

The structure of computer-based system of industrial railway traffic scheduling

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Summary. A structure of computer-based system of industrial railway traffic scheduling has been developed. Presented are: a range of tasks to be solved by the scheduler, processing car traffic volumes, and operating principle of the system.

Key words. Car traffic volume, ergatic system, scheduling (operational planning), scheduler (system of operational planning), industrial railway traffic, daily schedule (time-table).

INTRODUCTION

Current requirements towards arrangement and quality of transportation demand new organizational and technological solutions in transportation (traffic) management, based on a broad implementation of integrated data systems. Development and implementation of the data systems is aimed to improve industrial railway traffic and to reduce operating costs.

One of the ways to develop an enterprise in market economy conditions is to increase the competitiveness of products and services. From economics point of view the liquidity of goods (the ability of goods to be sold quickly) is affected by several factors: quality, cost, delivery time and quality, business terms and conditions, etc. High product quality is achieved by development and accurate meeting the production technology. And if this factor is affected by the production technology choice and compliance, the level of the remaining factors is significantly affected by forwarding services. Delivery time of both raw materials and goods, depends on the level of the

forwarding services at all stages. Delivery time plays an important role in modern economic conditions. All these facts point to the necessity of improving forwarding services. Railway transport (traffic) is the main carrier of both raw materials and finished goods for big enterprises with annual turnover exceeding 2 million tons/year.

At present, tasks associated with the scheduling process of car traffic volume are still being solved manually, without considering possible influencing factors in the operational environment. It is not possible to solve the problems of modern industrial railway traffic in an integrated setting without information technology and computers. Current information systems are still operating as I&R (information and reference) systems.

Consequently, it is necessary to automate the control of industrial railway traffic operation. The purpose of computer-based system of industrial railway traffic scheduling is to satisfy the needs of enterprise production and marketing units with timely, qualitative and complete services [16,18].

The purpose of the scheduling of a railway station operation is to carry out assignments for reception, connecting, disconnecting and departure of trains and railcars (including empty railcars for repositioning), loading, unloading, as well as meeting the timetable, train formation plan and established performance specifications [15].

The enterprise planning tasks, supervisory control, as well as assessment and control are carried out by a train dispatcher.

The dispatcher's duties are:

- to establish the efficacy of the order of priority of disconnecting and transmission of trains taking into consideration loading and unloading at railway loading complex and shunting areas;
- to carry out the plan of connecting the trains and in-plant transmissions;
- to carry out the plan of loading-unloading by timely filing of railcars to the railway loading complexes, controlling loading at railway loading complexes and loading-unloading mechanisms and machines;
- to distribute work between shunting locomotives based on the best usage of their power and time between shunting zones and sorting devices;
- to provide smooth operation of all parts of transportation department and minimum downtime based on dispatcher scheduling;
- to provide full and timely transportation for all shops and enterprise sectors on the basis of work process and transportation requirements estimate;
- to provide quantitative and qualitative performance in accordance with established timetable standards, minimizing inter-operational downtime; to use the equipment and labor in the best way, minimizing costs, to ensure safe and trouble-free operation and to avoid technical and commercial rejects.

OBJECTS AND PROBLEMS

In terms of general systems theory - the system of industrial railway traffic is structured, that is represents a set of input systems, which are called its elements. The elements of a structured system will be interpreted as a subsystem corresponding to the complete system.

We describe the interaction of the system elements of the industrial railway traffic of a conditional enterprise. On the basis of the described process we construct a model of computer-based system of industrial railway traffic scheduler. Simulation allows studying the essence of complex processes and phenomena with the help of experiments not with the real system but with its model. We know that it is not necessary to know all characteristics of the system to make reasonable decisions on system operation, - analysis of its simplified, approximate representation is always sufficient.

Process car traffic volume is transmitted between different levels; we call these levels - the levels of interaction.

Objects of industrial traffic, in which car traffic volumes are changed (the order of cars in the train, the size of the train, specification of goods and condition of railcars are changed), are meant under the selected levels. For example, a *connecting station* extracts to a separate level, because it has a number of distinct qualities, which significantly distinguish it from other objects of industrial transport. These qualities include, first and foremost, the fact that the connecting station belongs to the main-line traffic system and not to the railway traffic of the industrial enterprise.

Second, the following can be performed at the station: accumulation, generation and reorganization of car traffic volumes of adjacent enterprises that are being served.

Factory railway station should be allocated at the next level. Both levels are necessarily interconnected, but, unlike the connecting station, the factory railway station processes (generates, reorganizes, accumulates) the car traffic volumes of the enterprise only. *Special dead end tracks* for sorting, waiting, accumulation and other operations can be located in the loading and unloading areas of the enterprise. This element should be allocated in a separate level of interaction. The elements of this level can directly interact with the connecting station, bypassing the factory railway station.

Railway loading complex (RLC) can be selected as the next level that is specialized in loading and unloading of goods. All levels interact alternately with each other, but on a number of occasions some of the levels can be excluded.

The structure of the described system is determined by regular monitoring of engineering communications between the selected levels of interaction. These communications are described in detail by the process of industrial traffic system. Process is defined as total combination of operations on railcars processing (operations of acceptance, delivery of trains to the spur tracks; rebuilding trains, weighing, supply to the railway loading complex, cargo operations, taking from the railway loading complex, generation of supply to the station or dead end tracks, technological permutations of railcars or groups of cars; accumulation and weighting, minor repairs, cleaning, washing, cargo heating or other operations to restore looseness or flowability of cargo, collection of supplies to the connecting station) [9, 10].

All railcars involved in the calculation of the current period can be divided into three basic groups:

- wagons to be transported for unloading and loading within scheduling period;
- wagons to be collected and administrated within scheduling period;
- wagons to be transported under the dual operations and to be collected within scheduling period.

Imagine scheme of engineering communications in scheduling of shunting operations on the industrial railway transport (fig. 1).

It should be noted that the above process operations are conducted on specialized railway lines and certain enterprise points, so they correlate accurately with the selected levels of interaction.

The wagons received by the company, pass the following cycle [14]:

- 1) Acceptance procedures;
- 2) Rebuilding the train;
- 3) Distribution and delivery of wagons to the purpose fronts;
- 4) loading and/or unloading of wagons;
- 5) Removal of wagons from the spur tracks.

Sometimes some other operations are added to the above, such as weighing, but their structure resembles one of these operations.

All transactions are reflected in a daily timetable. Time for acceptance procedures is normalized and is in specific formulas, so computer-based scheduling of acceptance operations presents no difficulty.

Most of the railways loading complexes are equipped with shunting means, therefore, loading or unloading of railcars is not particularly difficult. But often it is not possible at big enterprises. The railcars should be pushed by the locomotive to be loaded or unloaded.

Let us consider process operations with car traffic volumes as some service requests for the purpose of subsequent implementation of the proposed model and based on it computer-aided generation of daily timetables for the industrial railway traffic. Imagine an interaction scheme of service requests for conditional industrial enterprise (fig. 2). For the block "Queuing service requests → Finding solutions → Generation of service requests" the service requests are organized on the following principle: incoming - from the connecting station, from the locomotive depot after having received a request from the factory station, the factory station, from the railway loading complexes, after submitting an request to the locomotive depot. After Finding Solutions block the generated service requests return to be fulfilled at: factory station, railway loading complexes and locomotive depot [1-3, 11].

In turn, the model presented is an element of the block 3 ergatic system (fig. 3). It consists of a plurality of different elements, which during operation is closely interact and affect one another.

In our case, this process control system of automatic construction of the daily schedule of the train station in an industrial plant, and the person who interacts with the system decision maker (DM) [4-7, 12, 13].

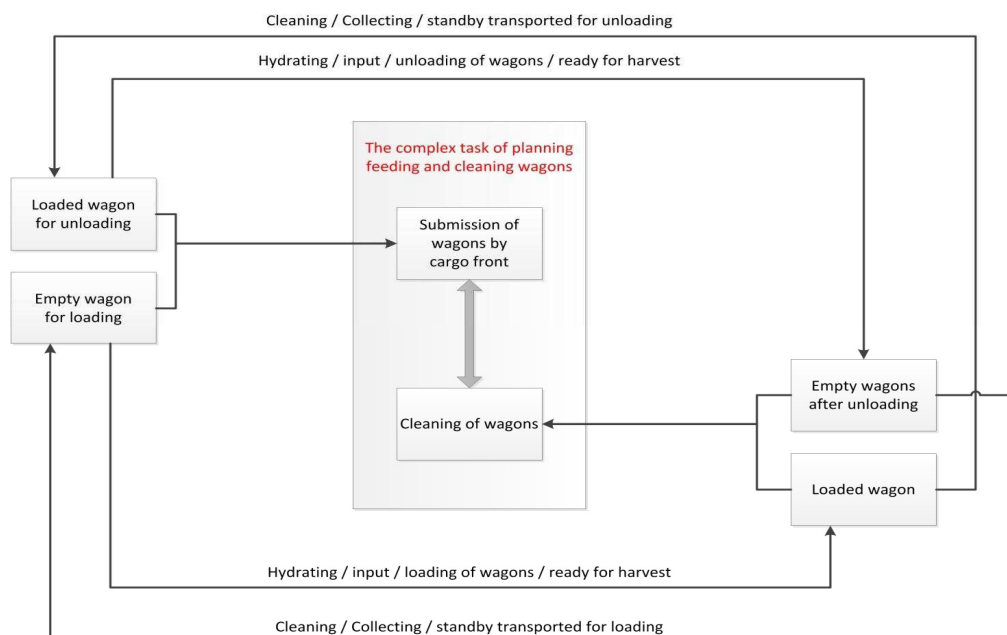


Fig. 1. Engineering communications in scheduling of shunting operations on industrial railway transport

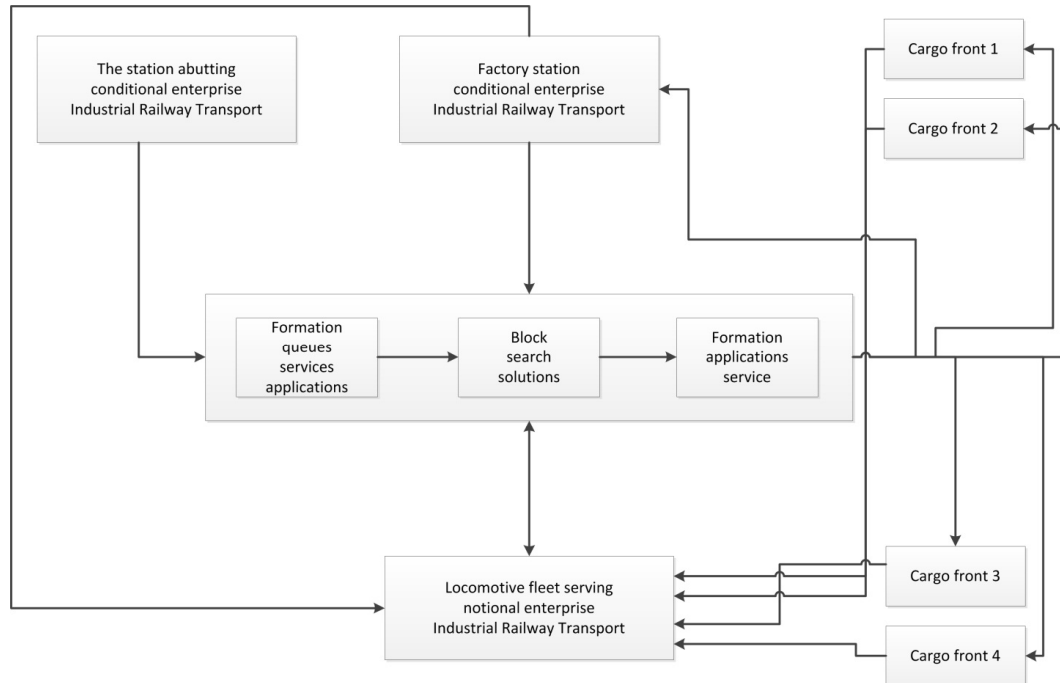


Fig. 2. The scheme of interaction between service requests for conventional industrial enterprise

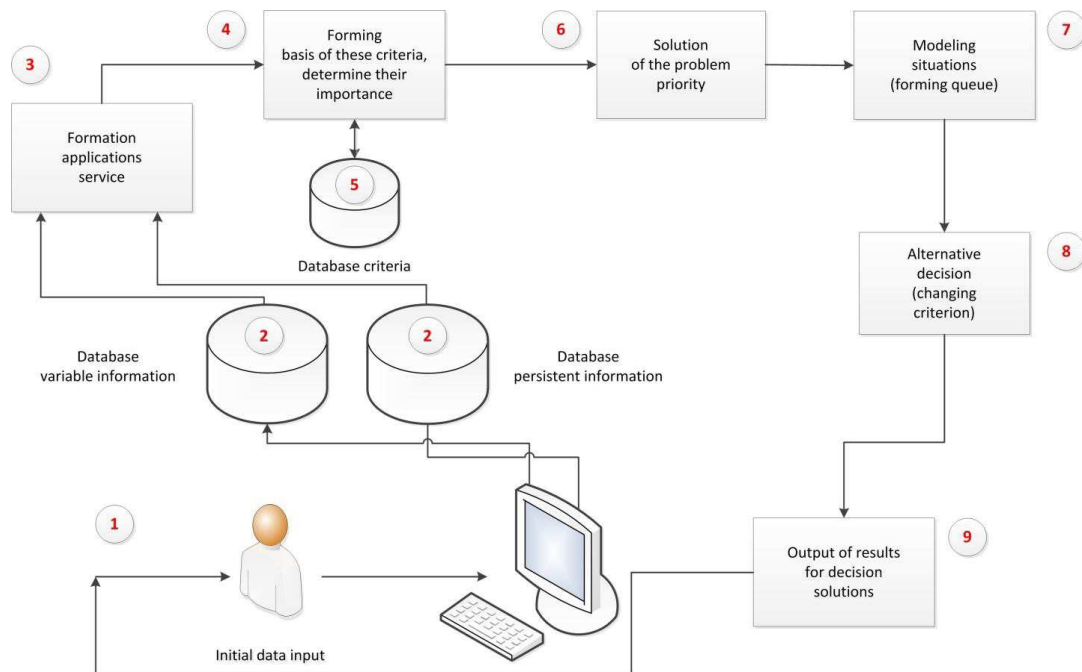


Fig. 3. The structure of functional ergatic system

The system includes the following elements:

1. Dispatcher, who acts as a decision-maker.
2. Databases containing: 1) constant information 2) variable information.

To constant information we refer information about the development structure of the enterprise railroads, tracking characteristics, normal position of shunts, traffic routes, etc.

To variable information - starting letter and transactions register.

The starting letter indicates freight end-station, date dispatched, registrar's name and a list of railcars. Each car has its serial number and type, freight name and railcar weight.

The transaction register contains information about the operation name, registrar's name, locomotive number, operation path number, start

time, end time and a list of railcars with their registration number, type of car and type of cargo.

3. Service requests are generated in the developed system of codification based on the constant and received data.

4. To select a service application (to meet the requirements) we shall create a database of criteria that then will be used to solve the problems of priority.

5. Criteria Database. By criteria we shall understand some certain conditions, subject to which simulation takes place:

- to rebuilt or not the train;
- to take into account the priority of railcars (own, someone else's);
- to cluster railcars in one group when supplying them to the station;
- to consider the minimum of locomotive operation;
- minimum running time at the railway loading complex;
- capacity of program execution at railway loading complex within time "window", etc.

6. Applying fuzzy multi-criterion analysis of alternatives with paired comparisons, based on experts' knowledge, we solve the problem of priority. Problem solution is prioritization of the generated requirements.

7. We create a queue for servicing based on solution of prioritization problem. We have a block of situation simulation.

8. By changing the criteria we shall get a set of alternative solutions.

9. The received results are provided to the decision-makers in the form of several daily schedules for the industrial railway traffic, which are accompanied with comments and are evaluated with time or monetary units to make final decision.

CONCLUSIONS

The following conclusion can be drawn out from the above stated. The range of tasks associated with the process of scheduling of car traffic volumes is very diverse and broad. Using information technology and computers in our model, we propose to design a computer-based system of scheduling of industrial railway traffic at the enterprise, center of which is the ergatic system. The basic idea of which is as follows: on the basis of information provided by the Dispatcher (DM), the system generates service requests using interconnections shown in Figure 1. Then some criteria are introduced for consideration

through direct participation of decision-makers and their importance is determined. Based on the importance of criteria we use methods of fuzzy multi-criterion analysis of alternatives with paired comparisons to solve the problem of priority. The problem solution is sorting of computer-generated service requests in the order of criteria importance. Then queuing of the service requirements generates, based on system-assigned priority. We can change one of the paired comparisons, suggested by DM, to get alternative solutions. Then a conclusion of the obtained results is drawn up to make the final decision and to build daily schedule for operation of the industrial railway traffic at the enterprise [8, 17, 19, 20].

Java object-oriented programming language is selected for implementation of the software package. Cross-platform, initially incorporated into the language, provided its popularity in programming for a wide range of devices, from personal computers with different operating systems, and to mobile phones and other gadgets. It is considerably easier to create reliable software with this programming language. Since Java programs are interpreted rather than compiled, their execution on different platforms is much simpler. In this case it is sufficient to create a platform-runtime Java-system. If such system exists for this operating system, any Java-program can be executed in the environment without additional compiling on this platform.

DBMS Firebird - a compact, cross-platform, free database management system – is used to develop a database. Its capabilities are virtually no way inferior to other database capabilities, and would be enough to do the job. In addition, it uses SQL dialect, which is very easy to learn. Other advantages of this database are resources simplicity, good-enough performance for high volumes of data, easy to install and fairly easy administration.

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СТРУКТУРА АВТОМАТИЗИРОВАННОЙ СИСТЕМЫ ОПЕРАТИВНОГО ПЛАНИРОВАНИЯ РАБОТЫ ПРОМЫШЛЕННОГО ЖЕЛЕЗНОДОРОЖНОГО ТРАНСПОРТА

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Дмитрий Марченко, Владимир Кучма*

Аннотация. Разработана структура автоматизированной системы оперативного планирования работы промышленного железнодорожного транспорта. Представлены задачи, которые будет решать предложенная система оперативного планирования переработки вагонопотоков и принцип действия системы. **Ключевые слова.** Вагонопоток, эргатическая система, оперативное планирование, промышленный железнодорожный транспорт, суточный план-график.

Diesel operation efficiency improvement based on modelling of fuel carburetion process

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Summary. Modeling of the droplet motion kinetics in the cylinder of the engine from the moment of the fuel injection rate to its falling on the parts of the cylinder-piston group taking into account the peculiarities of the temperature influences and acquired kinetic energy for finding out the influence of the carburetion conditions on the operational features of the engine in relation to the geometric characteristics of the cylinder-piston group is considered.

Key words: diesel, structure, fuel, drop, carburetion.

INTRODUCTION

The investigation performed within the scope of this work deals with the improving of carburetion and air-fuel mixture combustion processes and allows making conclusions on the occurrence of several contradictions concerning the description of intra-cylinder processes [1,5,12,15,17,18]. Certain physical and chemical processes, which are, in our opinion, significant, are not accounted for taking into consideration their unconditional complexity and multiple-factor character in the known developments of theoretical models. Thereupon, these approaches result in certain discrepancies between theory and practice.

This discrepancy can be seen in a multi-zone model of internal combustion engine operation [7,9] which is based on the equation systems set up by the law of conservation of energy and mass as well as Clapeyron-Mendeleev equation:

$$\frac{d(mu)}{d\tau} = \frac{dQ_x}{d\tau} - \frac{dQ_w}{d\tau} - P_c \frac{dV_z}{d\tau} + h_{vp} \frac{dm_{vp}}{d\tau} - h_{vyp} \frac{dm_{vyp}}{d\tau}, \quad (1)$$

$$\frac{dm}{d\tau} = \frac{dm_{vp}}{d\tau} - \frac{dm_{vyp}}{d\tau}, \quad (2)$$

$$\frac{dP_c}{d\tau} = \frac{mR}{V_z} \frac{dT_z}{d\tau} + \frac{mT_z}{V_z} \frac{dR}{d\tau} + \frac{RT_z}{V_z} \frac{dm}{d\tau} - \frac{RT_z m}{V_z^2} \frac{dV_z}{d\tau}, \quad (3)$$

where:

m - total mass of the working substance (air-fuel – combustion products) in the zone kg,

u - work performed by the working substance J/kg,

Q_x - energy received from the fuel combustion J,

Q_w - energy consumed for evaporating the droplet and heating the working substance J,

P_c - pressure in the cylinder of the engine Pa,

V_z - volume of the zone at the instant time τ m³,

h_{vp} - enthalpy of the working substance coming into the zone J/kg,

m_{vp} - mass of the working substance coming into the zone kg,

h_{vyp} - enthalpy of the working substance leaving the zone J/kg,

m_{vyp} - mass of the working substance leaving the zone kg,

R - gas constant of the working substance J/(kgK),

T_z - tempera of the zone K.

This model accounts little for the kinetics of the mass change of the fuel coming into the cylinder of the engine. The specification of the injected fuel ratio for each zone is required to solve the system. And further, a priori, there is an assumption that the carburetion meets the requirements of the volumetric process, that is the heat transfer is effected from the air charge in the combustion chamber on the micro-particles of the fuel evenly sprayed throughout it.

The specified conditions do not conform to the results concerning the formation of the air-fuel mixture received by the known researchers like N.F. Razleitsev [19], B.I. Sreznevskiy [22], A.S. Lyshevskiy [13], Kitamura T. [8] and others.

The work, thereby, sets a task to determine the kinetics of the droplet motion in the cylinder of the engine from the moment of the fuel injection to the moment of its falling on the parts of the cylinder-piston group taking into consideration thermal effect and gained kinetic energy. The consideration of such task is thought actual as it allows defining the level of influence of carburetion conditions on the operational characteristics of the engine depending on the geometrical features of the cylinder-piston group.

We find it possible to consider several variants of distributing the fuel in the cylinder taking into account a great amount of the components contained in the low-volatility fuel [3, 10, 21]. The droplets of the fuel evaporate partially not reaching the piston or the cylinder walls and thus provide carburetion, at the same time, the heavy fractions (asphaltenes, paraffines) do not evaporate and reach the surface of the piston and the cylinder absorbing the heat not only from gases but from the combustion chamber as well and only then they evaporate providing film carburetion. The process of their thermal decomposition is undoubtedly observed as well.

The processes of carburetion and, further, the processes of combustion in the cylinder of the engine are influenced by structural features of the injector and its location, diameter of the orifices of the atomizer, dimensions, physical and chemical properties of the material of the cylinder-piston group as well as operational parameters of the engine: pressure of the fuel injection, temperature of the fuel, pressure of the boost, temperature and humidity of the air, fractional composition of the fuel, temperature of the cooling liquid and oil,

engine load. The fuel injection advance angle and valve timing appear essential.

When the fuel jet moves, the air flow appears and it is caught by the fuel jet, the speed of the jet reduces due to the friction as the air medium resists the movement. Vortices appear on the surface of the jet, they are the main means of air retract and provision of the jet aeration. It results in the expansion of the fuel jet surface, the lateral section increases and its moving mass flow grows. Thus, the fuel jet expansion angle depends on air density, fuel viscosity, diameter of the nozzle orifice, speed of the fuel discharge, the shape of the nozzle and cleanness of its inner side and can be considered by the scheme represented on Fig.1.

