROBECO“ financed by the Ministry of Science of Montenegro. The next actions in development of the mobile platform for a terrain robot would be to define kinematic and dynamic model of the robot platform, realize a physical model of the mechanism for the robot moving, control of selected moving and dynamics testing on different bases.

**Literature:**


Abstract: The article presents results from the research of the reliability of Citroen Jumper and Fiat Ducato chassis using the Pareto method. Their most common failures and repairs are identified and presented in diagrams.

Keywords: reliability, failures, repairs, chassis of light lorry, Pareto chart

1. Introduction

The systems providing reliability comprise the entire lifecycle of the machines, from the design and the construction to the operation. The methods ensuring reliability are specific to each stage of the lifecycle. For example, achieving the organization’s reliability goals requires strategic vision, proper planning, sufficient organizational resource allocation and the integration of reliability practices into development projects. Reliability design describes the entire set of tools that support product and process design to ensure that the expected reliability is fully met throughout the life of the product.

The main factors influencing the reliability of machines, especially the means of transport, are the conditions and modes of operation, as well as organization and management processes of maintenance and repair.

The successful solution of tasks related to improving the reliability can be achieved by taking management decisions based on information obtained from statistical data of the occurred failures, the expenditure for repairs and the automobiles downtime.

The common failures of a certain structure, the likely causes of the failure occurrence and the ways to minimize them can be determined successfully using the Pareto chart.

2. Results and discussion

Pareto diagram represents a particular form of vertical bar graph that highlight the most important among a set of factors. In quality control, it gives the most common reason for faults and failures and helps to reduce or completely eliminate them. The construction of this chart is based on processing of statistical information or other form of data collection. Pareto chart focus on actually the most important factors of the study (the highest bars in the graph) and less to those which are insignificant. Pareto charts for analysis of the reliability (Fig. 1) are built on the following algorithm:

1. Selecting a proper classification of failures in accordance to the studied object.
2. Defining the form for registration of the failures.
3. Developing methodology for processing statistical information.
4. Processing data arranged in descending order.
5. Plotting a horizontal and two vertical axes. On the horizontal axis are plotted the considered factors. On the left vertical are plotted the measured values of the analyzed parameters, and on the right - relative values of this parameter as a percentage of total value.
6. Plotting a bar chart for different types of failures.
7. Drawing a Pareto curve. On the intervals corresponding to each vertical of the horizontal axis are plotted the accumulated sums (measured in units or in percentages) which are joined by straight lines.

Pareto principle was used as a scientific tool for reliability analysis. Based on this principle, an analysis of the cost of repairing various types of failures is made. Csp indicator is used to determine the average specific costs (materials and labor) for distance covered per unit of time (1).

\[ C_{sp} = \frac{\sum_{j} C_{ij}}{L_j} \]  \hspace{1cm} (1)

Where \( C_{ij} \) is the cost of removing the \( i \)th type of failure of the \( j \)th vehicle; \( L_j \) - the mileage of the \( j \)th vehicle covered during the study.

The study was conducted based on statistical data obtained from expenditures report made for the repairs or prevention of the failures of individual components of the chassis for 28 cars Citroen Jumper and 29 cars Fiat Ducato. The total distance covered \( \sum L_i \) is 829470km (Citroen Jumper) and 5134432km (Fiat Ducato), and the average distance is 286024km and 177049km respectively. For the chassis of Citroen 373 failures were registered and divided in 16 classes (groups), and for Fiat Ducato - 390 failures, divided in 9 classes (groups).

For each group of failures for the specific model, \( C_{sp} \) costs and their relative share in percentage \( C_{sp} \% \) was determined using formula (1) (Table 1 and Table 2).