The influence of the main structural and operational parameters on the fuel jet expansion angle is, in our opinion, to the fullest extent possible described in the following works [6, 13, 14, 23]. The expression is recommended for calculating the fuel jet expansion angle based on the analysis of the investigations:

$$\operatorname{tg} \beta = C_{\text{ras}} \operatorname{Re}_{\text{ras}}^{0,5} Fr^{0,125} \left(\frac{\rho_v}{\rho_k} \right), \quad (4)$$

where:

β - the fuel jet expansion angle, degrees,

C_{ras} - dimensionless coefficient characterizing the shape, dimensions and surface finish of the atomizer as well as the initial or the main segment of the jet,

$\operatorname{Re}_{\text{ras}} = \frac{d_c v_n \rho_k}{\mu_k}$ - Reynolds number,

d_c - diameter of the nozzle orifice m;

v_n - initial speed of the jet m/s,

ρ_k - fuel density kg/m³,

μ_k - coefficient of the dynamic fuel viscosity Pa·s,

$Fr = \frac{v_n^2}{gd_c}$ - Froude number,

ρ_v - air density kg/m³,

g - acceleration of gravity m/s².

The initial speed of the jet through the nozzle of the atomizer can be expressed the following way [2]:

$$v_n = \varphi \sqrt{\frac{2(P_{\text{vp}} - P_c)}{\rho_k}}. \quad (5)$$

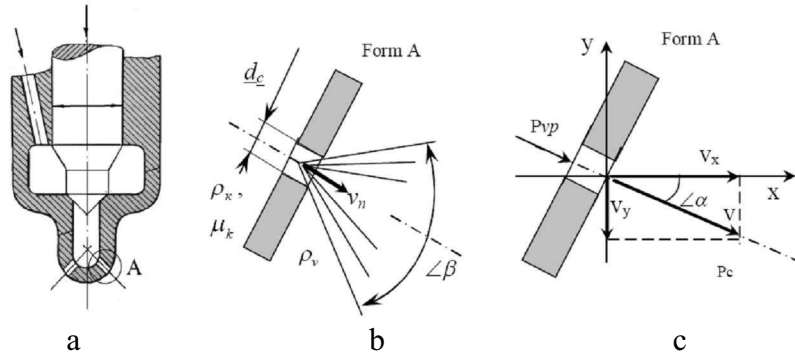


Fig.1. The scheme of normal atomizer construction and fuel discharge: a – general arrangement of the normal atomizer, b – the scheme for calculating the jet expansion angle, c – the scheme for calculating the speed of the jet

Providing that $\rho_k = \text{const}$ and after differentiating the equation (5) we get the following:

$$\frac{dv_n}{d\tau_{vp}} = \varphi \sqrt{\frac{1}{2\rho_k} \left(A \cdot \frac{dP_{vp}}{d\tau_{vp}} - A \cdot \frac{dP_c}{d\tau_{vp}} \right)}, \quad (6)$$

where:

τ_{vp} - time since the beginning of the fuel injection s,

φ - dimensionless coefficient of discharge through the atomizer depending on the shape of the orifice:

$$A = \frac{1}{\sqrt{(P_{vp} - P_c)}};$$

P_{vp} - pressure of the injection in the inner chamber of the atomizer MPa,

P_c - pressure in the engine cylinder MPa.

The speed of the droplet depending on the direction of the fuel jet (fig. 1-c) equals:

$$v = \sqrt{v_x^2 + v_y^2}, \quad (7)$$

where:

v - the speed of the droplet motion m/s,

v_x, v_y - velocity vectors along the axis m/s.

Taking into consideration that the motion equation accounting the resistance of the medium equals:

$$v_x = v_n \sin \alpha + \left(g - \frac{kv_x^2}{2} \right) \tau, \quad v_y = v_n \cos \alpha - \frac{kv_y^2}{2} \tau, \quad (8)$$

where:

α - the deviation angle of the jet direction relative to the horizontal plane degrees:

$k = \frac{C\rho_v F_k}{m_k}$ - generalized coefficient of the medium resistance m^{-1} ,

F_k - frontal area of the droplet m^2 ,

m_k - mass of the droplet kg,

C - dimensionless aerodynamic resistance coefficient,

τ - motion time s.

The aerodynamic resistance coefficient is usually taken for a spherical droplet which simplifies the calculation greatly. The dependence of determining the aerodynamic resistance coefficient is the following [16]:

$$C = \frac{24}{Re} + \frac{3,6}{Re^{0,317}} \quad \text{where } Re = 0 \dots 700, \quad (9)$$

$$C = 0,46 \quad \text{where } Re > 700, \quad (10)$$

where:

$Re = \frac{d_k v \rho_v}{\mu_v}$ - Reynolds number,

d_k - diameter of the droplet m,

μ_v - coefficient of the air dynamic viscosity

Pa·s.

Considering that such assumption to some extent does not correspond to the physical representation of the process as, when flying (especially at high velocity rates), the droplet deforms and deviates from the spherical form considerably [11], we defined the aerodynamic resistance taking into account the shape coefficient k_{dn} :

$$k_{dn} = \frac{d_{ek}^2}{d_k^2}, \quad (11)$$

where:

d_{ek} - volumetric diameter of the droplet m,

d_k - mean diameter of the droplet of the current discharge velocity m.

According to the results of research [4]:

$$d_k = d_c 2,88 Lp^{-0,0733} We^{-0,24} \left(\frac{0,25}{d_c} \right)^{0,7}, \quad (12)$$

where:

$$Lp = \frac{\sigma_k \rho_k d_c}{\mu_k^2} - \text{Laplace number,}$$

σ_k - coefficient of the superficial tension of the droplet kg/s²,

$$We = \frac{v^2 \rho_k d_c}{\sigma_k} - \text{Weber number.}$$

$$d_{ek} = 1,96 We^{-0,04} d_k. \quad (13)$$

After converting the expression (8) into the root equation we get:

$$v_x = \frac{-1 + \sqrt{1 + 2k\tau(v_n \sin \alpha + g\tau)}}{k\tau}, \quad (14)$$

$$v_y = \frac{-1 + \sqrt{1 + 2k\tau v_n \cos \alpha}}{k\tau}. \quad (15)$$

We have the equation of jet flow velocity change after substituting (14-15) into (7) and differentiating:

$$\begin{aligned} \frac{dv}{d\tau} = & \frac{(-1+B)(2kv_n \cos \alpha + 2\tau v_n \cos \alpha \frac{dk}{d\tau})}{2k\tau \sqrt{(-1+B)^2 + (-1+G)^2} + \frac{(2kg\tau + 2k(H))(-1+G)}{G}} + \\ & \frac{G}{2k\tau \sqrt{(-1+B)^2 + (-1+G)^2} - \frac{\sqrt{(-1+B)^2 + (-1+G)^2}}{\tau^2 k}} - \\ & \frac{\sqrt{(-1+B)^2 + (-1+G)^2}}{\tau k^2} \frac{dk}{d\tau} \end{aligned} \quad (16)$$

$$\text{where: } B = \sqrt{1 + 2k\tau v_n \cos \alpha},$$

$$G = \sqrt{1 + 2k\tau(v_n \sin \alpha + g\tau)},$$

$$H = g\tau + v_n \sin \alpha + 2\tau \frac{dk}{d\tau}(J),$$

$$J = 10\tau + v_n \sin \alpha.$$

Define the limits of the drop motion along the axis:

$$\int_{\tau_{vp}}^{\tau_k} v_x d\tau \leq R_k, \quad (17)$$

where:

R_k - horizontal distance from the atomizer to the walls of the cylinder.

$$\int_{\tau_{nvp}}^{\tau} v_y d\tau \leq \frac{\tau_{nvp}}{\pi R^2} \int dV \quad \text{where } \tau \leq \tau_{vmt}, \quad (18)$$

where:

τ_{nvp} - time of the start of the injection s,

V - volume of the cylinder involved in the process m³,

R - radius of the cylinder m,

τ_{vmt} - time when the piston reaches the top dead center C.

$$\int_{\tau_{vmt}}^{\tau} v_y d\tau \leq \frac{\tau_{vmt}}{\pi R^2} \int dV \quad \text{where } \tau > \tau_{vmt}. \quad (19)$$

The conditions of carburetion process character are defined. If condition (11) as well as (12) or (13) are met, then we observe the volumetric carburetion, if the conditions are not met, we observe film carburetion.

When the droplet flies, it is effected by the processes of heat and mass transfer, evaporation mostly. Research of the evaporation of separate droplets of the combustible fluid in the flow was conducted experimentally by B. I. Sreznevskiy [22] and theoretically by D. S. Maxwell [14]. That is why we can use the dependence shown in [20] for determining the volumetric flow rate of the liquid droplet evaporation:

$$\frac{dV_k}{d\tau} = \frac{1}{K_{vap} 4\sqrt{\pi}} \sqrt{F_k^n - \frac{\tau}{K_{vap}}}, \quad (20)$$

where:

V_k - volume of the droplet evaporated m³,

F_k^n - area of the fuel droplet surface m²,

K_{vap} - evaporation constant of the fuel s/m².

The influence of the temperature and air velocity on the evaporation constant of the diesel oil (fig. 2-a) and heavy fuel oil M40 (fig. 2-b) was investigated experimentally by the authors of the works [20]. Grounding on these research we determined the empirical dependences of calculating the evaporation constant for the temperature limits in the combustion chamber for diesel oil (21) and heavy fuel oil M40 (22):

$$\begin{aligned} \frac{1}{K_{vap}^d} = & 0,115v + 0,0032T_v - 1,2926, \\ & 550 \text{ K} \leq T_v \leq 2000 \text{ K}, \end{aligned} \quad (21)$$

$$\frac{1}{K_{vap}^{f.o.}} = 0,163v + 0,0028T_v - 1,763, \quad (22)$$

$$650 \text{ K} \leq T_v \leq 2000 \text{ K},$$

where:

K_{vap}^d - evaporation constant of the diesel oil c/m^2 ,

$K_{vap}^{f.o.}$ - evaporation constant of the heavy fuel oil c/m^2 ,

T_v - air temperature, K.

It should be noted that the empirical coefficient before the variables in the expression (21) have dimensions: for 0,115 - $[m]$; 0,0032 - $\text{m}^2/(\text{cK})$; 1,2926 - $[\text{m}^2/\text{s}]$, the same dimensions are in the dependence (22) as well.

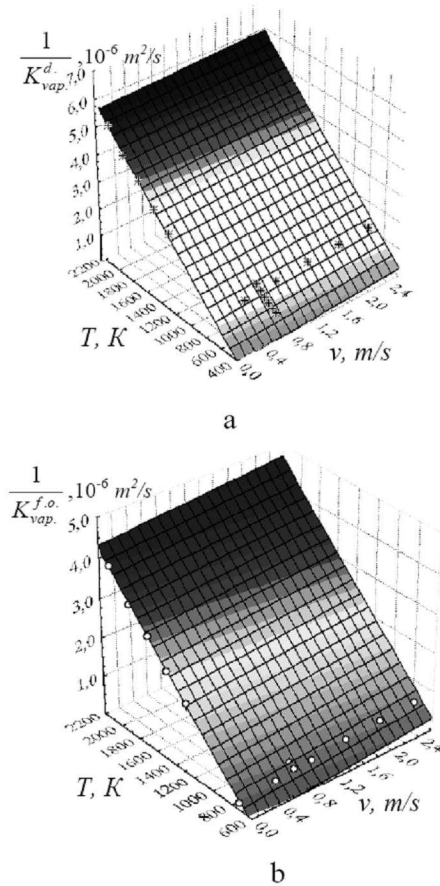


Fig. 2. The influence of the air temperature and velocity on the evaporation constant: a – of diesel oil (* - experimental data); b – heavy fuel oil M40 (o - experimental data)

Thus, the change of the droplet diameter in the motion process is defined from the expression:

$$\frac{d(d_{ek})}{d\tau} = 2 \sqrt[3]{\frac{3dV_k}{4\pi}}. \quad (23)$$

CONCLUSIONS

Grounding on the research performed it can be said that calculating of the volumetric flow rate of the fuel drop evaporation can be done by the expression (20) at the same time taking into account the change of its diameter by the expression (23) and the change in the drop motion velocity by the expression (16).

Using the simple comparison it is easy to see that in the expressions (1-3) the mass of the working substance can be defined with accounting for the dynamics of temperature influences, acquired kinetic energy and the character of carburetion processes.

The approaches on calculation the kinetics of the droplet shown in the present work permit to detail the methods of calculation of the operating processes in diesel engines taking into account structural and operational factors.

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**ПОВЫШЕНИЕ ЭФФЕКТИВНОСТИ
РАБОТЫ ДИЗЕЛЯ НА ОСНОВАНИИ
МОДЕЛИРОВАНИЯ ПРОЦЕССА
СМЕСЕОБРАЗОВАНИЯ ТОПЛИВА**

*Иван Берестовой, Галина Айнагоз,
Михаил Берестовой*

А н н о т а ц и я . Рассматривается моделирование кинетики движения капли в цилиндре двигателя, от момента впрыска цикловой подачи топлива до ее падения на детали цилиндропоршневой группы, с учетом особенностей температурных воздействий и приобретенной кинетической энергии с целью влияния условий смесеобразования на технико-эксплуатационные характеристики работы двигателя в зависимости от геометрических характеристик цилиндропоршневой группы.

К л ю ч е в ы е с л о в а : дизель, топливо, смесеобразование, капля, конструкция.

Forming of the optimum braking performance of gears movements of mobile cranes

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Summary: the concept of a method of calculation of the optimum (rational) braking performance of gears of movement of the mobile cranes, based on the multiparameter multifactorial analysis of transient effects are stat, the example of calculation are consider. Fig. 4, tab. 3, lit. 20.

Key words: bridge cranes, optimization of braking processes.

1. GENERAL PROVISIONS

1.1. Statement of a problem in a general view. It agreed [2, 7, 9, 10, 16-18, etc.] value of brake torque of the gear of movement of the mobile crane are determine from a repayment provision of a kinetic energy rotate and are translational moving weights of a drive and the crane for set time or on the set braking distance. Value of brake torque at whom the set reserve of hooking of tradable wheels with rails are ensure, determined at motion of the crane without freight. At determination of brake torque the crane are consider as a solid state; braking characteristics of the gear, real mass distribution, elastic properties of elements of the gear and a metal structures, the flexible podves of freight was not consider real, etc.

1.2. Analysis of the main researches and publications. In case of the equipment of cranes operate braking devices arisen the task of forming of braking characteristics of gears of movement ensure optimum (rational) braking action. In the sources enumerate above these tasks was not consider. For the first time the task of calculation (forming) of the optimum braking performance of gears of movement of mobile cranes are put in [4-5, 13, 14].

1.3. The statement are more whole than the article. The purpose of the article was presentation on a particular example of a method of calculation of the optimum (rational) braking performance of gears of movement of the mobile cranes which are based on the multiparameter multifactorial analysis of transient effects.

Of ways of raise of technical-operational parameters of mobile cranes optimization of transient effects are one. Such approach became actual in connection with creation of the operate starting and braking devices ensure adjustment of force of a drive largely. It are especially important, with a position of raise of efficiency, reliability and an operational safety of mobile cranes, optimization of processes of the braking action, assume determination and realization of such law of change of a braking force of the gear at whom main specifications of transient effect (*a braking time of t_r , maximum dynamic loads of a metal structure $P_m^{\max}$ and a drive $P_{pr}^{\max}$, the maximum amplitude of deflection of freight from a vertical $A^{\max}$ (a horizontal component of tension of freight chain cables $P_k^{\max}$ etc.)* received most acceptable values.

2. CALCULATION OF THE OPTIMUM BRAKING PERFORMANCE OF GEARS OF MOVEMENT MOBILE CRANES ON THE BASIS OF THE MULTIPARAMETER MULTIFACTORIAL ANALYSIS OF TRANSIENT EFFECTS

The example of calculation of the rational braking characteristic of the bridge hook crane of

a construction ASRILTM (load 10 t, by $V_k = 2$ m/s, $L = 34,5$ m, a drive separate) which gear of movement are equipped with the device for electrodynamic braking action are more low consider. Each drive of movement of the crane intend for activity indoors, consisted of the MTF 211-6 engine ($N = 7,5$ kW, $n_n = 15,5$ sec⁻¹, $M_{max} = 191$ N·m), the reduction gearbox ($u = 9,8$), brakes TT-160 ($M_{t(max)} = 100$ N·m), a tradable wheel in radius of $r_k = 0,2$ m bridge among themselves by joints. Weight of the crane span of 34,5 m of $m_{kr} = 31300$ kg, weight of a dolly of $m_r = 2600$ kg.

Owing to random character of the braking process determine by variable entry conditions of braking action (in the speed of the crane in the beginning of braking action, a weight cargo and altitude are more its than the suspension, to a vibration phase of freight, etc.) and a kind of the braking characteristic of the gear, the solution of such optimizing task possibly if to limit area of researches and to consider process of braking action as determine, that is the fix values of parameters of the crane and entry conditions of braking action. In this case the solution of a task of optimization of processes of braking action of mobile cranes actuated below-mentioned stages [8].

2.1 Construction of dynamic and mathematical models of the crane. At the first phase of researches experiment are reasonable for put on a mathematical model (computing experiment) and it consisted in determination of main specifications of transient effect (t_{ri} , P_{mi}^{max} , P_{ki}^{max} , P_{pri}^{max}) numerical integration of the equations of motion of the crane with freight at braking action on i-oh braking characteristic.

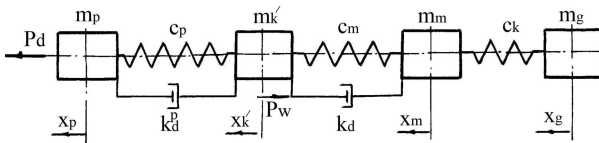


Fig. 1. Four-mass dynamic mock-up of a bridge crane

Research and optimization of transient effects of movement of bridge cranes, with sufficient accuracy for practical calculations, it are possible to execute on discrete a four-mass three-coherent dynamic mock-up [4, 11-14, etc.].

Motion of dynamic mock-up locate on fig.1 are describe by the equations:

$$\begin{aligned} m_p \cdot \ddot{x}_p + k_d^p \cdot (\dot{x}_p - \dot{x}'_k) + c_p \cdot (x_p - x'_k) - P_d &= 0; \\ m'_k \cdot \ddot{x}'_k - k_d^p \cdot (\dot{x}_p - \dot{x}'_k) - c_p \cdot (x_p - x'_k) + \\ + k_d \cdot (\dot{x}'_k - \dot{x}_m) + c_m \cdot (x'_k - x_m) + P_w &= 0; \quad (1) \end{aligned}$$

$$\begin{aligned} m_m \cdot \ddot{x}_m - k_d \cdot (\dot{x}'_k - \dot{x}_m) - c_m \cdot (x'_k - x_m) + \\ + c_k \cdot (x_m - x_g) &= 0; \end{aligned}$$

$$m_g \cdot \ddot{x}_g - c_k \cdot (x_m - x_g) = 0.$$

On fig. 1 and in the equations (1) designations was receive:

m_p – the reduced weight of rotate parts of drives of the mechanism of movement to tradable wheels; m'_k – the weight of the bridge to moving of end girders; m_m – the reduced weight of mean parts of the bridge to midbay and an empty dilly; m_g – a weight cargo kg,

P_d – reduced to a rim the driving of tradable wheels force of the engine of the mechanism of movement of the crane (in braking modes of $P_d = R_d$); P_w – force of static resistance to movement of the crane N,

c_p – the coefficient of rigidity mechanism of movement le to tradable wheels; c_m – coefficient of rigidity of a metal structures of the crane in a horizontal plane; $c_k = G/\ell$ – a horizontal component of tension of freight chain cables at $(x_m - x_g) = 1$ (thus the horizontal component is considered to proportional amplitude of deflection of freight), N/m (here ℓ – a length of the levitation of freight m),

k_d^p – an attenuation factor of oscillations (damp) of the mechanism movement of the crane; k_d – an attenuation factor of oscillations of a metal structures in a horizontal plane N·s/m,

x_p, x'_k, x_m, x_g – the ways pass by correspond weights from the origin m.

(1) values enter in the differential equations for the consider crane was equal:

– reduced masses: $m_p = 860$ kg; $m'_k = 18890$ kg, $m_m = 12645$ kg, $m_g = 10000$ kg,

– coefficients of rigidity: $c_p = 12520000$ N/m, $c_m = 868286$ N/m, $c_k = 19620$ N/m (at $\ell = 5$ m),

– resistance to the movement crane with freight under a grade in premise (the friction of detachable flanges are not consider) $P_w = 2330$ N,

– damping ratios: a drive of $k_d^p = 2500$ N s/m and metal structures in a horizontal plane of $k_d = 130,7$ N s/m.

2.2 About the independent variable (factors) which are unequivocally determine (set) the braking characteristic of the mechanism (drive). The case when the mechanism movement of the crane is equipped with the device for electrodynamic braking action with a separate excitation and the asymmetrical scheme of jointing of a direct-current source with a stator winding are consider. Any mechanic characteristic of an

asynchronous motor in a mode of a dynamic braking can be set unequivocally by means of two factors (a current of excitation of I_B and the fetch resistance of R_p of a chain of a blade ring), M_{kq} determine the maximum moment and critical slip of the s_{kq} [6, 20] electric motor. In a mode of a dynamic braking reduced to translational movement of the crane a braking force of the mechanism (fig. 2) are describe by the first equation of system (2):

$$P_T = \begin{cases} -\frac{2 \cdot M_{kq} \cdot s_{kq} \cdot v_0 \cdot u \cdot \dot{x}'_k \cdot \eta}{r_k \cdot (s_{kq}^2 \cdot v_0^2 + \dot{x}'_k{}^2)} & \text{при } \dot{x}'_k > v_{Bq}; \\ -M_T \cdot u \cdot \eta / r_k & \text{при } \dot{x}'_k \leq v_{Bq}, \end{cases} \quad (2)$$

where:

in addition to the values mention earlier: M_{kq} – the critical (overturn) moment and s_{kq} – critical slip of the electric motor in a mode dynamic braking action on q-oh characteristic (fig. 2 see); $v_0 = v_k (v_0/v_n)$ – speed of movement of the crane, correspond to synchronous rotational speed of a blade ring of the electric motor.

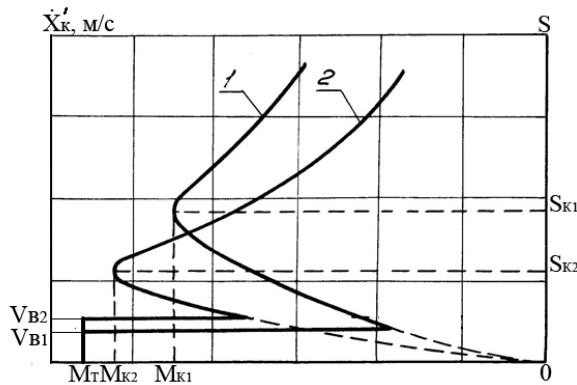


Fig. 2. Mechanic characteristics of the gear of movement the crane at a combination electrodynamic and mechanic braking action: 1–the initial; 2–the rational

As seen (fig. 2), value of brake torque in process of a speed reduction of crane movement are sharply moderate, and braking action became ineffective. It is reasonable to use and capabilities of normally closed expanding shoe type brakes. In this case braking action of the crane will be perform in two stages. In the beginning electric motors of the mechanism of movement worked in a mode of a dynamic braking that created the best conditions of dynamic loading of a metal structures and elements of the mechanism, promoted damping of oscillations of freight, and then, at achievement of the determined drop speed of V_{Bq} , engines was disconnect and the further braking

action of the crane to it is stop is perform with constant brake torque of M_T normally closed expanding shoe type brakes (a combination of electrodynamic and mechanic braking action).

In this case the braking characteristic is function of three factors: $P_T(M_{kq}, s_{kq}, v_{Bq})$.

2.3 Selection of the generalize criterion of braking process "quality". For optimization of braking processes it is necessary to be able to value them "quality". Transient effects of movement of the hoisting crane comprehensively could describe only by set of parameters. In particular "quality" of braking processes of bridge cranes is full enough characterized by means of four parameters: t_{ri} , P_{mi}^{max} , P_{ki}^{max} , P_{pri}^{max} .

To the solution of multi parameter optimizing tasks there were different lines of thought. In the case under consideration the aprioristic information allowed to state a tentative estimation to each separate parameter of transient effect, therefore as the generalize criterion it are convenient to use a generalized function of desirability of Harrington [1, 3, 15, 19]. For it constructions it are necessary to receive the relations, allow to transform value of parameters of t_{ri} , P_{mi}^{max} , P_{ki}^{max} , P_{pri}^{max} in values of dimensionless functions of desirability's of $d_{1i} = f_1(t_{ri})$, $d_{2i} = f_2(P_{mi}^{max})$, $d_{3i} = f_3(P_{ki}^{max})$ and $d_{4i} = f_4(P_{pri}^{max})$, and the last - in value of the generalize desirability of D_i (here i – serial number of experience).

On fig. 3 schedules of functions of desirabilities of $d_1, d_{2,3,4}$, a dimensionless scale of y' , and also scales of transfer of parameters of t_r , P_m^{max} , P_k^{max} , P_{pr}^{max} was present to private desirabilities. For obtaining of relations of $d_{1i} = f_1(t_{ri})$, $d_{2i} = f_2(P_{mi}^{max})$, $d_{3i} = f_3(P_{ki}^{max})$ and $d_{4i} = f_4(P_{pri}^{max})$ to boundary values of parameters should be g to by in correspondence of a mark on a scale of desirability.

The braking time of bridge cranes of t_r are limit with two parties: on the hand it should be more minimum braking time of t_{min} at whom hooking the driven tradable wheels with rails are upset, and with another – less maximum braking time of t_{max} is determined from features of a manufacturing process for whom the crane is intend.

To limit the type of two-way $t_{min} \leq t_r \leq t_{max}$ conversion of values of t_r to a scale of d_1 are effect by function:

$$d_1 = \exp[-(|y'|)^w]. \quad (3)$$

On fig. 3 at construction of the schedule of function (3) for a bridge crane load 10τ to value of $d_1 = 0,37$ scales of the desirabilities, on border of

areas "satisfactorily" and "badly", was put in correspondence of $t_{\min} = 6$ s (it are determine from condition of braking action of the crane by brakes TT-160, adjust on the maximum brake torques) and $t_{\max} = 12$ s (are determine from features of a manufacturing process), and to value of $d_1^* = 0,80$, 1 on border of areas "very well" and "well", - $t_r^* = 8$ s. The steepness of branches of curve d_1 depended on what value of t_r^* will be put in correspondence to value of $d_1^* = 0,80$.

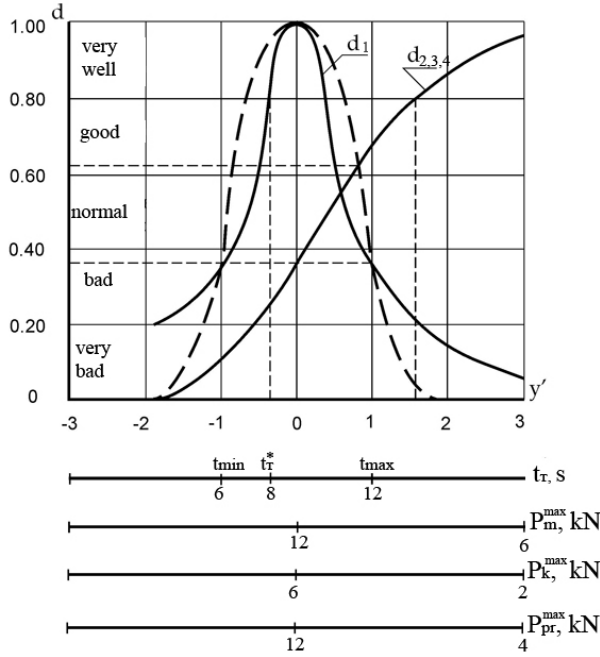


Fig. 3. Schedules of functions of desirabilities

For a case of combined braking action:

$$w = \frac{\ln(\ln(1/d_1^*))}{\ln|(2 \cdot t_r^* - (t_{\max} + t_{\min})) / (t_{\max} - t_{\min})|} =$$

$$= \frac{\ln(\ln(1/0,8))}{\ln|(2 \cdot 8 - (12 + 6)) / (12 - 6)|} = 1,365;$$

$$y' = \frac{2 \cdot t_{ri} - (t_{\max} + t_{\min})}{t_{\max} - t_{\min}} = \frac{2 \cdot t_{ri} - (12 + 6)}{12 - 6}.$$

Thus, expression for private function of desirability of d_{1i} is looked like $f_1(t_{ri})$:

$$d_{1i} = \exp[-|(2 \cdot t_{ri} - (12 + 6)) / (12 - 6)|^{1,365}]. \quad (4)$$

Limitations for parameters $P_m^{\max}$, $P_k^{\max}$, $P_{pr}^{\max}$ had one-way character. The form conversion to d_2 is more their, d_3 , served d_4 an exponential relation:

$$d_{2,3,4} = \exp[-\exp(-y'_{2,3,4})], \quad (5)$$

where:

$$y'_2 = b_{02} + b_{12} \cdot P_m^{\max}, \quad y'_3 = b_{03} + b_{13} \cdot P_k^{\max},$$

$$y'_4 = b_{04} + b_{14} \cdot P_{pr}^{\max}.$$

Coefficients of b_{02} , b_{03} , b_{04} , and b_{12} , b_{13} , b_{14} determined ha set value of 0,37 private functions of desirabilities of d_2 , d_3 , d_4 as much as possible acceptable values correspond to them $P_m^{\max}$, $P_k^{\max}$, $P_{pr}^{\max}$ (fig. 3, a curve of $d_{2,3,4}$ see), and to value 0,95 - desirable values of these parameters.

Let's consider determination of coefficients of b_{02} , b_{12} in the equation:

$$d_{2i} = \exp[-\exp(-b_{02} - b_{12} \cdot P_{mi}^{\max})]. \quad (6)$$

Let's appropriate to values of $d_{2i} = 0,37$ and $d_{2i} = 0,95$ acceptable and wish values of $P_m^{\max}$ (fig. 3):

$$0,37 = \exp[-\exp(-b_{02} - b_{12} \cdot 12)],$$

$$0,95 = \exp[-\exp(-b_{02} - b_{12} \cdot 6)].$$

Decide the system of the equations, we will find $b_{02} = +5,946$ and $b_{12} = -0,495$.

Ultimately for conversion of the values of $P_{mi}^{\max}$ receive at computing experiment to values of d_{2i} the relation are receive:

$$d_{2i} = \exp[-\exp(-5,946 + 0,495 \cdot P_{mi}^{\max})]. \quad (7)$$

For conversion of values of $P_{ki}^{\max}$ and $P_{pri}^{\max}$ in values of d_{3i} and d_{4i} relations was receive:

$$d_{3i} = \exp[-\exp(-4,461 + 0,743 \cdot P_{ki}^{\max})], \quad (8)$$

$$d_{4i} = \exp[-\exp(-4,452 + 0,371 \cdot P_{pri}^{\max})], \quad (9)$$

Value of the generalize desirability of D_i in an i-ohm computing experiment:

$$D_i^3 = \sqrt[3]{d_{1i} \cdot d_{2i} \cdot d_{3i} \cdot d_{4i}}. \quad (10)$$

where: i – serial number of experience.

2.4 Calculation of the rational braking characteristic of the mechanism of movement of the crane by a method of abrupt climbing.

2.4.1 Determination of the main level $\tilde{Z}_{jo}$ and intervals of a variation $\Delta\tilde{Z}_j$ of each factor.

Values of the main level of each factors (that is mechanic characteristic of a drive with whom researches begun) got out proceeding from the aprioristic information.

At selection of intervals of a variation of factors $\Delta\tilde{Z}_j$ it is necessary to consider that too big values could lead that the equation of a regression (11) will appear inadequate to probe process, and

too small - to not conspicuity of results of experiment.

2.4.2 Selection of a kind of the regression equation. In conduct research the task of determination of a gradient of response function $D_p = f(Z_j)$, therefore as a mathematical model the polynomial of the first order who contained the information on a direction of a gradient are receive

$$D_i^p = a_0 + \sum_{j=1}^k a_j \cdot Z_{ji}, \quad (11)$$

where: a_0, a_j - coefficients of a regression, Z_{ji} - the cod value of j -go of the factor in an i -ohm experience.

Communication between cod Z_j and natural $\tilde{Z}_j$ values of factors are express by the formula

$$Z_j = (\tilde{Z}_j - \tilde{Z}_{j0}) / \Delta \tilde{Z}_j. \quad (12)$$

2.4.3 Selection of the plan of experiment. Coefficients of $a_0, a_1, a_2, \dots, a_j$ of the equation of a regression (11) was calculate by handling of the values of the generalize criterion of optimization of D_i^3 receive as a result of computing experiment. As the plan of experiment it is possible to recommend at figure of factors of $k \leq 4$ the full factorial plan of type 2^k , at $k > 4$ - fractional factorial plans of type 2^{k-c} (c - figure of the linear effects equal to coupling effects).

2.4.4 Calculation of the rational braking characteristic of the movement mechanism of the crane is execute by a method of abrupt climbing. Values of the main levels of factors $\tilde{Z}_{j0}$, intervals them a variation $\Delta \tilde{Z}_j$ was locate in tab. 1.

Table 1. Entry conditions of experiences

Factors	$\frac{M_{kq2}}{N \cdot m}$	$\frac{S_{kq}}{m/s}$	$\frac{V_{Bq2}}{m/s}$
Main levels ($\tilde{Z}_{j0}$)	80	0,20	0,20
Intervals of a variation ($\Delta \tilde{Z}_j$)	5	0,05	0,05
Upper layers ($Z_j = +1$)	85	0,25	0,25
Lower layers ($Z_j = -1$)	75	0,15	0,15

For calculation of coefficients of the linear regression equation (11) complete factorial experiment of type 23 are put, the plan (columns 2-4) and which results (columns 5-8) was locate in tab. 2. In columns 9-12 was locate calculate on formulas (4, 7-9) values of private functions of desirabilities, and in column 13 - a generalized function of desirability.

2.4.5 Realization of computing experiment. As it are mark above, at the first phase of researches experiment is reasonable for put on a mathematical model of the crane (computing experiment). To each experience there corresponded the solution of system of the differential equations of crane motion (1) for a case of braking action on one of the mechanic characteristics, determine by values of factors $\tilde{Z}_{ji}$ (column of 2-4 tab.2) in an i -ohm experience of the full (fractional) factorial plan. As results of experiment was receive in an i -ohm experience of value of $t_{ri}, P_{mi}^{max}, P_{ki}^{max}, P_{pri}^{max}$ (columns of 5-8 tab. 2) and private desirabilities of d_{ti} correspond to them, (columns of 9-12 tab. 2) by convertible in the generalize criterion of optimization of D_i^3 (column of 13 tab. 2).

2.4.6 Determination of coefficients of a regression and check of adequacy of model (11).

By results of the conduct series of computing experiments (tab. 2, column 13) was calculate by a method of least squares coefficients of the linear equation of a regression

$$D^p = 0,678 + 0,03398 \cdot Z_1 + 0,05703 \cdot Z_2 + 0,01333 \cdot Z_3 \quad (13)$$

As an estimation of approximation accuracy the variation are e

$$\rho = \frac{1}{a_0} \sqrt{\frac{\sum (D_i^p - D_i^3)^2}{N - n^*}} < \alpha, \quad (14)$$

where:

D_i^3 and D_i^p - accordingly receive in computing experiments and the regressions (13) values of a generalized function of desirability forecast by the equation (tab. 2 see, columns 13 and 14), N and n^* - accordingly figure of experiences of a die of planning and figure of coefficients of the regression equation (13).

(13) it is possible to consider the linear equation of a regression adequate, as for a consider case $\rho = 0,03 < \alpha = 0,05$.

2.4.7 Abrupt climbing on a surface of the response. After construction of linear model (13) for each factor the step of abrupt climbing are calculate. By a step on most strongly act factor was set, and on remaining factors the step are calculate from the relation

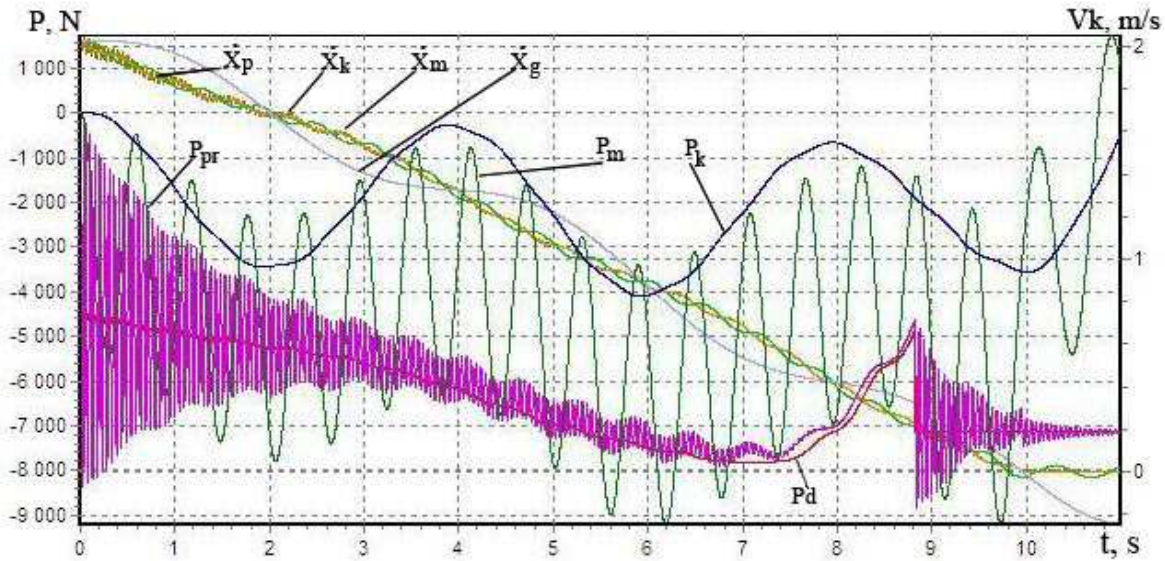
$$\frac{h^*}{h_j} = \frac{a^* \cdot \Delta \tilde{Z}^*}{a_j \cdot \Delta \tilde{Z}_j}, \quad (15)$$

Table 2. The plan and results of the first series of experiences at combined braking action

N ₀	M _{kq} , N·m	S _{kq}	V _{bq} , m/s	t _{ri} , s	P _{mi} ^{max} , kN	P _{ki} ^{max} , kN	P _{pi} ^{max} , kN	d _{1i}	d _{2i}	d _{3i}	d _{4i}	D _i ³	D _i ^p
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	85	0,25	0,25	10,44	8,385	3,700	8,108	0,693	0,847	0,835	0,791	0,782	0,789
2	85	0,25	0,15	10,61	8,385	3,700	9,681	0,652	0,847	0,835	0,657	0,756	0,742
3	85	0,15	0,25	12,41	7,814	3,357	7,756	0,304	0,882	0,870	0,814	0,668	0,660
4	85	0,15	0,15	12,42	7,814	3,357	7,924	0,302	0,882	0,870	0,803	0,642	0,657
5	75	0,25	0,25	11,22	8,383	3,576	8,624	0,515	0,847	0,848	0,753	0,714	0,727
6	75	0,25	0,15	11,38	7,744	3,576	10,220	0,483	0,886	0,848	0,598	0,688	0,683
7	75	0,15	0,25	13,39	7,780	3,275	7,355	0,186	0,884	0,877	0,838	0,600	0,590
8	75	0,15	0,15	13,44	6,927	3,116	8,710	0,181	0,922	0,890	0,746	0,574	0,577

Table 3. The plan and results of experiences of abrupt climbing at combined braking action

N ₀	M _{kq} , N·m	S _{kq}	V _{bq} , m/s	t _{ri} , c	P _{mi} ^{max} , kN	P _{ki} ^{max} , kN	P _{pi} ^{max} , kN	d _{1i}	d _{2i}	d _{3i}	d _{4i}	D _i ³
1	81,2	0,22	0,205	11,21	8,233	3,817	8,634	0,517	0,857	0,822	0,752	0,7235
2	82,4	0,24	0,210	10,79	7,935	3,617	8,655	0,610	0,876	0,844	0,750	0,7626
3	83,6	0,26	0,215	10,49	8,792	3,733	8,704	0,681	0,816	0,831	0,746	0,7662
4	84,8	0,28	0,220	10,02	9,017	3,947	8,795	0,795	0,797	0,805	0,739	0,7836
5	86,0	0,30	0,225	9,62	9,305	4,144	8,927	0,890	0,770	0,778	0,728	0,7893
6	87,2	0,32	0,230	9,38	9,604	4,312	9,066	0,942	0,738	0,753	0,716	0,7823
7	88,4	0,34	0,235	9,05	9,816	4,454	9,651	0,996	0,714	0,729	0,660	0,7649

**Fig. 4.** Schedules of parameters at braking action of the crane load 10 t span of 34,5 m on the rational combined characteristic

where:

h^* and h_j - a step of abrupt climbing on most strongly act and to a j -ohm to factors; a^* , a_j - coefficients of the regression equation (13) at correspond factors; $\Delta \tilde{z}^*$, $\Delta \tilde{z}_j$ - natural values of intervals of a variation of correspond factors.

Abrupt climbing began from the main level. Conditions of realization of experiences of abrupt climbing on a surface of the response received consecutive addition (subtraction) to values of

factors at the main level of value of a step on correspond factors.

In a consider example the step on the second factor are receive equal $\Delta_2 = 0,02$, then:

$$\Delta_1 = \Delta_2 \cdot \frac{b_1 \cdot \Delta M_k}{b_2 \cdot \Delta s_k} = 0,02 \cdot \frac{(0,03398) \cdot 5}{(0,05703) \cdot 0,05} = 1,19 \text{ N} \cdot \text{m};$$

$$\Delta_3 = \Delta_2 \cdot \frac{b_3 \cdot \Delta v_b}{b_2 \cdot \Delta s_k} = 0,02 \cdot \frac{(0,01333) \cdot 0,2}{(0,05703) \cdot 0,05} = 0,0047 \text{ m/s}.$$

After rounding the step for the first factor is receive equal $\Delta_1 = 1,2 \text{ N} \cdot \text{m}$, for third $\Delta_3 = 0,005 \text{ m/s}$.

In tab. 3 the plan of experiences of abrupt climbing and the values of parameters of τ_{ri} receive as a result of computing experiment, P_{mi}^{max} , P_{ki}^{max} , P_{pi}^{max} , and also values of d_{mi} correspond to them and D_i was locate.

The generalize criterion of optimization of $D_i^3 = 0,7893$ reaching a peak value in fifth experience. Schedules of parameters of a bridge crane braking process load 10 т on the rational characteristic of the mechanism (tab. 3, experience 5) was locate by span of 34,5 m on fig. 4.

Motion on a gradient proceeded until improvement of the generalize criterion of optimization of D_i^3 took place. As soon as it value will start to be moderate, or the task of optimization is decide (if the contributor is satisfy by the receive results), or a new series of experiences with center of $\tilde{Z}_{ji}^*$, to correspond conditions of the best reach result are conduct. In a consider example it was decided to stop at the achieved results.

CONCLUSIONS

The offer method allowed to calculate the optimum (rational) braking performance of gears of movement of the mobile cranes arrange with various types of braking devices. It considered objective braking parameters, real mass distribution, rigidity of elastic elements of the crane, etc. that done not allow to make methods exist now. Researches on development of a similar method of calculation for turn mechanism of hoisting cranes was perspective.

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ФОРМИРОВАНИЕ ОПТИМАЛЬНЫХ ТОРМОЗНЫХ ХАРАКТЕРИСТИК МЕХАНИЗМОВ ПЕРЕДВИЖЕНИЯ ГРУЗОПОДЪЕМНЫХ КРАНОВ

Леонид Будиков, Роман Шшикин

Аннотация. Изложена концепция метода расчета оптимальных (рациональных) тормозных характеристик механизмов передвижения грузоподъемных кранов, базирующаяся на многопараметрическом многофакторном анализе переходных процессов, рассмотрен пример расчета. Рис. 4, табл. 3, ист. 20. Ключевые слова: мостовые краны, оптимизация тормозных процессов.

The knowledge base model of decision support system development for improving the e-learning resources quality

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S u m m a r y . The analysis of e-learning resources functional properties which is applied to the task of automated information support to the decision-making for improving the quality of e-learning resources is made. The knowledge base model of decision support system, which is adapted to the complex criterion of quality that takes into account the academic performance, validity, manufacturability and reliability of the learning resources, is developed.

K e y w o r d s . E-learning, quality, criteria, knowledge base model.

INTRODUCTION

The implementation of the basic concepts of Bologna process is impossible without the active using of e-learning resources in the educational process. The assurance of high quality education [8, 15, 16] requires the continuous monitoring of learning resources throughout its life cycle. Providing the high quality of e-learning resources in situation with wide accessibility to the higher education and rapid obsolescence of information requires an organization of the automated monitoring, analysis and evaluation of e-learning systems educational content using new information technologies.

OBJECTS AND PROBLEMS

To improve the quality of e-learning resources we should take into account the complex evaluation of the functional properties and results statistics of e-learning resources using in learning and training. The decisionmaking automated

support is impossible without the decision support system knowledge base model that is adapted to the task of complex evaluation of e-learning resources quality. Analysis of research papers and publications about evaluation of e-learning resources quality [7, 14, 19, 21- 23] has shown that existing systems can only assess the quality of e-learning resources individual indicators and do not provide automated support to the decisionmaking. The purpose of this research is to develop the knowledge base model of decision support system, which is adapted to the task of complex evaluation of e-learning resources quality.

THE RESULT OF RESEARCH

According to [2, 4, 5] the main types of learning activities are: lectures, labs, workshops, seminars and self-study. Diversity of species, types and forms of e-learning resources is caused by the diversity didactic approaches to learning and training. The collection of standards and specifications for web-based e-learning SCORM [1, 17] declares no restrictions to the amount and the way of representation of e-learning-resources (the *базлайфстайліс* blocks of e-learning resources – assets – are the “...electronic representation of media, such as text, images, sound, assessment objects or any other piece of data that can be rendered by a Web client and presented to a learner”).

In the context of the task of decisionmaking information support to improve the e-learning

resources quality the classification of types and functional properties of e-learning resources is developed. Depending on the type of learning activity the main functional types of educational resources are: theoretical material (theory), training workshop (workshop) and control.

The main purpose of the theory is the orientation function, which describes the framework subject area of the course, topics, tasks, definitions, concepts.