<table>
<thead>
<tr>
<th>№</th>
<th>Type of failure</th>
<th>C_{sp} \text{ lv/1000 km}</th>
<th>C_{sp} %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Front strut bearing replacement</td>
<td>0,91</td>
<td>25,3</td>
</tr>
<tr>
<td>2</td>
<td>Front hub bearing replacement</td>
<td>0,81</td>
<td>22,5</td>
</tr>
<tr>
<td>3</td>
<td>Front wishbone bushes replacement</td>
<td>0,8</td>
<td>22,2</td>
</tr>
<tr>
<td>4</td>
<td>Ball joint replacement</td>
<td>0,77</td>
<td>21,4</td>
</tr>
<tr>
<td>5</td>
<td>Rear hub bearing replacement</td>
<td>0,099</td>
<td>2,7</td>
</tr>
<tr>
<td>6</td>
<td>Power steering rack replacement</td>
<td>0,061</td>
<td>1,7</td>
</tr>
<tr>
<td>7</td>
<td>Bar link replacement</td>
<td>0,06</td>
<td>1,7</td>
</tr>
<tr>
<td>8</td>
<td>Welding on the base of the front shock absorber</td>
<td>0,05</td>
<td>1,3</td>
</tr>
<tr>
<td>9</td>
<td>Inner steering connecting rod replacement</td>
<td>0,04</td>
<td>1,1</td>
</tr>
</tbody>
</table>

Fig. 1 Pareto chart for reliability analyze (cumulative curve)
Tabl. 2 Specific costs for failures elimination of Fiat Ducato

<table>
<thead>
<tr>
<th>№</th>
<th>Type of failure</th>
<th>( C_{sp} ) $/1000 km</th>
<th>( C_% )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Front hub bearing replacement</td>
<td>1,84</td>
<td>33,6</td>
</tr>
<tr>
<td>2</td>
<td>Front strut bearing replacement</td>
<td>1,31</td>
<td>24</td>
</tr>
<tr>
<td>3</td>
<td>Front wishbone bushes replacement</td>
<td>0,96</td>
<td>17,5</td>
</tr>
<tr>
<td>4</td>
<td>Ball joint replacement</td>
<td>0,87</td>
<td>15,9</td>
</tr>
<tr>
<td>5</td>
<td>Bar link replacement</td>
<td>0,23</td>
<td>4,2</td>
</tr>
<tr>
<td>6</td>
<td>Power steering rack replacement</td>
<td>0,12</td>
<td>2,2</td>
</tr>
<tr>
<td>7</td>
<td>Welding on the base of the front shock absorber</td>
<td>0,06</td>
<td>1,1</td>
</tr>
<tr>
<td>8</td>
<td>Inner steering connecting rod replacement</td>
<td>0,05</td>
<td>0,9</td>
</tr>
<tr>
<td>9</td>
<td>Rear hub bearing replacement</td>
<td>0,02</td>
<td>0,3</td>
</tr>
</tbody>
</table>

To analyze the reliability of the chassis for the investigated vehicles based on data from Table 1 and Table 2, bar and Pareto charts were built.

In order to choose standard for classification of the typical failures for the mentioned vehicles it is required the cumulative growth curve for specific costs \( C_\% \) to be greater than the calculated average for this model. The average value of the specific costs to repair the chassis’ components for Citroen Jumper is:

\[
C_\% = \frac{100}{9} = 11,1\%
\]

The average value of the specific costs to repair the chassis' components for Fiat Ducato is:

\[
C_\% = \frac{100}{9} = 11,1\%
\]

From the Pareto chart (Fig. 2 and Fig. 3) can be determined that Citroen Jumper and Fiat Ducato include the following four typical failures:
- front strut bearing replacement;
- front hub bearing replacement;
- front wishbone bushes replacement;
- ball joint replacement.

3. Conclusion

More detailed analyze shows that the frequent replacement of the chassis and suspension components (bearing, hub bearing, front wishbone bushes, ball joint) is due to the poor country road conditions and the replacement of the original spare parts with alternative, which have less reliability and higher probability for failures.

The comparison of specific costs for eliminating of failures of both vehicles shows that Citroen Jumper has significantly lower cost for maintenance than those for Fiat Ducato. The reason is the poor road conditions in urban compared to rural areas. The distance Citroen Jumper covered is up to 200,000 km of rural areas while Fiat Ducato operated only in urban regions. This show how significant is the influence of the road conditions and correct vehicle operation on the cost of maintaining the chassis.

The results of the study allow detecting the most unreliable components of the chassis and suspension. This can help the management staff responsible for maintenance and repairs to take appropriate decisions to improve reliability and increase the efficiency of operation of these vehicles.

4. References