Workshops can include laboratory works, training exercises, individual tasks with calculations and graphics. Educational resources of this type are characterized by a high level of interactivity and require the organization of the feedback. The main purpose of the workshop is to form the skills and abilities. The workshop can be represented by application the wide range of intelligent multimedia and visual instructions, virtual labs and multimedia simulators.

Control can include exam-questions, tests, problematic tasks, qualifying and graduate work. Analysis of scientific publications in the field of teaching jobs [2, 5, 13] showed that the testing control is the most researched activity.

In the context of the task of automated information support the most important e-learning resources functional properties are realization of feedback, cognitive level, form and maintainability.

The e-learning resources can be classified as:

1. **Implementation in the text form (text).** In this case e-learning resource is an electronic copy of a hard copy (book) in any format.

2. **Unilateral multimedia.** There is an implementation of e-learning resources in the form of audio or video streams without feedback there.

3. **Implementation in the form of hypertext (hypertext).**

4. **Intelligent multimedia.** E-learning resources are interactive multimedia with elements of artificial intelligence.

According to the result of the analysis [11, 18] the main life-cycle processes of e-learning resources as applied to the task of automated evaluation of quality are: "Organisation of use" (subprocess of "Implementation"), "Learning Process", "Analysis", "Evaluation", "Optimization".

The best way to improve the e-learning resources quality must be a least time-consuming. The grading scale for the expert judgments is represented in the table 1. This scale is depended on the ways of e-learning resources implementation and the possibilities of providing

access to the learning system repository. The maintainability can be evaluated by experts on the step "Organisation of use" of e-learning resource's life-cycle. The maintainability will be different for different organizations.

Table 1. The grading scale of maintainability

Gradation	Points	The way of implementation
Impossible	0-1	Unilateral multimedia or intelligent multimedia
Very difficult	2-3	Unilateral multimedia or intelligent multimedia
Difficult	4-6	Unilateral multimedia or intelligent multimedia, hypertext
Possible	7-8	Text, hypertext, unilateral or intelligent multimedia
Very easy to implement	9-10	Text, hypertext

In the context of the task of automated information support the e-learning resource cognitive level taxonomy is developed. This taxonomy joins Bsepalko's taxonomy and Bloom's taxonomy [3, 6] to cover all types of e-learning resources. The ranking levels of educational purposes are made on the interval from 1 to 8 (the level of learning $\alpha \in [1;8]$). The first part of taxonomy contains the simplest cognitive levels (tbl. 2). These levels are used very often and feedback for these resources must be fully automated in the learning process.

Table 2. E-learning resource learning level taxonomy (part 1)

Graduation	Examples of requirements	Cognitive process	α
Perception new information	Percepts new information, demonstrates the primary understanding.	Perceiving	1.0
Knowledge. Exhibit memory of previously learned materials by recalling facts, terms, basic concepts and answers	Recognizes the studied objects and processes, find and selects the objects in a presented set of different.	Recognizing	2.0
	Knows terms, facts, rules, principles, methods, definitions.	Recalling learned material	2.5
Comprehension. The ability to create values that are based on e-learning materials or experiences, to transform of learned material from one form to another. Interpretation and prediction.	Understands the facts, rules, principles. Interprets the study material of various types. Converts, translates course material from one species to another. Predicts the consequences arising from the data.	Interpreting	3.0
		Creating examples	3.1
		Classifying	3.2
		Generalizing	3.3
		Reasoning	3.5
		Comparing	3.7
		Explaining	3.9

The second part of this taxonomy contains levels that can use manually processing or partially automated processing of results (tbl. 3).

The cognitive level can be evaluated by experts on the step “Organisation of use” of e-learning resource’s life-cycle.

The classification of types and functional properties of the e-learning resources which is applied to the task of automated information support to the decisionmaking is shown at fig. 1. The functional properties according to the ways of implementation of e-learning resources are presented in table 4.

Table 3. E-learning resource learning level taxonomy (part 2)

Graduation	Examples of requirements	Cognitive process	α
Application. Using a procedure. The ability to use the material in specific conditions and new situations with applying of the rules, principles, and theories.	Uses the learned material in the new conditions. Applies the learned material in individual situations.	Implementing	4.0
	Demonstrates the proper using of the method.	Applying	4.5
Analysis. The ability to break learning material to the components, to structure knowledge, to identify parts of a whole, to identify the relationship between the two entities. Awareness of the principles of organization of the whole.	Allocates latent assumptions. Sees errors in logic reasoning, difference between facts and consequences. Assesses the significance of the data.	Differentiating	5.0
		Organizing	5.3
		Relating	5.7
Synthesis. The ability to develop new unique structures, systems, models, approaches, ideas; creative thinking, operations.	Develops plans or procedures, designs solutions, integrates methods, resources, ideas, parts; creates teams or new approaches, writes protocols or contingencies	Generating	6.0
		Planning	6.5
		Producing	7.0
Evaluation. The ability to judge the value of material for a given purpose	Assesses the logic of learning materials. Assesses the correspondence of conclusions to available data. Assesses the significance of the result (product) of activity.	Examination	7.5
		Critical thinking	8

Table 4. The learning resources functional properties

Type	Implementation	Feedback	Learning level	Maintainability, Forms
Theory	Text, hypertext, Intelligent multimedia	All types	$\alpha \in [1;2]$	All types
Workshop		Manual and mainly manual processing, partially, mainly automated and full automated processing of results	$\alpha \in [2;5]$	
Control			$\alpha \in [2;8]$	

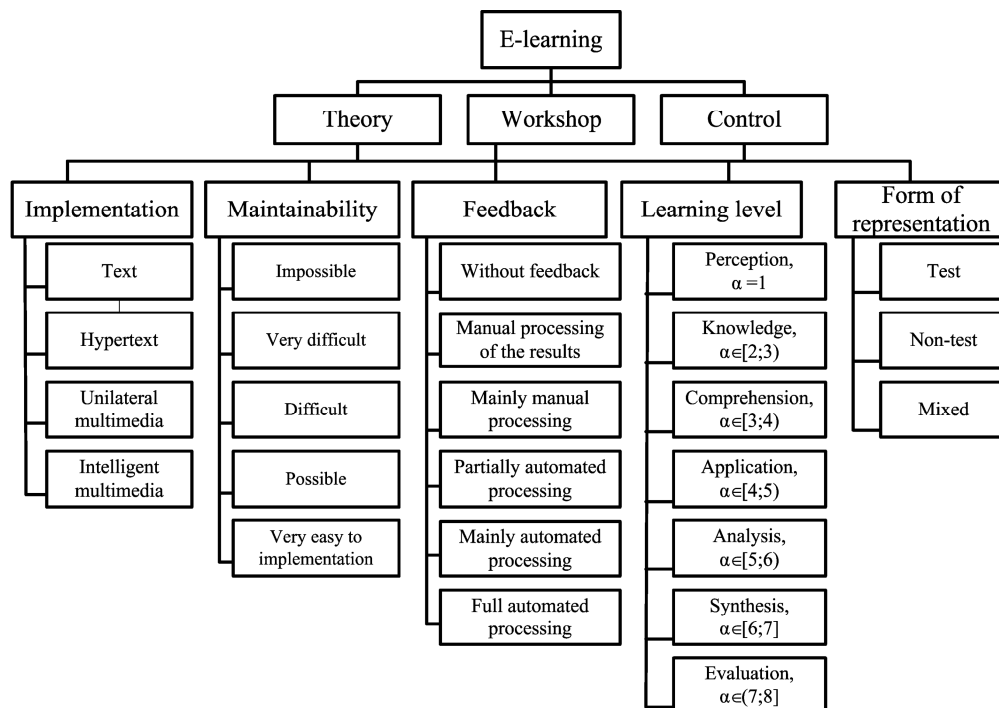


Fig. 1. The classification of e-learning resources’ types and functional properties

The Form of presentation (Test, Non-test, Mixed – e-learning resources are partially in the test-form) is used to describe the form of e-learning resources. It is simpler to automate the feedback for the test-form e-learning resources. So, the transformation into the test-form will be recommended for resources in non-test form with low cognitive levels, and the transformation into the mixed form will be recommended for resources in non-test form with high cognitive levels.

According to [5, 12] the set of quality criteria are the academic performance, validity, manufacturability and reliability. The complex criteria can be written as:

$$Q^f(S_{KOP}) = \prod_{i=1}^n (Q_i(S_{KOP}))^{w_i} \quad (1)$$

where:

w_i – weights of criteria, $\sum_{i=1}^n w_i = 1$; S_{KOP} – the semantic graph of the discipline; $n = 4$ – number of criteria: $Q_1(S_{KOP})$ – the academic performance; $Q_2(S_{KOP})$ – the validity; $Q_3(S_{KOP})$ – the manufacturability; $Q_4(S_{KOP})$ – the reliability.

The academic performance criteria $Q_1(S_{KOP})$ is:

$$Q_1(S_{KOP}) = \begin{cases} \frac{\sum_{i=0}^m x_i}{n}, & \text{if } \frac{\sum_{i=0}^m x_i}{n} \leq \varphi_{\max} \\ 1 - \frac{\sum_{i=0}^m x_i}{n}, & \text{if } \frac{\sum_{i=0}^m x_i}{n} > \varphi_{\max} \end{cases}, \quad (2)$$

$$x_i = \begin{cases} 1, & X_{Si} \geq \Delta y_{\min} \\ 0, & X_{Si} < \Delta y_{\min} \end{cases}, X_S \in [0; \Delta y_{\max}]$$

where:

$\Delta y_{\min}$ is a minimum acceptable grade on the local scale of grades (the scale of grades is an interval $\Delta y = [\Delta y_{\min}, \Delta y_{\max}]$); X_S – primary points of learners; n – number of learners; $\varphi_{\max}$ – maximal academic performance according to the interval of the academic performance $\varphi^l \in [\varphi_{\min}, \varphi_{\max}]$ (this interval must be set by the e-learning course developer).

The validity criteria $Q_2(S_{KOP})$ is:

$$Q_2(S_{KOP}) = \frac{\int_{\theta_{\min}}^{\theta_{\max}} I(\theta) d\theta}{\int_{\theta_{\min}}^{\theta_{\max}} I^E(\theta) d\theta}, \quad (3)$$

where:

$I^E(\theta)$ – standard of the information function, $I^E(\theta) = 5.6644$; θ – ability of learners, $\theta \in [-5; 5]$; $I(\theta)$ – the item information function for the two parameter model:

$$I(\theta) = D^2 \cdot \sum_j d_j^2 p_j(\theta) q_j(\theta),$$

where:

D – scaling coefficient, $D \approx 1.7$; d_j – parameter of discrimination; $p_j(\theta)$ – probability of success for the task j ; $q_j(\theta)$ – probability of unsuccess $q_j(\theta) = 1 - p_j(\theta)$.

For e-learning resources which are presented in the form of tests, when the response is evaluated as 1 or 0, the probability of success can be written as:

$$p_{ij} = \frac{e^{Dd_j(\theta_i - \beta_j)}}{1 + e^{Dd_j(\theta_i - \beta_j)}}, d_j = \frac{r_{bis}}{\sqrt{1 - r_{bis}^2}}$$

where:

r_{bis} – biserial correlation coefficient; β – difficulty of item j .

If result of responses must be integrated to a single grade (for the cases with multi-step task) the learners can take from 0 to m points. For these e-learning resources the conditional probability of success of the step k can be written as:

$$p_{nj} = \frac{e^{Dd_j(\theta - \beta_{jk})}}{1 + e^{Dd_j(\theta - \beta_{jk})}}, d_j = \frac{r_j}{\sqrt{1 - r_j^2}},$$

where:

r_j is Pearson correlation coefficient.

The result of researching of the Birnbaum's function in reference to the e-learning resources monitoring are presented at [Ul'shin, 2012].

The criteria of manufacturability $Q_3(S_{KOP})$ is:

$$Q_3(S_{KOP}) = \frac{\sum_{i=0}^j k_i^T \cdot k_i^\alpha}{j}, k_i^T = \frac{t_i}{t_{\max}}, k_i^\alpha = \frac{\alpha_i}{\alpha_{\max}}, \quad (4)$$

where:

k_i^α – learning level coefficient of the task i ; α is a learning level, $\alpha \in [1..8]$ (table 2, 3); k_i^T – manufacturability coefficient of the item i , $k_i^T \in [0..1]$; t_i is a level of the feedback (fig.1, table 5), $t_{\max} = 10$.

Table 5. The grading scale of feedback

Points, t	Gradation
0	Without feedback
1	Manual processing of results
2-3	Mainly manual processing
4-6	Partially automated processing
7-8	Mainly automated processing
9-10	Fully automated processing

The criteria of the reliability $Q_4(S_{KOP})$:

$$Q_4(S_{KOP}) = 1 - \frac{\sum_{l=0}^j k_{il}^\varepsilon}{n}, k_{il}^\varepsilon = \frac{L_{il}^\varepsilon}{L_{\max}^\varepsilon}, \quad (5)$$

where:

k_{il}^e is a coefficient of the defect of the item i of the attempt l , $k_{il}^e \in [0..1]$; L_{il}^e is a level of the priority of the defect of the item i , $L_{il}^e \in [1..10]$; n – total number of interaction attempts with the e-learning resources.

The main categories of e-learning resources' defects are: "Uncertainty", "Inaccuracy", "Incompleteness", "Non-balanced". The category "Non-defined" is used for temporary identification of defects that cannot be identified by any of the listed categories. In this situation the decision maker receives a special recommendation to develop and add to the knowledge base the new category of defects. The category "Composited" is used for an identification of defects elements that are located on the nested levels of the e-learning course hierarchy structure. The e-learning

resources defects can take status values: "Registered", "Confirmed", "Ignored" or "Fixed".

The knowledge base model of decision support system, which takes into account the complex criterion of quality, is a network of frames (fig. 2). The network contains three hierarchies of frame-prototypes ("Learner", "Structure of the course" and "Learning results"). A frame prototype "LR" is used to describe the learning content, the frame prototype "Gradebook" sets relations between class instances "Group" and class instances "Version" (class "Version" belongs to the hierarchy "Structure of course"). The prototype frames "Feedback", "Defect", "Maintainability", "Learning level" are used to determine the learning resources properties such as the level of learning, the type of feedback, bugs, and maintainability.

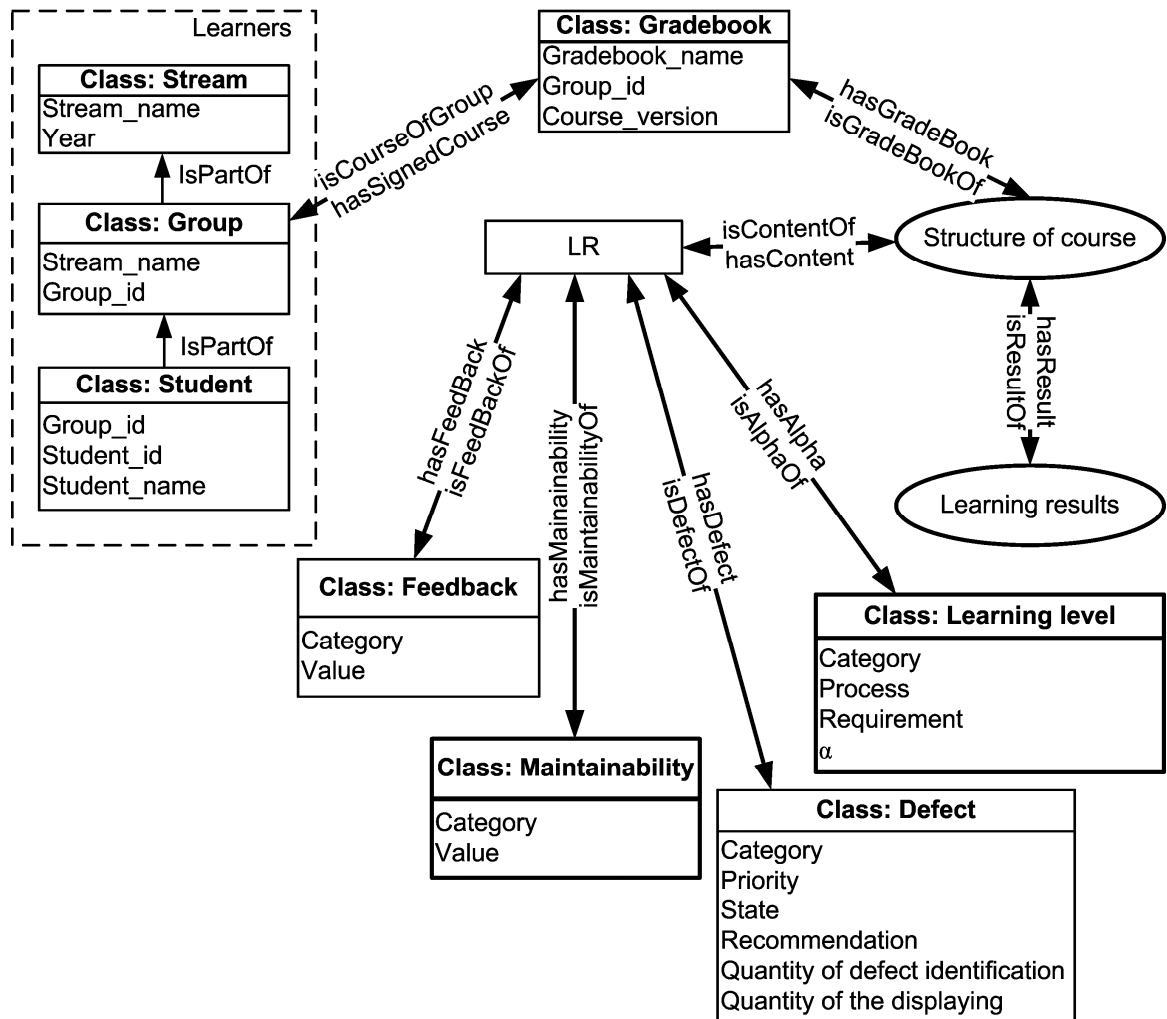


Fig. 2. The knowledge base model of decision support system

Hierarchy “Structure of course” contains six levels of the inheritance. The set of frames of the hierarchy “Structure of course” $S = \{scf_1^c, scf_2^c, scf_3^c, scf_4^c, scf_5^c, scf_6^c\}$, scf_1^c – the frame-prototype of the class «Course», scf_2^c – the frame-prototype of the class «Version», scf_3^c – the frame-prototype of the class «Modul», scf_4^c – the frame-prototype of the class “Theme”, scf_5^c – the frame-prototype of the class «Task», scf_6^c – the frame-prototype of the class «Step». The frame-prototype of class Version is presented in the table 6.

Table 6. Class „Version“

Name of slot	Date type	Way to get	Demon
Name	[String]	External source	
Year	[Date]	External source	
Q^f	[REAL]	AP	EvQ^f
Q_1	[REAL]	AP	EvQ_1
Q_2	[REAL]	AP	EvQ_2
Q_3	[REAL]	AP	EvQ_3
Q_4	[REAL]	AP	EvQ_4
The maximum score	[REAL]	External source	
Failure of information function	[LIST]	AP	$EvExtr$
Technological factor	[REAL]	AP	$EvkT$
Learning Level	[REAL]	AP	$EvAlpha$
Discriminatory parameter	[REAL]	AP	$Ev\delta$
Difficulty	[REAL]	AP	$EvBeta$
Defect	[LIST]	AP	$EvDef$
Maintainability	[REAL]	AP	$EvMaintain$

The class „Theme“ and its descendants contains additional slots for establishing hierarchy associative relation ‘hasContent-isContentOf’ with frame “LR” and relation “hasResult-isResultOf” with frame “Learning Result”. Class “Version” makes relation “hasGradebook-isGradebookOf” with frame “Group” of hierarchy “Learners” for connecting the instances of class “Group” to instances of class “Version”.

The associated procedure (AP) of this hierarchy is executed according to the current level of the inheritance. EvQ performs the calculation of the complex criteria according to the (1); EvQ_1 , EvQ_2 , EvQ_3 , and EvQ_4 perform the calculation of local criteria according to (2), (3), (4), (5) respectively. $EvExtr$ provides information about the failures of the information function according to [Ul’shin, 2012], $EvBeta$ provides data about the difficulty of tasks, $Ev\delta$ calculates the discriminatory ability; $EvkT$ returns the value of the manufacturability coefficients, $EvAlpha$ returns the values of the learning levels, $EvMaintain$ –

returns the values of the maintainability, $EvDef$ provides information about defects and recommendations for fixing defects.

The prototype of knowledge base model is constructed by the ontology editor Protégé [11]. The hierarchy of entities is present at fig. 3.

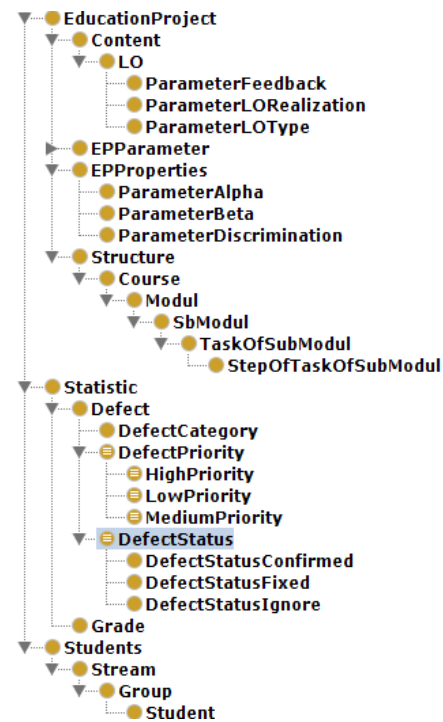


Fig 3. Entity Hierarchy of the knowledge base model

The semantic graph of the knowledge base model that is generated by Protégé is presented at fig. 4.

The consistency of the developed ontology was tested and confirmed by reasoners Fact ++ [20] and Pellet [9].

CONCLUSIONS

The analysis of e-learning resources functional properties which is applied to the task of automated information support to the decisionmaking for improving the quality of e-learning resources is made. The main functional properties are: implementation, maintainability, feedback, learning level, form of representation.

The grading scale of maintainability and feedback are proposed. In the context of the task of automated information support the e-learning resource cognitive level taxonomy is developed.

The ranking levels of educational purposes are made on the interval from 1 to 8 ($\alpha \in [1;8]$).

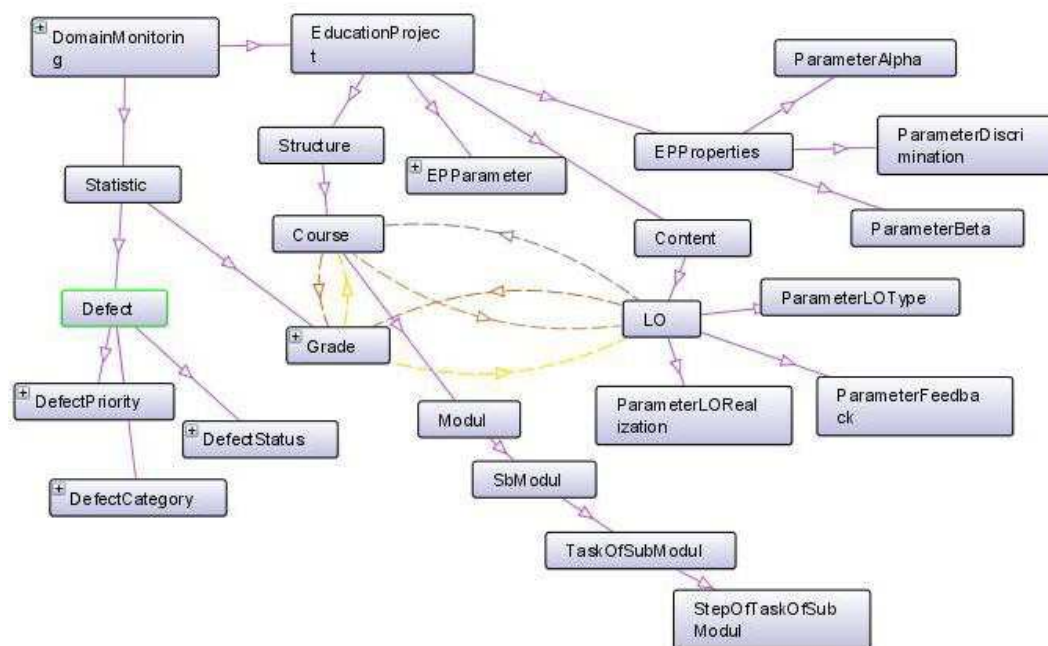


Fig. 4. The semantic graph of the ontology

The knowledge base model of decision support system, which is adapted to the complex criterion of quality that takes into account the academic performance, validity, manufacturability and reliability of the learning resources, is developed.

The prototype of knowledge base model is constructed by the ontology editor Protégé. The consistency of the developed ontology was tested and confirmed by reasoners Fact ++ and Pellet.

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РАЗРАБОТКА МОДЕЛИ БАЗЫ ЗНАНИЙ
СИСТЕМЫ ПОДДЕРЖКИ ПРИНЯТИЯ РЕШЕНИЙ
ПО СОВЕРШЕНСТВОВАНИЮ КАЧЕСТВА
ЭЛЕКТРОННЫХ ОБРАЗОВАТЕЛЬНЫХ
РЕСУРСОВ

Алла Данченко

А н н о т а ц и я . Выполнен анализ функциональных свойств электронных образовательных ресурсов применительно к задаче автоматизации информационной поддержки принятия решений по совершенствованию качества электронных образовательных ресурсов. Разработана модель базы знаний системы поддержки принятия решений, адаптированной к комплексному критерию, который учитывает успеваемость, валидность, технологичность и надежность электронных образовательных ресурсов.

К л ю ч е в ы е с л о в а . Электронный образовательный ресурс, качество, критерий, база знаний

Results of research by the numerical methods impact on the way special and specialized rolling stock in the curves of small radii

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Summary. Calculations of interaction forces and special wagons are specialized industrial vehicles and the way to the curves of small radius with use of program payments dynamic system, "the crew-way." The influence of these forces as the geometric characteristics of the rail track - the radii of curves, elevation and other external rail and horizontal geometric irregularities way.

Key words: special and specialized rolling stock, rail track in curves, interaction of rolling stock and track.

INTRODUCTION

In modern conditions the way and rolling stock of industrial railways has increased the influence of horizontal transverse dynamic forces. Experimental studies have established [1], which is one of the most powerful reasons contact - fatigue damage of rail heads are acting on their side and the horizontal transverse direction of force.

To identify the characteristics of impact on the way certain types of specific and specialized industrial railway carriages were conducted a quantitative research with using calculations program received as a result of a mathematical model of the spatial dynamical system "crew - the way" with the software package "Mathcad" [2].

ANALYSIS OF PUBLICATIONS

The first studies of dynamical system "crew - Way" came to studying fluctuations in the simplified calculation schemes in the form of

goods or of goods on the springs. [3] Determined by the natural frequency and range of possible resonance. Then the more complex design models and examined separately fluctuations in the vertical and transverse planes of symmetry of the crew [4, 5]. The analysis was performed for horizontal interaction determine the natural frequencies of vibration path and compare them with the frequencies of the winding movement wheelset [6]. Development of new methods for solving problems of nonlinear oscillations and the use of computers allowed to fulfill the deep study of the dynamics of cars and their interaction with the railway track [7, 8]. Moreover, some researchers have focused their attention on the study of oscillations to determine the parameters of an elastic suspension and stability of motion [9, 10], others - on the interaction of rolling stock and track, and others - on the dynamics of the unsprung weight of the crew and the railroad. [11]. To date, has a long experience in dealing with complicated tasks dynamics and road crews and extensive results obtained studying the patterns of oscillations of dynamical systems "crew - the way" with different parameters. In the vast majority of studies investigated linear vibrations and road crews elements as solids. In recent years, the problem of interaction of crew and the way they started to solve using design schemes that take into account the effect of non-linear characteristics of the spring suspension and strain path bending vibration body,

random characteristics of disturbances transmitted to the crew, etc. [12-18]. Based on the analysis of these works, studies [2] adopted as the design space scheme crew who is on the way in the form of spatial structure, which consists of the rails - beams, which are based on the individual elastic - dissipative support - sleepers. The use of such schemes allows to consider *neravnoprugost* rail base, which is caused by discrete leaning rails, consider the differences in stiffness and dissipation parameters of individual support, the nonlinearity of these characteristics.

OBJECTS AND PROBLEMS

The numerical methods using for the study allows to establish the influence of the characteristics of rolling stock and track exactly when the the original data set, meanwhile in experiments on a real road to ascertain the source data is not possible.

The calculations are performed for the road sections consisting of a straight length of 30m, the transition curve and circular curve length of 60m. The lengths of transition curves and the elevation of the outer rail in circular curves were made at rates in accordance with [19]. Thus, the total estimated length of the way was usually 100-120 m.

The variables in the calculations were accepted following path settings:

- Radius of the circular curves - from 80 to 600 m;
- Length of horizontal irregularities - from 1 to 8 m;
- Arrow of bending horizontal irregularities - from 0.003 to 0.05 m;
- Rail support - concrete or wooden sleepers;
- Sleepers diagram - from 1440 to 2000 units / km;
- The way's service - from 0 to 15 years.

Location of horizontal irregularities along the length of the settlement area was varied and examined variations in which the irregularities were in direct, in transition and circular curves.

Spatial stiffness of rail supports and given the equivalent dissipation factors were taken depending on the service life of the way by results of researches presented in [20,21].

As calculated crews were taken, some types of special and specialized wagons operated on the metallurgical and mining enterprises in Ukraine:

- Hot metal transfer car capacity of 140 tons;
- Dumpcars 6 VS-60 VS-85;

- Cart for mould I-120-5500

The choice of these crews was identified the need of analysis for more of a wide range of operating conditions of industrial railways.

The impact on the way locomotives in the transport industry was not considered because the magnitude of axial loads do not exceed the locomotives axle loads of special and specialized wagons and these cars are the most massive crews and determine the operating conditions of the way. In addition, some special industrial transport's locomotives (propulsion units PE-2, EL-10, PEI 2, PEI PEI-1A and-1B, etc.) made constructive schemes of four-crew, and their characteristics are similar to those of dump cars.

Also, as a settlement was received most massive main transport wagon - four-gon model 12-1000 bins CRI-X3-0, which considered as the reference load.

Figure 1 shows plots of changes in horizontal shear forces acting on the path from the one (the first in the direction of travel) wheelset dumpcars 6 VS-60 while driving on the way to the section of concrete sleepers, which consists of the straight length of 30m, transition curve length of 20m and the circular curve. The radius of the curve in the calculations is assumed to be 350m. The value of the outer rail elevation was assumed to be 0 mm at a speed of the car 5 km / h, 5 mm at a speed of 10 km / h and 10 mm at a speed of 15 km / h, which corresponds to the established norms. The maximum values of the horizontal shear forces resulting from the calculations are 1.8 kN, 2.5 kN and 7.6 kN, which represents a very small value. However, if the speed of cars go up to the upper boundary of the interval for a given value of the outer rail's elevation, the values of the horizontal shear forces increase substantially. For example, in fig. 1 shows a plot of the velocities of the horizontal shear forces acting on a path in the circular curves, without irregularities.

Characteristics of the path taken for the construction of the wooden sleepers. On approaching speeds of cars to the upper limit interval values of the horizontal shear forces can be 15-35kN for the half wagon model 12-1000, 17-64kN for dumpcars VS-85, to 65kN for hot metal transfer cars capacity of 140 tons and up to 49 kN for the carriage of I-120 5500.

At the same time speed of hot metal transfer cars and trucks do not exceed 10 km. During the operation the way the value of horizontal shear forces in circular curves increase by 2,5-7,0%, depending on the service life of the ways and characteristics of circulating cars (figs. 5 and 6).

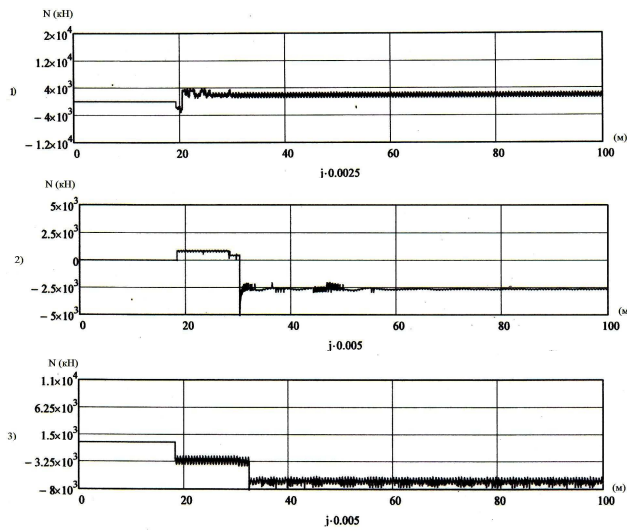


Fig. 1. Graphs of horizontal shear forces while driving on road section dumpcars 6 VS-60, 350m radius of the curve 350 m:
1 - speed of 5 km / h, elevation of outer rail 0 mm
2 - speed 10 km / h, elevation of the outer rail of 5 mm
3 - speed of 15 km / h, elevation of outer rail 10 mm

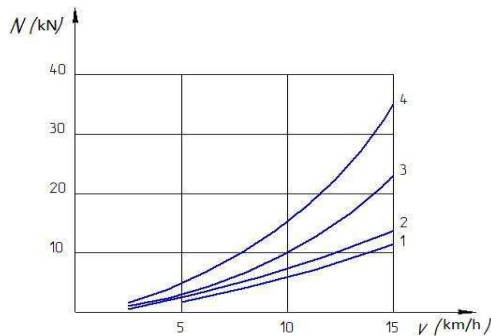


Fig. 2. Graphs of dependences horizontal shear forces from the velocities of the half wagon car model 12-1000, the elevation of the outer rails - 5 mm:
1 - R=350 m; 2 - R=250 m;
3 - R=150 m; 4 - R=100 m

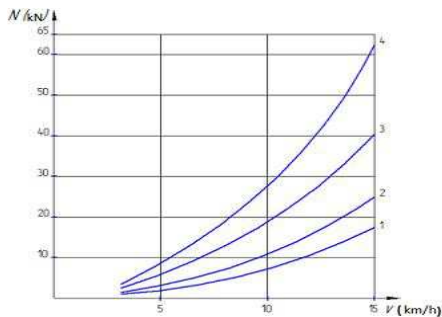


Fig. 3. Graphs of dependences horizontal shear forces from the velocities of the dumpcar VS-85, the elevation of the outer rails - 5 mm:
1 - R=350 m; 2 - R=250 m;
3 - R=150 m; 4 - R=100 m

Horizontal irregularities in the straight sections of road causing the appearance of horizontal shear force, whose magnitude can be significant. Particularly intense dynamic processes occur at movement on a short (to 6 m) isolated irregularities.

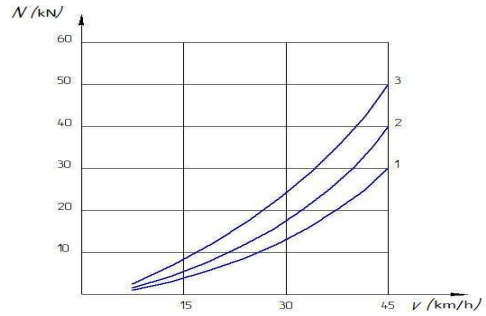


Fig. 4. Graphs of dependences horizontal shear forces from the velocities of the dumpcar VS-85, the elevation of the outer rails - 10 mm:
1 - R=450 m; 2 - R=350 m; 3 - R=250 m

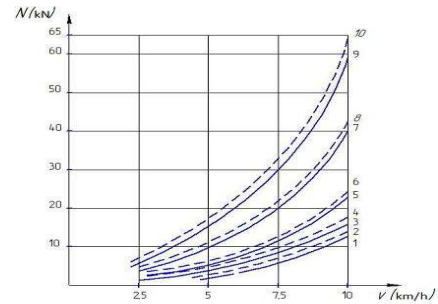


Fig. 5. Graphs of dependences horizontal shear forces from the velocities of the dumpcar VS-85, the elevation of the outer rails - 5 mm:
1 - R=450 m, $t_f=0$; 2 - R=450 m, $t_f=10$ years;
3 - R=350 m, $t_f=0$; 4 - R=350 m, $t_f=10$ years;
5 - R=250 m, $t_f=0$; 6 - R=250 m, $t_f=10$ years;
7 - R=150 m, $t_f=0$; 8 - R=150 m, $t_f=10$ years;
9 - R=100 m, $t_f=0$; 10 - R=100 m, $t_f=10$ years

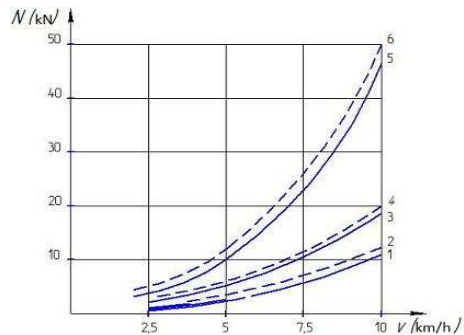


Fig. 6. Graphs of dependences horizontal shear forces on the velocity of the cart for mould I-120-5500, the elevation of the outer rails - 5 mm:
1 - R=350 m, $t_f=10$ years; 2 - R=250 m, $t_f=0$;
3 - R=250 m, $t_f=10$ years; 4 - R=150 m, $t_f=0$;
5 - R=150 m, $t_f=10$ years; 6 - R=100 m, $t_f=0$

In fig. 7, as an example, shows graphs of changes of horizontal shear forces a pair of wheel at movement on isolated irregularities plan 4m dumpcar VS-85 with the speed 20 km/h. The figure shows the graphs for the track sections on wooden and concrete sleepers, and for different amplitudes of the irregularities. The graphs show that the characteristics of stiffness and dissipation of rail supports have a decisive influence on the character of dynamic processes occurring at the same level with the amplitude of the horizontal irregularities.

In fig. 8 and 9 are given diagrams of dependences horizontal shear force of the amplitude of irregularities in the movement of half wagon model 12-1000 and dumpcar VS-85 with the speed 20 km/h. Roughness length was taken equal to 2 or 4 m, the roughness was in the straight section of road.

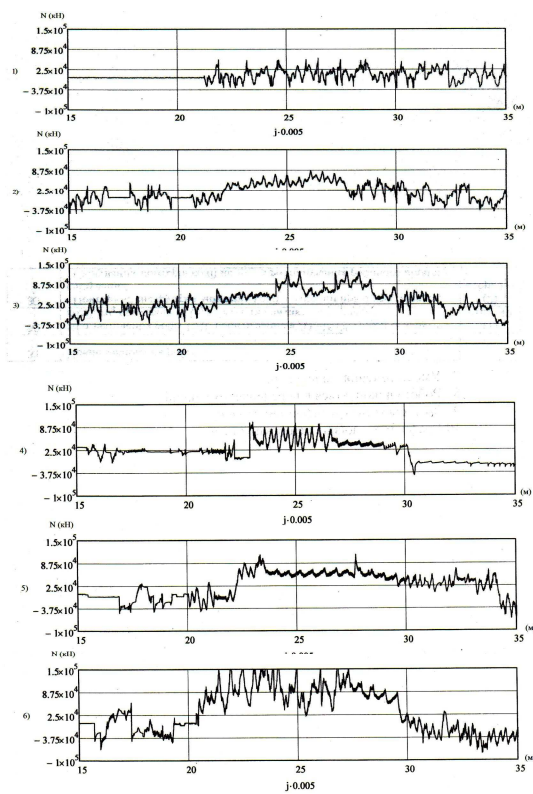


Fig. 7. Graphs of horizontal shear forces during the motion dumpcars VS-85 by the horizontal irregularities length of 4 m in the straight section of road:
 1 - wooden sleepers, the amplitude of the irregularities 10 mm;
 2 - wooden sleepers, the amplitude of the irregularities 20 mm;
 3 - wooden sleepers, the amplitude of the irregularities 40 mm;
 4 - concrete sleepers, the amplitude of the irregularities 10 mm;
 5 - concrete sleepers, the amplitude of the irregularities 20 mm;
 6 - concrete sleepers, the amplitude of the irregularities 40 mm

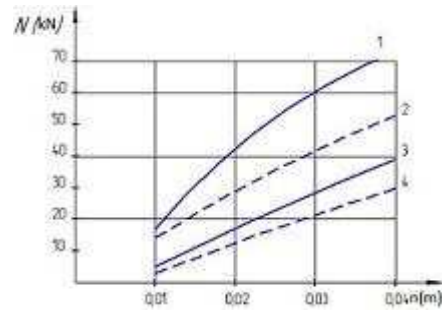


Fig. 8. Graphs of dependences horizontal shear force of the amplitude of the horizontal irregularities during the motion of half wagon 12-1000 with the speed 20 km/h:

- 1 - length of the irregularities 2 m, concrete sleepers;
- 2 - length of the irregularities 2 m, wooden sleepers;
- 3 - length of the irregularities 4 m, concrete sleepers;
- 4 - length of the irregularities 4 m, the wooden sleepers

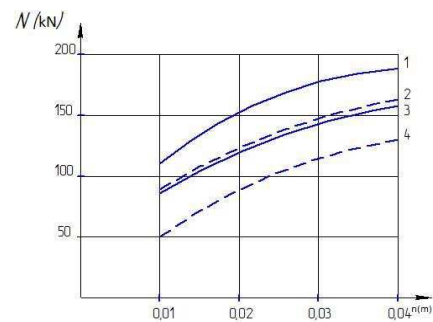


Fig. 9. Graphs of dependences horizontal shear force of the amplitude of the horizontal irregularities during the motion of dumpcar VS-85 with the speed 20 km/h:

- 1 - length of the irregularities 2 m, concrete sleepers;
- 2 - length of the irregularities 2 m, wooden sleepers;
- 3 - length of the irregularities 4 m, concrete sleepers;
- 4 - length of the irregularities 4 m, the wooden sleepers

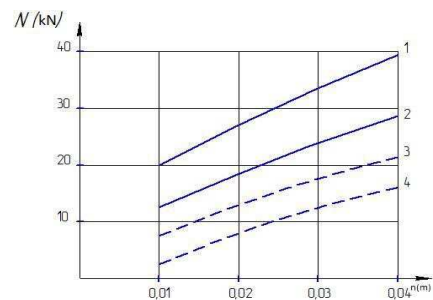


Fig. 10. Graphs of dependences horizontal shear force of the amplitude of the horizontal irregularities during the motion of cart for mould I-120-5500 with the speed 10 km/h:

- 1 - length of the irregularities 2 m, concrete sleepers;
- 2 - length of the irregularities 2 m, wooden sleepers;
- 3 - length of the irregularities 4 m, concrete sleepers;
- 4 - length of the irregularities 4 m, the wooden sleepers

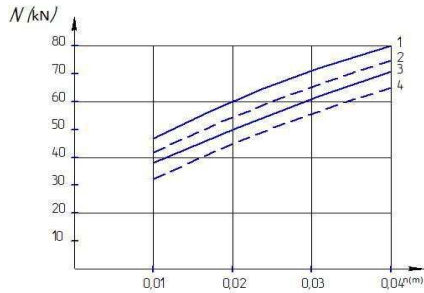


Fig. 11. Graphs of dependences horizontal shear force of the amplitude of the horizontal irregularities during the motion of hot metal transfer car capacity of 140 tons with the speed 10 km/h:

- 1 – length of the irregularities 2 m, concrete sleepers;
- 2 – length of the irregularities 2 m, wooden sleepers;
- 3 – length of the irregularities 4 m, concrete sleepers;
- 4 – length of the irregularities 4 m, the wooden sleepers

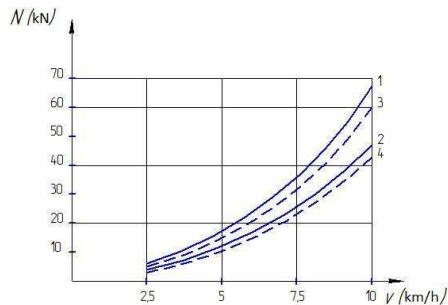


Fig. 12. Graphs of dependences horizontal shear force of the amplitude of the horizontal irregularities during the motion of hot metal transfer car capacity of 140 tons along a straight section of track with irregularities:

- 1 – length of the irregularities 4 m, concrete sleepers; amplitude 0,04 m;
- 2 – length of the irregularities 2 m, wooden sleepers; amplitude 0,02 m;
- 3 – length of the irregularities 4 m, concrete sleepers; amplitude 0,04 m;
- 4 – length of the irregularities 2 m, the wooden sleepers; amplitude 0,02 m

Calculations have shown that during the motion dumpcars VS-85 in the same with the half wagon conditions value of horizontal shear force is higher by more than 2.5 times and may reach 185 kN. On the road with concrete sleepers levels resulting horizontal shear forces higher than the design of their way to the wooden sleepers by 12-47%. Similar relationships were obtained by comparing the calculation results of horizontal shear forces during the motion of with the speed of 10 km/h on the same irregularities in the straight sections of road carts for mould molds I-120-5500 and hot metal transfer car capacity of 140 tons.

The value of horizontal shear forces during the motion of hot metal transfer car exceeds the

value of the forces during the motion of cart more than doubled and reaching values of 80 kN (fig. 10 and 11).

The influence of speed on the magnitude of horizontal shear forces shown in the example calculations movement of hot metal transfer car in the same horizontal irregularities in straight lines (fig. 12). During change the speed from 2.5 to 10 km/h horizontal shear forces increase from 7.3 kN to 42-68 kN, taking into account the length of L_H and amplitude of the irregularities η_z and type of rail poles - concrete or wooden sleepers.

Especially unfavorable interactions of the crew and way in the curves of small radii, with the horizontal irregularities. For example, in fig. 13 shows the results of calculations for the horizontal shear force curve radius from 350 to 150 m with a horizontal isolated irregularities with the length of L_H 2 and 4 m and amplitude of the irregularities η_z from 10 mm to 40 mm. As current crew was adopted hot metal transfer car capacity of 140 tons/ Considered the way to the wooden sleepers.

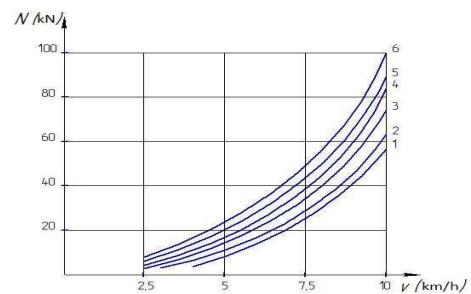


Fig. 13. Graphs of dependences horizontal shear force of the amplitude of the horizontal irregularities during the motion of hot metal transfer car capacity of 140 tons along a unevenness curves:

- 1 – $R=350$ $L_H=2$ m $\eta_z=0,01$ m;
- 2 – $R=250$ $L_H=2$ m $\eta_z=0,01$ m;
- 3 – $R=150$ $L_H=2$ m $\eta_z=0,01$ m;
- 4 – $R=350$ $L_H=4$ m $\eta_z=0,04$ m;
- 5 – $R=250$ $L_H=4$ m $\eta_z=0,04$ m;
- 6 – $R=150$ $L_H=4$ m $\eta_z=0,04$ m.

During the change of speeds from 2.5 to 10 km/h values of the horizontal shear forces increase from 2,5-12 kN to 46-106 kN. Similar irregularities in the way of wooden sleepers, which are in the straight sections, causing the appearance at a speed of 10 km/h horizontal shear force equal to 42-62 kN depending on the length and amplitude of the irregularities.

CONCLUSIONS

The calculations revealed that the horizontal shear forces can achieve in the operating conditions of industrial railways values greater than 60-100 kN. The main factors influence on the

level of these forces are the types of circulating cars, characteristics of isolated horizontal irregularities of a way, curve radii and elastodynamic characteristics of the path in the horizontal transverse direction.

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РЕЗУЛЬТАТЫ ИССЛЕДОВАНИЙ ЧИСЛЕННЫМИ МЕТОДАМИ ВЗАИМОДЕЙСТВИЙ НА ПУТЬ СПЕЦИАЛЬНОГО И СПЕЦИАЛИЗИРОВАННОГО ПОДВИЖНОГО СОСТАВА В КРИВЫХ МАЛЫХ РАДИУСОВ

Александр Даренский

Аннотация. Выполнены расчеты сил взаимодействия специальных и специализированных вагонов промышленного транспорта и пути в кривых малых радиусов с использованием программы расчетов динамической системы “экипаж-путь”. Установлено влияние на эти силы как геометрических характеристик рельсовой колеи – радиусов кривых, возвышения наружного рельса и других, так и горизонтальных геометрических неровностей пути. Ключевые слова. специальный и специализированный подвижной состав, рельсовый путь в кривых, взаимодействие подвижного состава и пути.

Created on 3D printers conjunction details design problems

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Summary. Today urgent problem is making the relevant connections. The author propose to manufacture such products compounds using rapid prototyping technology. To design such parts and create them using fusion depositing modeling technology, confidence accuracy intervals were calculated using mathematical statistics methods making both internal and external surfaces, and possible tolerances are suggested.
Key words: rapid prototyping, profiled compounds, fused depositing modeling accuracy.

INTRODUCTION

Profiled compounds used to transmit torque from the shaft to the hub. In profile compounds contact between the shaft and the hub is on a non-circular surface. Profiled compounds are transverse to the connection axis on noncircular cross section of a smooth profile the contact surface of the shaft and hub. More often equiaxed connection of triangular profile are used. Applicable profile has the property of equiaxed - constancy of the diametrical size [1-5].

Advantages of relevant connections:

- lack of torsion stress concentrators;
- good centering of the connection;
- increased reliability by bonding strength compared to the compounds with an interference fit.

Disadvantages of profile connections:

- complexity of the manufacturing surface profile;
- when a connection torques there are significant spacer forces that deform the hub.

- no construction methods in the appointment of the nominal dimensions and tolerances

Here is an example of profile connections (fig 1). In the profile connection inner and outer surfaces have a non-circular cross-section. Due to this possible torque force transfer without the use of additional parts. Compared with keyway and spline connection profile has a lower concentration of stresses and better parts centering. Disadvantage is in complexity of such parts production. Examples of mating parts can serve as engineering parts, and models of feet - shoes in light industry. Lack of establishment of mating components can be eliminated using rapid prototyping technology, which also should be described [6-9].

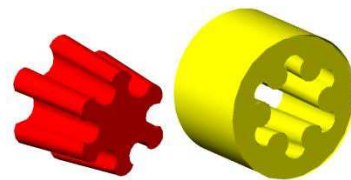


Fig. 1. Profiled compounds

Rapid prototyping – is a number of methods that allow you quickly build and scale physical model of a part or assembly using the data of three-dimensional modeling CAD systems. There are many different ways of rapid prototyping such as stereolithography, Selective Laser Sintering, Fused Depositing Modeling, Solid Ground Curing, Laminated Object Modeling, Multi Jet Modeling,

Ballistic Particle Manufacturing [6]. In this work the Fused Depositing Modeling method was studied as the most cheaper and available. This method is based on melting the polymer. That are pass trow the extrusion head and then lie down layer by layer forming the future detail (fig 2) [10-15].



Fig. 2. Up! 3d printer (that uses fused deposition modeling method)

Advantages of the rapid prototype method are[7]:

- Acceleration of production process 2-4 times,
- Reduction of production costs 2-3 times,
- Increasing production flexibility,
- Integration with CAD,
- The ability to create parts of any complexity.

OBJECTS AND PROBLEMS

The methods of rapid prototyping are the most suitable of the modern techniques to create a mating products as it was mentioned above. The main limiting factor in the production of mating products by this method is the lack of reference for the design dimensions and tolerances with respect

to this method of production. It's needed to create such recommendations.

Thus, the purpose of this article is to create guidelines for the production of mating parts by rapid prototyping, and specifically Fused Depositing Modeling on the Up! 3d printer equipment.

RESEARCH ANALYSIS

The simplest example of mating parts are cylindrical shaft and sleeve (fig. 3).

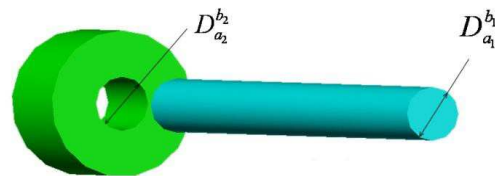


Fig. 3. Shaft and sleeve

To make conjugation details should meet the conditions. To the outside diameter of the shaft $D_1 = D_{a_1}^{b_1}$, Internal sleeve diameter $D_2 = D_{a_2}^{b_2}$, where D – nominal size, a_1 – lower deflection of the inner part, b_1 – deviation of the inner part, a_2 , b_2 – deviation, respectively, of the outer part. When pairing the moving parts of conditions must be met: $b_1 < 0$, $a_1 < b_1$, $a_2 > 0$, $b_2 > a_2$. The sliding connection conditions take the form: $b_1 = 0$, $a_1 < 0$, $a_2 = 0$, $b_2 > 0$. When you create a fixed connection conditions take the form: $b_1 > a_1$, $a_1 > 0$, $a_2 < b_2$, $b_2 < 0$. Details of this type can be made on metal-cutting equipment. Ways to ensure that are determined by a well-developed manufacturing technology. The task of creating such parts becomes much more complicated when the mating parts are the parts with complex geometry, for example the parts can be profiled connections. We propose to create such products using rapid prototyping technologies.

For such complex parts matching conditions is much more complicated due to the following factors: significant increase in the number of measurable traits, which also can vary in length parts (fig 4).

A separate piece of different sizes can act as external and internal. In the manufacture of parts for printers, rear to the junction conditions must be added to a manufacturing error, which is still not exactly explored.

To obtain data on the accuracy of prototyping studies were carried out on the equipment Up! 3d printer with the following characteristics: printing material - ABS & PLA Plastic, obtained dimensions details: - 140W x 140D x 135H mm, thickness -0.15/0.20 / 0.25 / 0.30 / 0.35 / 0.40 mm.

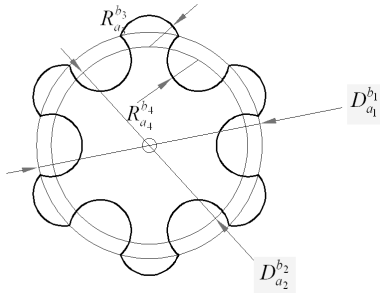


Fig. 4. Profiled connections

Size of the parts that are designed to be print on 3D printer have to be based on following conditions:

For external mating sizes $D_1 = (D - \Delta_1)_{a_1}^{b_1}$. Internal dimensions of the mating $D_1 = (D + \Delta_2)_{a_2}^{b_2}$, where $\Delta_1 = 3\sigma_1$, a $\Delta_2 = 3\sigma_2$.

To determine the range of tolerance studies were conducted on 3D printer printing accuracy.

Studies were made on a series of prototypes comparable size (nominal sizes of 10-15 mm) containing both internal and external surfaces (fig. 5).



Fig. 5. Researched prototypes

After the measuring of the prototypes the graph (fig. 6) was create. And the assumption was made that distribution of deviations law is closed

to normal $f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$ (fig. 5).

To check such decision were calculated math expectation and dispersion. Basing on them was

calculated and checked the Pearson criteria [9]. This criteria showed that the law distribution of deviations is close to normal with such parameters: for internal surfaces expectation - 0.05 mm, standard deviation of 0.03 mm [16-18]. For external surfaces of the expectation 0.115, standard deviation 0.025.

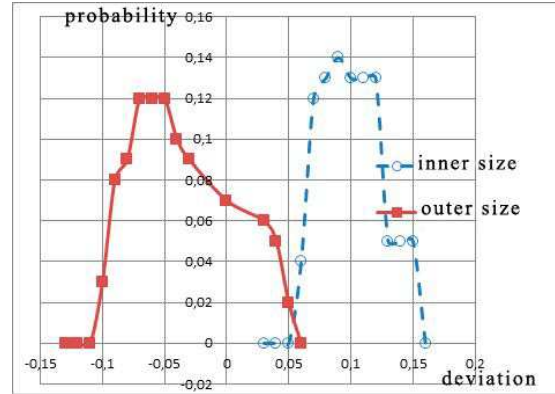


Fig. 6. Deviation of outer and inner size of details that are used in profiled connection

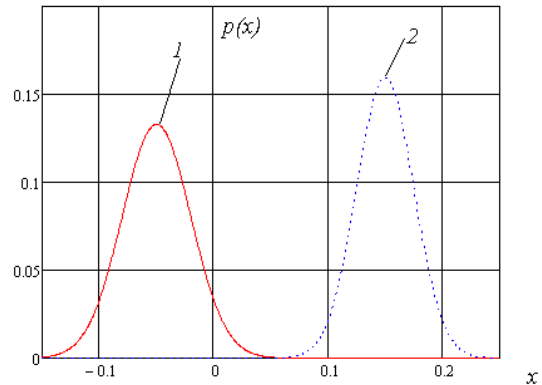


Fig. 7. Normal deviation law

Research of details actual dimensions size deviation, that are produced on FDM printers show that, detail showed be designed for internal dimensions $x = x_{nom}^{+0,04}_{-0,16}$, and for external $x = x_{nom}^{+0,19}_{+0,04}$.

CONCLUSIONS

Rapid prototyping technology can be used to manufacture the parts involved in the relevant connections. Thus during the design deviations should be taken into account, they will be - for internal dimensions $x = x_{nom}^{+0,04}_{-0,16}$, for external $x = x_{nom}^{+0,19}_{+0,04}$.

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ПРОБЛЕМЫ ПРОЕКТИРОВАНИЯ СОПРЯГАЕМЫХ ДЕТАЛЕЙ, ИЗГОТАВЛИВАЕМЫХ НА 3Д ПРИНТЕРАХ

Инесса Дейнека, Александр Рябчиков

Аннотация. На сегодняшний день является актуальной проблема изготовления профильных соединений. Автором предложено изготовление изделий для подобных соединений с помощью технологии быстрого прототипирования. Используя методы математической статистики были рассчитаны доверительные интервалы точности изготовления как внутренних так и внешних поверхностей с помощью технологии отверждения на твердом основании, и предложены возможные допуски для проектирования подобных деталей для изготовления их в дальнейшем с помощью данной технологии.
Ключевые слова: быстрое прототипирование, профильные соединения, точность метода отверждения на твердом основании

Concepts of energetic system personnel development

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Summary. The article considers the approaches to the analysis of the concepts of power systems personnel development. The paper presents the fundamental basis of the theory of modeling as a synthesis of the considered paradigms. The article analyzes the use of the modern paradigm as the basis for the development of methods for the power systems personnel development.

Key words: concept of development, energy systems.

INTRODUCTION

Energy efficiency [18] are one of the main factors of sustainable industrial development. Development of the energetics determines the requirements for the technical and human resources that are involved in this field.

The character of the description of the environment and reality by depends on the suppositions which are involved into the analysis and its methods. The whole of such fundamental suppositions, statements, assumptions and methods which define the view of the world is called the paradigm. There are defined the following modern paradigm:

1. Neoclassical theory [4]. It studies actors making the rational choice in terms of stable preferences and interacting within the equal market.

2. New institutional theory [10, 23]. It studies structures of interacting actors making the limited rational choice within stable preferences the interaction of which is expensive and it leads to creation of institutes.

3. Evolutional theory [14]. It studies the dynamics of the environment of interacting actors

which make irrational choice based on the indefinite preferences.

OBJECTS AND PROBLEMS

According to the Ukrainian scientist A.S.Galchinskiy [7], there is a problem of reconceiving a range of postulates in the modern economic theory:

1. Causality principle. A.S. Galchinskiy considers that the major problem in this field is the absolution of determinism which cannot be applied to complicated dynamic open systems one of which is economy. As it is impossible to receive absolutely accurate information about the system its description will be inaccurate and its behavior will be unpredictable and the more complicated the system will be the greater errors in the calculation may occur in the functioning of the system. Scientific achievements in the field of analysis of complicated economic systems in particular the theory of structure, stability and fluctuations of Nobel Prize holder I.R.Prigozhyn allow us to speak about the following presuppositions of modification of causality principle [7]: the understanding of causality as the system of complicated interaction of forces of different nature; the necessity of taking into account both direct connection and feedback; explanation of complicated processes and phenomena based on the combination of the casual and the necessary; admitting the possibility of self-triggering processes.

2. Rational behavior of economic actors. The researches of Princeton University Professor D. Kahneman [11] who received the Nobel Prize

“For Research in the field of Taking Decisions” showed decisions taken by people differ essentially from adopted standard economic model: people can rationally evaluate neither profit or loss amount nor their probability. Instead of decision making theories based upon probability theory D.Kahneman and A.Tversky offered a prospective theory according to which an ordinary person is unable to evaluate future profit in its absolute form, in reality he evaluates them in comparison with a definite common standard tending to escape worsening of its condition first of all.

3. Equilibrium principle. However, with the reference to the modern economy, according to A.S.Galchinskiy [7], economic equilibrium is limited in time and space, only corresponds to simple systems and is considered as a particular case and thus, the principle of inequilibrium development is of more adequacy.

According to the member of the Academy V.L.Makarov [12], “the theory of general economic development which is currently dominating both in the science and the economic education, as it is well-known does not correspond to the reality, as least in its classical version In the real economic world there is observed a huge range of effectiveness, in particular in the profit of companies, branches, regions. This variety does not descend within the time, but on the contrary increases. The theory of general economic equilibrium cannot explain this phenomenon”.

According to the mathematician and economist of Lebanese origin N.N. Taleb, reliable forecasting in the modern economy is impossible and we can use the script method for future forecasting and your actions [21]. The above mentioned D. Kahneman considers that N.N.Taleb changed the way of thinking about uncertainty of many people especially in the financial markets, and his book “Black Swan [21], is interesting and brave analysis of what is the human way of comprehension of unexpected events”.

RESULTS OF INVESTIGATIONS

According to Professor of Management State University (Moscow) Y.V.Balatskiy, “unlike science of the 19th and 20th centuries the science of the 21st century must contain ... technology (methods and suggestions) of making modern behavioral models. All contemporary theories and conceptions will ... only be significant at the definite point of space and time. have significance in well-defined space-time point. Actually

contemporary economic researches turn into complicated engineering art with any a priori patterns do not apply referring the final conclusions.” [2].

To our mind for more detailed reflection of economic processes it will be useful to apply the economic theory of modeling as development not taking into account the contradictions based on synthesis:

1. Indefinite preferences and irrational behavior of actors.
2. Network interaction of actors.
3. Scholastic character of complicated systems.
4. Constant character of changes and as a result inequilibrium system development.

As a result of model analysis within the theory it is impossible to get 100% definite results. Conclusions will have the probability less than 100 %, we will be unable to evaluate it precisely.

Mathematical instrument of modeling theory makes it possible to take into account the uncertainty, in that the notion of a number is substituted with the notion of an uncertain number which may be accidental, fuzzy or interval. Accidental numbers are specified by probable distribution of their possible value, fuzzy numbers are specified by linguistically formed distributions of their possible value and studied in the theory of fuzzy majorities, interval numbers are specified by intervals of their possible value and studied in interval mathematics.

Methods of modeling theory may be guided by the system theory [1].

One of the notions of neoclassical theory is transformation expenses, i.e. production costs. With respect to staff development the production costs are defined with the help of the notion of human capital which was initially developed by American scholars the Nobel Prize winners T.Schultz [20] and G.Becker [3]. Usually the resource of people’s abilities, knowledge, skills, motivation and energy is understood as human capital which can be used to get profit by its owner

The aim of the staff training system is to make the knowledge, skills and experience of the staff correspond to the desired indices at different levels: enterprise strategy, branch activity, work duties [13]. The specification of employees who need this training, its content and duration is the supposition of the effective work of staff training system. The generalizing, integral index characterizing the correspondence of professional features of the employee is offered as the amount of human capital. According to the work duties the

amount of human capital is calculated which is necessary to fulfill the duties. The latter is differentiated as specific for a definite work place, position, enterprise, branch or region, country and general human capital. Specifying the present amount of human capital of a definite employee and comparing it with the necessary one it is possible to identify the content (according to the lack of capital) and the amount (according to the existing and the necessary levels) of training. The realization of the above mentioned scheme requires the use of methods of human capital calculation which is a part of the more general notion "intellectual capital". The chosen method should be quite simple for wider use in the production and simultaneously take into account knowledge and skills decay, i.e. moral deterioration of human capital. For the exact definition of training content there exist special assets of human capital which depend on the competence of the employee and can be changed by the training. The resources of these assets are investments, in particular different types of training. Corresponding the amount of these assets are defined according to the investments into the human capital as definite types of training.

Neoinstitutional theory enriched the economic theory with the notion of transaction expenses, i.e. non-production costs. According to this theory the expenses of production consist of two types: transformation and (production) ones and transaction (non-production) ones. The latter are considered as interaction expenses of the economic system in their wide sense. Transaction expenses are connected with uncertainty of behavior of market agents and economic situation in general in the process of making and providing the contract execution. One of the ways to decrease the uncertainty is the use of institutes. According to one of the founders of the institutional theory Douglas North, the institute is "created by a human limitations which arrange the relations between people" [15]. The latter, as a rule, are connected with the relations between actors, which are described by the notion of social capital. As it is known, the division of the capital into physical, human and social is connected with the defining productive features of production means of a person and productive features of interpersonal relations which are created as a result of investments and is profitable by forming through the production process. Social capital is defined as the whole trustworthy relations, public standards, interaction networks and information or as the value connected with the interaction of economic

actors. The assessment of social capital is done within the analysis of social networks which allows to express the effectiveness of the existing networks, offer the improvement of the existing networks and create effective networks.

The analysis of social networks of informal training allows to specify the network structure, provide the effective work of social network (of connection channels: including the use of information communication technologies); the fight against the work break downs (violation of signal work, connection disorders; to arrange the analysis "what if"), to find the best solutions.

Thus, the methods of staff development within the considered paradigms must include:

1. Taking into account transformation expenses of staff development as investment into human capital.
2. Taking into account and reduction of transaction expenses of staff development defined with the evaluation of social capital.
3. Taking into account the uncertainties with the methods of interval mathematics.

The protection from uncertainty in the market relations and the way of transaction expenses reduction are: from objective uncertainty connected with the incomplete information and unforecasted of the market environment – possibilities of getting the necessary information with the best quality; from subjective uncertainty caused by the opportunistic actions of partners – common behavioral rules: axiomatic truth and credibility.

Another way of uncertainty reduction, and consequently, transaction expenses may be considered the use of social capital.

One of the first scholars who paid attention to economic value of network relations was Granovetter [9], who pointed out that economic behavior is "included into the network of interpersonal relations". Granovetter [8] pointed out that the success of the search of work depends on their personal connections: individuals who have more informal (weak) connections find work easier than those who only have regular (strong) relations. Possibly, this approach may be favorable for consideration the access to information resources in a wider context, in particular the educational process. According to DiMaggio and Powell [6], the process of production education is simplified for the individuals with a wide range of weak connections, getting and using the knowledge greatly depend on the density and quality of the outer professional connections not connected with the work duties, inside the

company and the specialists from other companies [19,22]. As it is supposed [6], the training mostly takes place during the process of the best experience simulation transferred through social networks what allows to reduce transaction expenses connected with the information search. According to many researchers networks simplify the training process both for the individuals and the organizations. It is interesting to analyze the mutual influence of training, social capital and transaction expenses under the conditions of its investment into the latter one.

According to the research of R.Putnam [16, 17], informal training in groups and organizations increases the life quality and develops the social connections, credibility and tolerance, increasing the social capital as a result. On the other hand, as it was proved in the research of J.Coleman [5], there exists the inverse interaction: social capital influences the training success: those who are trained in the favorable training environment are more probable to succeed in training completion. Possibly, exactly the high level of social capital reduces the transaction expenses and encourages successful training and human capital growth. Informal training which is not usually taken into account by calculation of expenses for human capital is greatly defined by the social capital of the group in which the employee is trained. The amount of informal training and consequently the human capital of the employee without doubt depends on the amount of social capital in his environment. Thus, the amount of the created human capital can be considered the income of social capital.

It is interesting to define the part of informal networking training in the creation of human capital and the influence of social capital on this process.

As income of the social capital there is considered:

1. The reduction of transaction costs: partners' actions monitoring; resource access, providing altruistic behavior of customers and sellers.
2. More effective coordination of collective actions: information exchange; common use of physical capital; common supply and sales, marketing; common development.
3. Training arrangement: feedback from customers.

It is interested to analyze the ways, effectiveness and means of investment attraction of the state, companies and physical persons into the social capital with the aim of getting income.

Obviously, such an activity must be provided with the corresponding institutional support and regulated by the state. As investments there can be considered the resources which belong to the investor and are used to increase the social capital: financial resources, physical capital, time.

CONCLUSIONS

The proper functioning of the energy depends on sustainable development industry. On the other hand, determines the development of the electricity requirements for the technical and human resources that are involved in this field.

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КОНЦЕПЦИИ РАЗВИТИЯ ЭНЕРГЕТИЧЕСКИХ СИСТЕМ

Юрий Дьяченко

А н н о т а ц и я . В статье рассмотрены подходы к анализу концепций развития энергетических систем. В работе предложена фундаментальная основа теории моделирования как синтез рассмотренных парадигм. В статье проанализировано использование современной парадигмы в качестве основы для разработки методов развития энергетических систем.

К л ю ч е в ы е с л о в а . концепция развития, энергетические системы.

Mathematical support of the system of computer-aided design of screw extruders

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Summary. Exact analytical calculation of the screw pair, the most widespread working body of extruder, is difficult. The necessity of the creation of CAD system for screw extruders is explained. The functions of the provided computer-aided design system are considered. Mathematical models of motion of the material recycled in the extruder are presented. The finite element analysis and the theory of heat conduction are used for the calculation of the stressed state of the material.

Key words: extruder, CAD, finite element approach, equilibrium equation.

INTRODUCTION

Technologies of extrusion considering its high productivity are widely used in food, chemical and other industries. Exact analytical calculation of the screw pair, the most widespread working body of extruder, is difficult because of the variety of complex shapes of extruders and properties of the recycled material. Calculation of screw extruders nowadays is made by approximate, as a rule empirical formulas, with a large number of assumptions [17].

Creation of an automated instrument of the design of screw units which enables to make theoretically grounded kinematic, strength calculations, calculations of wear resistance, calculations of stress state in different points of the recycled material will improve the quality of the made design decisions in their synthesis, increase the accuracy of calculation and informativity of it for a designer. Creation of new constructional solutions using the methods of virtual engineering

saves time and costs related to the design through the use of computer simulation [8].

OBJECTS AND PROBLEMS

The functions of the proposed system of automation of the screw extruders design:

1. Structural synthesis of the construction. Engineer-user of the system makes a block scheme using specified primitives of the elements of the extruder. Selection of different geometry (cylindrical or cone body shape, flat or corrugated walls and so on.) is possible at this stage. The database of primitives required for this function contains data caused by the system developer. The results of structural synthesis are displayed on the screen and may be stored in the database of constructions [10].

2. Editing of existing solutions. Extruder elements selected in the process of structural synthesis, as a rule, have adjustable parameters, such as the angularity of the screw line, thickness of the blades and so on. The system enables the engineer-user to vary these parameters within the acceptable limits from the viewpoint of feasibility of the design. The results are recorded in the database of designs.

3. Engineering calculations. Design automation system performs the necessary calculations based on specified by the engineer-user structure, design parameters, parameters of the technological mode (operating pressure in front of the matrix, rotation speed of the screw and so on),

the properties of the recycled material. The system should provide the possibility of such types of calculations as heat and strength calculations, calculations of the stress state in different point of the recycled material and the calculations of wear resistance. The results of calculations are displayed on screen in the form of dependencies diagrams, as well as may be printed.

4. Analysis of the parameters impact. Design automation system allows to display diagrams of dependencies of the chosen parameters according to the results of engineering calculations (for example, the moment dependence on the angular velocity of rotation or on the angularity of the screw line).

5. Modeling of technological process. As a result of emergency situations in the production process, such as sudden increase or decrease of pressure, boundary temperature conditions, the use of the plant for a new material with fundamentally different properties, the indicators of the efficiency of the extruder may change abruptly. Design automation system allows the engineer-user to simulate the behavior of the designed solution in emergency situations [18].

6. Development of documentation. According to the chosen by the engineer-user standards of the compilation of design documentation the system produces design drawings necessary for the performance of the designed solution and the explanatory notes to them.

The basis of the system of the screw extruders design automation is mathematical support of engineering calculations [1].

Analysis of the behavior of the recycled material in different points of the workspace of the extruder allowed to reveal several areas with different mathematical models. The main areas are the following: the zone of fluidity, the zone of mixing and compression, the zone of sealing and filling. In close proximity to the matrix the material is in quite mixed condition, close to the continuum in classical meaning [15]. Pressure caused by the resistance of the matrix and the product pressing-out, on the one hand, and by the pressure enters this zone under the influence of the rotary screw of the material, on the other hand, it is transmitted in all directions without changes according to the law of Pascal. The movement of the material is described by Navier–Stokes equations and by the continuity equation:

$$\frac{\partial \vec{v}}{\partial t} = -(\vec{v} \cdot \nabla) \vec{v} + \mu \Delta \vec{v} - \frac{1}{\rho} \nabla p + \vec{f},$$

$$\nabla \cdot \vec{v} = 0,$$

where: ∇ – Hamilton operator, Δ – Laplace operator, t – time, μ – Newtonian viscosity of the material, ρ – density, p – pressure, $\vec{v} = (v_x, v_y, v_z)$ – vector field of velocities, $\vec{f}$ – vector field of body forces [13].

Due to the cylindrical shape of the body these equations are convenient to use in cylindrical coordinate system $\vec{v} = (v_r, v_\varphi, v_z)$.

Because of stationarity of the flow inside the extruder the velocity derivatives are equal to zero in time. Due to the fact that the gravitational force is negligible compared to the internal forces in the layers of the material, the relevant components can be neglected [6].

As the boundary condition the condition of “adhesion” to the cylinder appears (velocity in a thin layer close to the cylinder equals to zero). For the same reason the velocity in the area of the material which borders with the screw is equal to the velocity of the screw rotation: $v_\varphi = \omega r$, $v_r = v_z = 0$.

The initial conditions considering the stationarity of the process are absent.

In the zone of mixing and compression the mixing is not completed and the pressure is small compared to the previous zone; the material shows the properties of pseudoplastic body. Mechanical properties of the material are presented by rheological equation, that relates the shear stress to the velocity of the shear of the material [2].

The matched condition with previous zone is the equality of pressure in the zone of the fluidity to the normal stress in the zone of mixing and compression.

The intense displacement of the added in the process of filling air and the sealing of the recycled material takes place in the zone of sealing. Because of this the shear stress on the body of the extruder changes direction in relation to the zone of mixing and compression [9].

Thus, the equality to zero of the shear and normal stress can be chosen as the condition of matching with the zone of mixing and compression. The computational model of motion of the recycled material is similar to the model for the previous zone, except for the continuity equation because of the compressibility of the material [16].

The ingoing material is received in the zone of ignition inside the extruder. This usually occurs under the influence of gravity, but the pressing of the material by the previous mixing device is also

possible. There is a problem of the continuity of the feed [5].

The condition of matching with the zone of sealing is the occurrence of normal stress parallel to the axis of the extruder. We can apply for the quantitative analysis in this zone a statistical approach with the research of such values as the average size of air chambers and their number per unit of volume of the material [19].

The most appropriate for engineering calculations is the finite element approach [8] successfully applied in different industrial sectors.

Adequate from technological and computational points of view method of splitting the working space of the screw extruder into finite elements is shown in the figure 1:

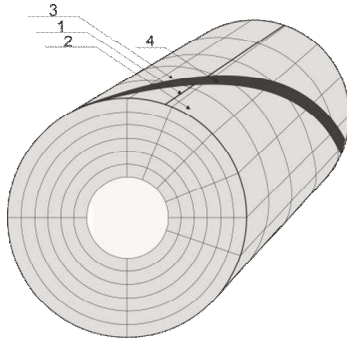


Fig. 1. Splitting the working space into finite elements: 1 - element adjacent to the blade; 2 - element not adjacent to the blade; 3 - element closing the ring; 4 - blade

The working space of the extruder is split into finite elements in three directions. The working space is split into discs by the surfaces perpendicular to the axis of the screw [3].

Discs, in their turn, are divided into rings by means of cylindrical surfaces the axis of which coincides with the axis of the screw. We obtain sectoral parts by breaking the rings with radial planes [4].

In each ring let us distinguish by the feature of neighborhood with the blade of the screw the following:

- element of the type 1 adjacent to the blade and experiencing the stress transferred to it and geometrically approximated to a triangular prism;
- elements of the type 2, not adjacent to the blade and geometrically approximated to a rectangular parallelepiped;
- element of the type 3, closing the ring and which is the mirror image of the element of the type 1 relative to the blade [20].

The dynamic equilibrium of the elements of type 1, 2 and 3 is determined by the total action of forces shown in figures 2, 3 and 4 respectively. To

make a force calculation we direct the axis x in the circle direction, the axis y parallel to the axis of the screw, the axis z in the direction from the worm shaft to the cylindrical body. Having equated the total force and the total moment of force to zero we make an equilibrium equation for the element of the type 2 (for the elements of the types 1 and 3 the equations are made similarly):

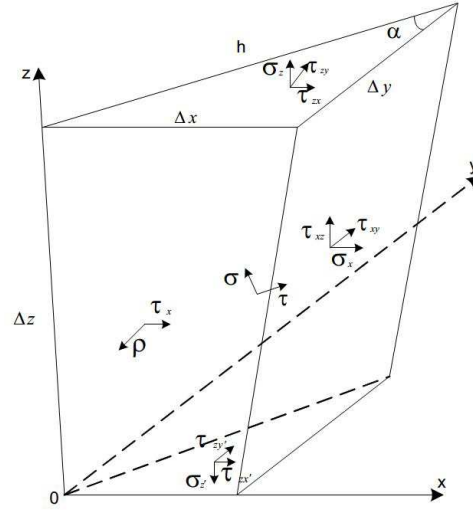


Fig. 2. Model of the element of the type 1

$$(\tau_x + \tau_{x'}) \cdot \Delta x \Delta z + (\sigma_{x'} + \sigma_x) \cdot \Delta y \Delta z + (\tau_{zx} + \tau_{zx'}) \cdot \Delta x \Delta y = 0,$$

$$(\rho' + \rho) \cdot \Delta x \Delta z + (\tau_{zy} + \tau_{zy'}) \cdot \Delta y \Delta z + (\tau_{zy} + \tau_{zy'}) \cdot \Delta x \Delta y = 0,$$

$$(\tau_{xz} + \tau_{xz'}) \cdot \Delta y \Delta z + (\sigma_z - \sigma_{z'}) \cdot \Delta x \Delta z = 0,$$

$$(\sigma_z - \sigma_{z'}) \Delta x \Delta y \frac{\Delta y}{2} - \tau_{zy} \cdot \Delta x \Delta y \Delta z + (\rho - \rho') \Delta x \Delta z \frac{\Delta z}{2} + (\tau_{xz} - \tau_{xz'}) \Delta y \Delta z \frac{\Delta y}{2} - (\tau_{xy} - \tau_{xy'}) \Delta y \Delta z \frac{\Delta z}{2} = 0,$$

$$(\sigma_{x'} - \sigma_x) \Delta y \Delta z \frac{\Delta z}{2} + (\sigma_{z'} - \sigma_z) \Delta x \Delta y \frac{\Delta x}{2} + \tau_{zx'} \Delta x \Delta y \Delta z + (\tau_x + \tau_{x'}) \Delta x \Delta z \frac{\Delta z}{2} - \tau_{xz'} \Delta x \Delta y \Delta z = 0,$$

$$(\rho' - \rho) \Delta x \Delta z \frac{\Delta x}{2} + (\sigma_x - \sigma_{x'}) \Delta y \Delta z \frac{\Delta y}{2} - (\tau_{zx} + \tau_{zx'}) \Delta x \Delta y \frac{\Delta y}{2} + (\tau_{zy} + \tau_{zy'}) \Delta x \Delta y \frac{\Delta x}{2} - \tau_{x'} \Delta x \Delta z \Delta y + \tau_{xy'} \Delta x \Delta z \Delta y = 0.$$

An additional equation is necessary for unambiguous solution of this system of equations regarding the unknowns ρ' , $\tau_{x'}$, $\sigma_{z'}$, $\tau_{zx'}$, $\tau_{zy'}$, $\tau_{xz'}$, $\tau_{xy'}$. For its generation let us turn to the theory of heat conduction and make the energy balance equation in the environment of the material.

Mechanical and thermodynamic properties do not change over time taking into account the stationarity of the considered process. Thus, the work of the viscous friction forces is equal to the amount of heat that is emitted from the layer of the material [11]. Let the temperature distribution in the direction from the body to the worm shaft be known and the change of the temperature of the material during the processing be negligibly small [7].

According to Fourier law of heat conduction, the power of thermal losses in a steady state is proportional to the temperature gradient [14]:

$$|P_1| = kS|\text{grad}(T)|,$$

where: P_1 - total power of thermal losses, S - area through which the heat passes, $\text{grad}(T)$ - velocity of the temperature change along the normal axis, k - thermal conductivity coefficient.

The work of viscous friction forces dA in the infinitesimal area with the volume dV for the case of constant density of the material is determined by the equation [15]:

$$\frac{dA}{dVdt} = -\tau\dot{\gamma}.$$

Let us consider work of friction forces in the layers of the material in the planes parallel to zOx , zOy , yOx independently of one another:

$$xOy: |P_2| = \int_{\Delta V} \tau\dot{\gamma}dV = \Delta x\Delta y \int_0^{\Delta z} \tau\dot{\gamma}dz,$$

$$yOz: |P_3| = \int_{\Delta V} \tau\dot{\gamma}dV = \Delta y\Delta z \int_0^{\Delta x} \tau\dot{\gamma}dx,$$

$$xOz: |P_4| = \int_{\Delta V} \tau\dot{\gamma}dV = \Delta x\Delta z \int_0^{\Delta y} \tau\dot{\gamma}dy,$$

where: τ and $\dot{\gamma}$ are the vector sums of voltages or shear rates acting in the directions parallel to the given plane inside the element, which depend on the integration variable [12].

Let us write the energy balance equation:

$$|P_1| = |P_2| + |P_3| + |P_4|,$$

By means of the rheological law the shear rate $\dot{\gamma}$ can be expressed through stress τ , and thus excluded from the abovementioned integrals. The rheological law can also include temperature. In the case, when the temperature is given only on the borders of the finite elements, internal values can be approximated linearly, considering the boundary values T_1 and T_0 :

$$T = \psi(T_1 - T_0) + T_0,$$

where: ψ - dimensionless coordinate located in the interval $[0; 1]$.

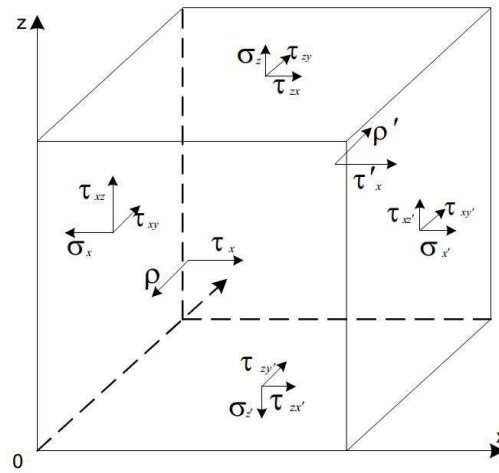


Fig. 3. Model the element of the type 2

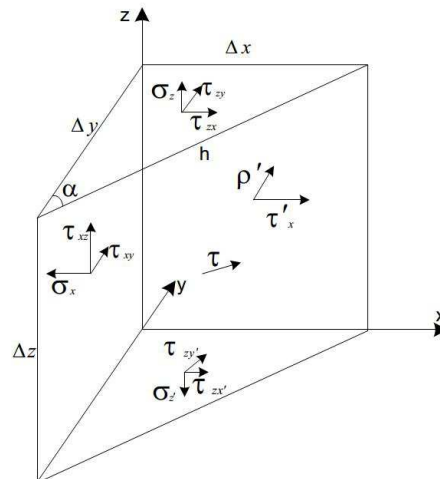


Fig. 4. Model the element of the type 3

Within a small finite element the internal stress distribution τ along the axis can also be

considered approximately linear, that is determined by the boundary values τ_0 and τ_1 :

$$\tau = \psi(\tau_1 - \tau_0) + \tau_0.$$

Turning to the integration through the non-dimensional coordinate, we obtain:

$$\begin{aligned} \int_0^{\Delta x} \dot{\gamma} dx &= \Delta x \int_0^1 \dot{\gamma} d\psi, \\ \int_0^{\Delta y} \dot{\gamma} dy &= \Delta y \int_0^1 \dot{\gamma} d\psi, \\ \int_0^{\Delta z} \dot{\gamma} dz &= \Delta z \int_0^1 \dot{\gamma} d\psi. \end{aligned}$$

These integrals are possible concerning the values on the opposite faces of the element τ_0 and τ_1 , using the rheological law for the recycled material.

Thus, for example, for the rheological equation $\tau = \tau^* + \mu_H \dot{\gamma} \exp(a(T - T_H))$, where τ^* - yield point, μ_H - viscosity at normal temperature T_H , a - coefficient of the temperature sensitivity of the viscosity, the integral is solved like

$$\begin{aligned} \int_0^1 \dot{\gamma} d\psi &= \int_0^1 \tau \frac{\tau - \tau^*}{\mu_H \exp(a(\psi(T_1 - T_0) + T_0 - T_H))} d\psi = \\ &= \int_0^1 \tau \frac{(\psi(\tau_1 - \tau_0) + \tau_0)(\psi(\tau_1 - \tau_0) + \tau_0 - \tau^*)}{\mu_H \exp(a(\psi(T_1 - T_0) + T_0 - T_H))} d\psi = \\ &= \frac{1}{\mu_H} \left(\int_0^1 \psi^2 (\tau_1 - \tau_0)^2 + \psi(\tau_1 - \tau_0) \tau_0 e(\psi) d\psi + \right. \\ &\quad \left. + \int_0^1 (\psi(\tau_1 - \tau_0)(\tau_0 - \tau^*) + \tau_0(\tau_0 - \tau^*)) e(\psi) d\psi \right) = \\ &= \frac{(\tau_1 - \tau_0)^2}{\mu_H} \int_0^1 \psi^2 e(\psi) d\psi + \frac{(\tau_1 - \tau_0)(2\tau_0 - \tau^*)}{\mu_H} \times \\ &\quad \times \int_0^1 \psi e(\psi) d\psi + \frac{\tau_0(\tau_0 - \tau^*)}{\mu_H} \int_0^1 e(\psi) d\psi = \\ &= \frac{(\tau_1 - \tau_0)^2}{\mu_H} \frac{(b^2 - 2b + 2) \exp(b + c) - 2 \exp(c)}{b^3} + \\ &\quad + \frac{(\tau_1 - \tau_0)(2\tau_0 - \tau^*)}{\mu_H} \frac{(b - 1) \exp(b + c) + \exp(c)}{b^2} + \\ &\quad + \frac{\tau_0(\tau_0 - \tau^*)}{\mu_H} \frac{\exp(b + c) - \exp(c)}{b}, \end{aligned}$$

where: for short it is indicated: $e(\psi) = \exp(b\psi + c)$, $b = a(T_0 - T_1)$, $c = T_H - T_0$.

Substituting the possible, concerning τ_0 and τ_1 , integrals into the equation of energy balance, we can obtain the closing given system of equations and calculate the given element.

CONCLUSIONS

Thus, the finite-element approach is put into the basis of the calculation of screw extruders. Its advantage is the versatility of the usage in a wide range of the properties of the recycled material and designs of screw extruders. The further research should be focused on the further detection of typical finite elements and computational schemes for other designs, calculating the shear rate in the recycled material and the development of the appropriate algorithmic support.

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МАТЕМАТИЧЕСКОЕ ОБЕСПЕЧЕНИЕ СИСТЕМЫ АВТОМАТИЗИРОВАННОГО ПРОЕКТИРОВАНИЯ ШНЕКОВЫХ ЭКСТРУДЕРОВ

Валерий Дядичев, Вячеслав Жариков

Аннотация. В работе разъяснена необходимость создания системы автоматизации проектирования шнековых экструдеров. Рассмотрены функции предполагаемой САПР. Представлены математические модели движения перерабатываемого в экструдере. Для расчета напряженного состояния материала применены конечно-элементный анализ и теория теплопроводности. **Ключевые слова.** Экструдер, САПР, конечно-элементный подход, уравнения равновесия.

Prediction trends exterior designs gondola by analyzing arrays infringement

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S u m m a r y . The article describes the analysis of changes in patenting designs gondola car bodies over the past 20 years and their development prospects. It was conducted during the study of the dynamics of patenting designs gondola in leading countries. There is the distribution of patent fund by country patent search and problems of structural components. The article displays the dynamics of patenting in the country.

K e y w o r d s : body, gondola, patent search of the technical solutions.

improvement of basic units and structures in general - the chronological development of the system over time, which must not be based on an analysis of patent information content determines the future development of alternative designs.

INTRODUCTION

Improving of technical level of produced freight cars and their competitiveness on the international market on the basis of new scientific and technological development is an important task of the transport sector of Ukraine.

In accordance with the state program "Ukrainian wagon" which was approved by the Ministry of Infrastructure of Ukraine on February 4th 2011 one of the main objectives was to create models of freight cars of new generation. According to the Cabinet of Ministers of Ukraine dated September 7, 2011 № 942 "On approval of the list of priority thematic areas of research and scientific and technological development for the period up to 2015 and the Law of Ukraine" On Amending the Law of Ukraine "On priority directions of science and technology "dated September 9, 2010 N 2519-VI of the priority directions of science and technology until 2020, which resulted in forecasting the development and

PROBLEM DESCRIPTION AND THE ANALYSIS OF RECENT RESEARCH

The operation of modern gondolas showed the significant design flaws, which entail additional costs for repairs. Gondola is the most easy-to-break type of rolling stock. The line of basic constructions of gondola has more than 20 models, but they all have a certain number of drawbacks. The above is confirmed by the fact that solid support body in some places can receive serious damage in operation, including cracks in the welds pillars pivot in the joints and lower substrate binding and cracks in vertical sheets of intermediate transverse beams in the area of the low link. These damages are caused by significant tensions that arise in operation [2-7,10, 13, 17]. The above proves the relevance of the deployment of research and development work to address scientific and applied tasks - development of new structural solutions and patent searches.

One of the important stages of the research and determine trends, current and future level of performance cars is to analyze patent search. The

patent research regulated by the state standard GOST 3575-97 in Ukraine. It sets out the basic terms and procedures for patent research. The patent research is important for budget institutions or partially financed from the state budget. Mathematical methods of calculation and analysis of the patent fund allow assessment of trends object technology. Using these methods defined areas of structures, including long-term trends and who have exhausted their potential [1, 8-16, 18-21]. The relevance of the chosen research topic is determined by the fact that the prediction of gondola structures can decide in the direction of search and research, upgrades designs of cars in general.

THE PURPOSE OF THE ARTICLE

The article presents an analysis of the dynamics of patenting designs gondola body for the past 20 years and prospects for their development. The analysis conducted in the study of the dynamics of patenting designs gondola in leading countries.

MAIN CONTENT

The patent information is most valuable material for the prediction of construction technical system which is the body gondola because of its specificity, novelty, accuracy, concentration, completeness of information about the technical nature.

Analysis of the entire array of patent information allows us to trace not only the evolution of structures, but also to determine the status for a given period and identify prospects. To identify existing structures of gondola body patent search conducted in the following countries: Germany, U.S., EU, China, Canada, Ukraine and Russia. There was the search of technical information in journals, newsletters, directories listed industrial countries. The depth patent search was defined research objectives: determine trends and identify the most promising developments. Using patent information is based on the fact that the patent application is implemented in 10-12 years in the first sample and another 8 years - in mass production. The analysis revealed that the average time of development in the production of patented technical solutions to improve the gondola is 17-20 years. [15,16].

The distribution of patent search by countries is shown in figure 1

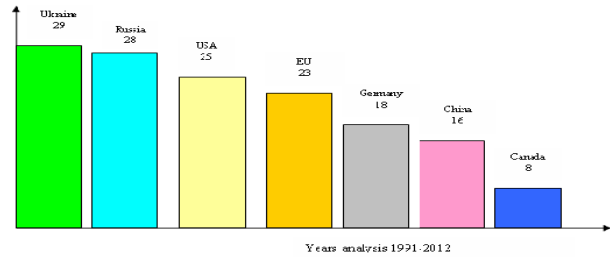


Fig. 1. The distribution of patent fund by country

The distribution of patent search is valuable information but it gives only a generalized notion of patenting by country patent search and more valuable information is the direction of body structures from patents.

The Distribution Patent Foundation on issues of patent search by countries is shown in figure 2

Analyzing the problem areas are the main structural elements to be baskets gondola upgrades are: a wall socket, frame, removable roof sheathing. This dramatically upgraded body gondola through the introduction of various forms of profiling in Russia and Ukraine. Directions for searching of solutions to implement new profiles with ample roof are prevalent in the United States and Chinese. Development of reverse body has evolved in Europe. Covering improvement is engaged by scientists in Canada.

The analysis of the patent was based on the so-called patent numbers that show the distribution of patent documents in time. Generally, the study of the dynamics of patenting is conducted for each selected direction for the region as a whole, separately for each country search. In addition, the dynamics of patenting is determined separately for domestic security document and in general, the "global" data. Determining the quantitative characteristics of the dynamics of the study area can be done by various methods, the most famous of which is to compute the so-called coefficient of dynamic (dynamic curves), the value of which characterizes the intensity of a particular area. Method of calculating dynamic coefficients is rather complicated and time-consuming [18]. The prospect of technical areas revealed by regression analysis selected array of inventions, consistently developing specific technical solution or signs. The criteria adopted by the prospects of the dynamics of patenting rates offered by N.M. Timofeev [20]:

$$N_i = N_0 \cdot e^{t_i}, \quad (1)$$

N_i - The number of applications per year t_i

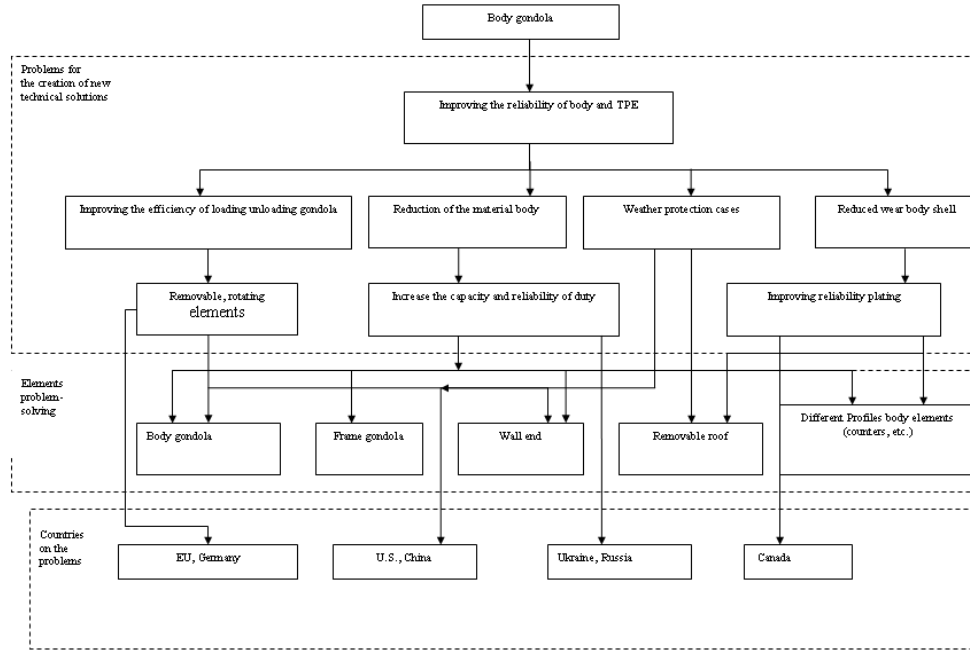


Fig. 2. Distribution of the patent fund issues

N_0 - The number of patents per year at beginning point,

e - base of natural logarithms,

B - coefficient of prospects,

$t_i = \tau_i - \tau_0$ - number of years,

τ_i - current year,

τ_0 - year of origin.

Year of the origin; we obtain a linear relationship, which is solved by the method of least squares(1):

$$\ln N_i = \ln N_0 + B t_i, \quad (2)$$

Let , $\ln N_i = y_i$, $\ln N_0 = a$, , and get , $y_i = a + B t_i$ or

$$y_i = \bar{y} + B(t_i - \bar{t}). \quad (3)$$

Where: $\bar{t} = \frac{\sum_{i=1}^k t_i}{K}$, $\bar{y} = \frac{\sum_{i=1}^k y_i}{K}$ k -number of points on axis « t »

Prospect coefficient B is given by formula:

$$B = \frac{\sum_{i=1}^k (y_i - \bar{y})(t_i - \bar{t})}{\sum_{i=1}^k (t_i - \bar{t})^2} \quad (4)$$

For the mode of assessment of the reliability of the regression slope coefficient in having random variation, was conducted in relation to the value of this quantity standard deviation of the experimental points (S_b). Thus test the significance of the slope coefficient (per Student) was determined from the equation

$$t_{\alpha} = \frac{B}{S_b}, \quad (5)$$

where:

$$S_b = \sqrt{\frac{S^2}{\sum_{i=1}^k (t_i - \bar{t})^2}} \quad \text{standard deviation for the prospect coefficient:}$$

deviation for the prospect coefficient:

$$S = \sqrt{\frac{\sum_{i=1}^k (\bar{y} - y_i)^2}{K - 2}} \quad \text{standard deviation for the regression line.}$$

deviation for the regression line.

For existing tables so-called Student's distribution $\frac{B}{S_b}$ for the ratio and the number of degrees of freedom defined width of the confidence interval. Were selected for analysis only those values in, for which bilateral confidence probability was at least 90%.

Figure 3 graphs the regression dynamics patenting gondola body on the countries and technical areas of the body structures.

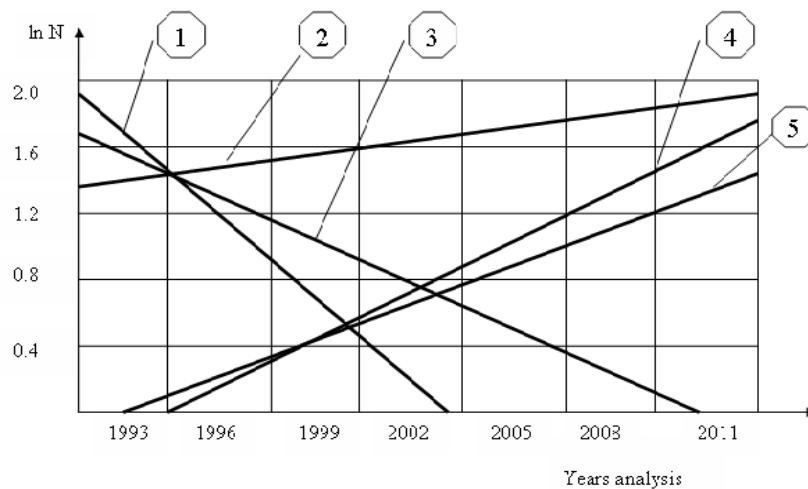


Fig. 3. The dynamics of patenting body gondola Country Patent Search

1. Canada ($b=-0,181, S_b=0,087, =2,08$)
2. US and Germany ($b=0,032, S_b=0,031, =1,03$)
3. the USA and China ($b=-0,142, S_b=0,072, =1,92$)
4. Ukraine ($b=0,315, S_b=0,12, =2,625$)
5. Russia ($b=0,304, S_b=0,15, =2,03$)

The analysis of patenting trends in technical development and improvement of gondola body should be complemented by statistical studies. The most significant inventions in each direction patented in many countries. This so-called "patent-analogues", they are sometimes 60% of the total amount of patents. The practical value of such inventions confirmed production experience in priority countries.

Therefore latitude extent of patenting and patent solutions also allow for a comparative assessment of the prospects of individual inventions and various technical areas.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE USE

The greatest test of significance patents gondola body prevails in countries such as Ukraine and Russia.

The results of the research allow identifying the main directions for the development work of modernization of gondola body.

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ПРОГНОЗИРОВАНИЕ ТЕНДЕНЦИЙ РАЗВИТИЯ КОНСТРУКЦИЙ КУЗОВА ПОЛУВАГОНОВ НА ОСНОВЕ АНАЛИЗА МАССИВОВ ПАТЕНТОВ

Алексей Фомин, Алексей Бурлуцкий

Аннотация: В статье представлены анализ динамики патентования конструкций кузовов полувагонов за последние 20 лет и перспективы их развития. Анализ проведен при исследовании динамики патентования конструкций полувагонов по ведущим странам. Определены распределение патентного фонда по странам патентного поиска и проблематика конструктивных составляющих. Приведена динамика патентования по странам.
Ключевые слова: кузов, полувагон, патентный поиск технических решений.

Using the aerosol of $\text{SiO}_2/\text{ZrO}_2$ catalyst nanoparticles to obtain gasoline and diesel from vacuum gasoil

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Summary. It has been examined the use of aerosol nanocatalysis technology for implementing new high catalytic cracking process to produce gasoline and diesel fuel from a vacuum gas oil. the temperature in the new process is at 250 °C lower than in industrial cracking processes, and the amount of catalyst is reduced to a concentration of 2.38 g/m³ reactor. The $\text{SiO}_2/\text{ZrO}_2$ -catalyst at conditions of the new technology displayed higher than 99 % of selectivity of light products formation.

Key words: gasoline, diesel, aerosol nanocatalysis

INTRODUCTION

Catalytic cracking currently is the most important and large-tonnaged process among other oil refining processes.

The overall productive capacity of catalytic cracking units in USA is higher than 250 million tons/year of the raw materials. This process has gained a very wide development in the countries of Western Europe. The total capacity of catalytic cracking units has reached 35% in U.S. (13.9% in Western Europe, and 6.0% in Russia) of the capacity of primary oil refining [5,12,18].

In the 60s of the past century, it was discovered the high activity of zeolites in cracking reactions. In this regard, in cracking process they started to use catalysts with Y- zeolite content ($\text{Me}_{2/n} \text{O} \cdot \text{Al}_2\text{O}_3 \cdot x\text{SiO}_2 \cdot y\text{H}_2\text{O}$) not more than 20% wt, which resulted in a significant growth of the yield of desired products of the process, especially at the transition to the cracking of heavy feedstocks.

In order to utilize from all advantages of zeolite catalyst, they began to use new types of

reactor-regenerator devices: at first was the fluidized bed reactor, and then the lift-reactor. Thus, the process of catalytic cracking became the fastest growing in the oil refining. Gasoline and diesel fuel in the rural economy needs [4, 17].

At present, the work is continuing to intensify the process of catalytic cracking based on the modernization of the reactor and regenerator of catalytic cracking units, simplifying the construction of reactor-regenerator block, creating the most effective ways of contacting the catalyst with the raw materials and preparation of raw materials in order to increase the yield of desired products and improve their quality [22]. But at the same time from the intensifications of existing technologies topically remains the task of creating new ways of carrying out a catalytic cracking process with increased technical and economic indicators.

In the Technological Institute of East-Ukrainian National University, Volodymyr Dahl (Severodonetsk) at the Department of Technology of organic substances, fuels, and polymers are conducted perspective researches on the study of cracking of vacuum gasoil by using the aerosolized nanocatalysis (AnC). The essence of aerosolized nanocatalysis technology is to apply a continuous mechano-chemical activation of the catalyst directly in the reaction volume, resulting in decreasing the required amount of catalyst to 1 - 2 g/m³ reactor and increasing the catalyst activity up to 10⁵ - 10⁶ times.

Researches of properties of different catalysts were already conducted (Nexus-345p, Y-

zeolite, Si/Zr-catalyst) at conditions of AnC, they showed the possibility of increasing the yield of light products in the 1.14 times, reducing the volume of reactor up to 10 times and the volume of regenerator to 1500 times in comparison with the existing technologies [10].

This work is a logical continuation of research in this field, and its main purpose is to study the kinetic characteristics of a new modification of Si/Zr-catalyst at conditions of aerosolized nanocatalysis with the subsequent creating of the basics of technology of catalytic cracking with increased technical and economic indicators.

ANALYSIS OF PUBLICATION, MATERIALS, METHODS

The disadvantages of the industrial organization of catalytic cracking process, which greatly increase the capital and operating costs include [7, 16]:

1. In order to obtain a productive capacity of 2 million tones/year of raw material (unit G-43-107/M1), the volume of reactor (zone of separation and reaction volume) is 800 m^3 , the volume of regenerator - 1600 m^3 ;
2. The need of constant regeneration of catalyst after the 1 - 2 seconds of work, which leads to additional losses of the catalyst due to its abrasion. In the industry this requires an additional makeup of catalyst in an amount of 0.545 kg per ton of raw material, which is 3 tons of additional catalyst in 24 hours, with a minimum price of catalyst ≈ 25 thousands U.S.\$/ton;
3. The relatively high concentration of catalyst (up to 700 kg/m^3 reactor);
4. The relatively low specific productivity of reactor and catalyst ($205.3 \text{ kg}/(\text{m}^3_{\text{reactor}} \cdot \text{hr})$ and $0.444 \text{ kg}/(\text{kg}_{\text{kat}} \cdot \text{h})$).
5. Necessity of steam injection into the reaction zone for stripping the cracking products from the catalyst surface in an amount of 0.5 - 0.75 GJ/ton raw material;
6. The Relatively big single charge of catalyst in the reactor (350 tons).

At the end of the twentieth century, a new trend in the technology of implementing gas-phased chemical processes has been formulated by Ukrainian scientists - aerosol nanocatalysis (AnC - Aerosol nanoCatalysis) [6]. Its distinctive features:

- catalytic system consists of moving dispersing material at a size of 1 - 2 mm, and a powder of catalyst with initial size till 200 microns;

- the internal diffusion stages are excluded from the catalytic process;

- synthesis (in situ) of superactive nanoparticles of catalyst at a size of 8-100 nm;

- avoiding the use of carrier (catalyst and dispersing material in the reaction space are not integrated in a homogeneous system);

- implementing (in situ) of a continuous mechano-chemical activation on the surface of catalyst by moving solid material;

- equal access of reactants on the active surface.

It was experimentally shown and theoretically proved that the reaction speed rises at about 10^4 - 10^6 times in comparison with traditional catalysis on carriers. This can be explained by the characteristic properties of the nanoparticles surface, which can be remained for 15-30 seconds [1, 11]. Content of catalyst in the reaction zone is reduced to $1\text{-}5 \text{ g/m}^3$ of the reaction volume [15]. (under the classical catalysis on carriers of catalyst mass, the catalyst concentration is $0.7\text{-}0.8 \text{ ton/m}^3$ and more, including catalytically active material on basis of noble metals - up to 10 kg or 200 - 1000 kg of other substances).

In reactors of aerosol nanocatalysis, the catalytically active material undergoes a continuous mechano-chemical activation (in situ) by means of forced mechanical oscillations of an inert dispersing material - (glass spheres with diameter of 1.0 - 1.2 mm). A continuous grinding of the coagulated particles of catalyst is applying and converting the particles to nano-sizes (10^{-8} - 10^{-9} m) and maintaining their high activity for unlimited time [20].

Thus the vibro- fluidized bed reactor allows to regulate the frequency of pulses of mechano-chemical activation of particles surface. The surface of nanoparticles is full of free valence bonds, electrons, and structural defects [21]. These factors determine the effectiveness of AnC.

Currently, there are two technologies of research and possible equipment design of the aerosol nanocatalysis in the industry. The first suggested technology is with fluidized bed (ACFB- Aerosol Catalysis with Fluidized Bed) of inert particles with approaching to ideal displacement by regime of movement of reagents and catalyst aerosol. At present, the technology was fulfilled on a number of large experimental units (reactors with diameter of 150 - 250 mm and a height of up

to 3 m) with a recycle of catalyst, when developing ACFB it must be considered the resistance of layer of inert particles. The possible time of contact was limited by the speeds range of beginning the fluidizing and carrying over the solid phase, which constricts the technology possibilities.

Recently a relatively new proposed technology of AnC (AnCVB - Aerosol nanoCatalysis with Vibrating Bed) with vibro-fluidized bed of catalytic system. The mechanical activation of the catalyst is applied by forced vibration of reactor. Regime of motion of reactants in the reactor is approaching to the ideal mixing. It is possible to organize the regime to be closer to the displacement. The technology is free from the characteristic disadvantages of ACFB :

The layer has a very low resistance and can be operated at any speeds of the gas stream. Furthermore, for some processes the recirculation of catalyst can be excluded. The catalyst is constantly undergoing to mechano-chemical activation and displaying a catalytic activity in 10 - 100 times higher than in the option ACFB, i.e. 10^5 – 10^6 times higher than the achieved activity in the catalysis on carriers [9]. However, the organization is required vibrating layer with certain parameters. Working with literature and our own experience have shown significant benefits of using vibrated reactor AnC, especially for kinetic studies [19]. In principle, in a new and extremely effective it was showed that it is possible by changing the frequency and amplitude of vibration to control by the regime of mechano-chemical activation and optimize the conditions for each individual taken reaction. Managing of vibration allows to apply in principle a new organization of chemical reactions and extends the possibility of controlling by process. Furthermore, the regime of mechanical activation changes the catalyst activity AnC.

Set of specific properties AnCVB [16] allows to anticipate in advance the improving of indicators of the existing production and to increase the effectiveness of the catalytic cracking (CC) of oilproducts.

1. Increasing the reaction speed and corresponding reduction of the residence time of raw material in the reaction zone due to the exclusion of internal diffusion stages of the process at aerosol nanocatalysis technology.

2. Using metal oxides as cracking catalysts in amounts of 0.3 - 10 g/m³ reactor instead of large volumes of existing industrial catalysts on carriers with additives of noble metals. This will reduce the capital and operating costs and decrease product cost.

3. In pyrolysis process, using these catalysts will lower the process temperature and reduce energy costs.

4. Technology of aerosol nanocatalysis will constantly maintain a high activity of catalyst. The produced coke will not be fixed on the active surface of the catalyst particles since the nanoparticles do not have pores and they subject to continuous mechano-chemical activation; consequently, will be possible to exclude (or substantially reduce) the steam flow into the reaction zone since the suppression of coke formation reactions will not be required.

5. Technology of aerosol nanocatalysis on vibrating bed has no restrictions on the residence time of material in the reaction zone, that will allow to approach the products output, which is closer to the thermodynamically possible.

Technology AnC will allow to principally change the flow chart of cracking processes, work with a small mass of catalyst and catalyst makeup will be no more than 5% or without catalyst makeup. Apparently, it is possible to exclude stages of regeneration and recirculation of catalyst from the technical scheme of the process. it only needs to arrange a separation of catalyst particles and coke from the reaction products, coke oxidation and supplying the thermal energy to cracking zone. In the industry, these solutions are realized, it is reasonable for AnC [8]. All this will lead to reduce capital and operating expenditures during processing of oilproducts.

The industrial catalyst Nexus - 345p (Grey Davidson, England) was the first catalyst, which was studied for the catalytic cracking process in the conditions of AnCVB. The results obtained from him exceeded the industrial indicators, as follows, [2, 3, 13, 14]:

1. to increase the total yield of the gasoline and diesel fractions in 1.14 times;

2. reduce the reactor dimensions (volume) up to 420 m³;

3. reduce the total loaded charge of catalyst from 350 ton to 70 kg;

4. the catalyst concentration became only 1 g/m³ of the reactor (less than in the industry);

5. owing to the small amount of the used catalyst, it is possible to avoid the regeneration stage or make it periodical;

6. the specific productivity of reactor and catalyst increased to (1184 kg / (m³_{reactor} .h) and 394548 kg / (kg_{kat} . h)) respectively;

7. avoiding use of steam, since there are no pores on the catalyst at conditions of AnCVB ;

therefore the reaction products will not clog them [10].

For this catalyst the temperature of process was 570-640°C at conditions of AnCVB.

PURPOSE AND DIRECTION OF RESEARCH TASKS

Purpose - evaluating effectiveness of creating the necessary conditions for process of catalytic cracking of vacuum gasoil using technology AnCVB.

Tasks of the experimental part of study:

- learning the procedure of conducting the experiment;
- modernize the laboratory unit with a set of the placed experimental tasks;
- learning the procedure of obtaining the initial raw material;
- learning the procedure of analytical control;
- learning the procedure of preparing the catalyst;
- obtaining preliminary results of studies;
- determining the optimal parameters of conducting the process and studying their influence;
- evaluate the perspective of continuing the work in this direction.

THE EXPERIMENTAL PART AND RESULTS DISCUSSION

Process of catalytic cracking at conditions of AnCVB was conducted on laboratory unit shown on fig 1. [13, 20].

The heated vacuum gas by a syringe batcher (1) is fed into the reactor (5) which is located inside a thermal locker (2), and heated by heater (13). In the reactor, the cracking reactions take place. The temperature in the reaction zone is measured by thermocouple (11) and supported by a regulator (12). Metal-clothed filter is provided in order that the catalyst will not be carried away from the reaction zone along with the cracking products (6). The products after the reactor pass through water-cooled condenser and enter into the receiver of liquid fraction (8), the uncondensed gases of cracking pass a point of samples selection (9), and enter into gas washer (10), where the gases are bubbled through the water layer and then enter into the receiver of gaseous phase (15) by passing through water vessel (14). The reactor performs reflexive and translational motions with assistance

of vibrating device (4), frequency of oscillation is provided by regulator (12).

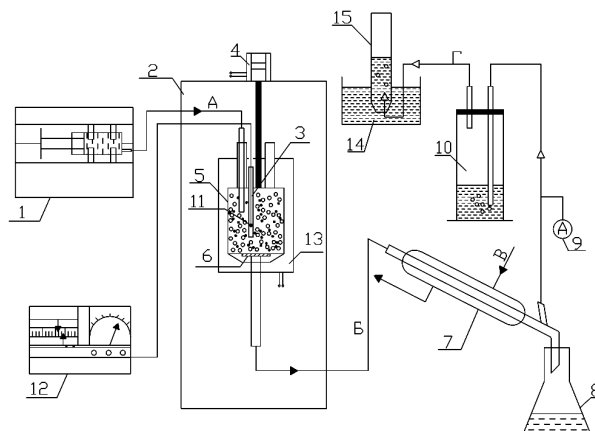


Fig. 1. Laboratory unit for studying process of cracking of vacuum gasoil at technology of aerosol nanocatalysis

1 – syringe batcher; 2 – thermal locker; 3 – pocket for thermocouple; 4 – vibrating device; 5 – reactor; 6 – metal-clothed filter; 7 – water-cooled condenser; 8 – receiver of liquid fraction; 9 – point of gathering samples for analysis; 10 – gas washer; 11 – thermocouple; 12 – regulator for oscillation frequency and temperature; 13 – heater; 14 – vessel with water; 15 – collector of gaseous phase

Experiments were conducted at temperatures 300°C, 350°C, 400°C, 450°C, 500°C, 550°C, and at frequency MCA 4 - 7 Hz.

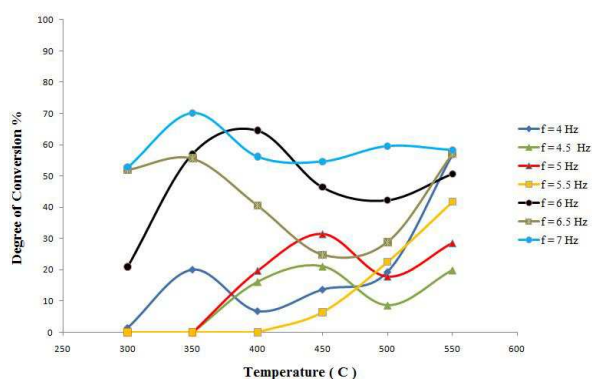


Fig. 2. Graphic of degree of conversion (% weight) vs. temperature (°C)

The maximal degree of conversion (more than 70% weight) for the studied interval of parameters was observed at 350°C and frequency MCA 7 Hz (fig.2). With further growing of temperature, the degree of conversion decreases in a little. At frequency of 6 Hz, the maximal conversion of gasoil (more than 64%) was observed at 400°C. It may be noted that the maximal values of degree of conversion based on temperature are observed almost for all the studied range of activation frequency. Perhaps, this is due to the fact that at low temperatures there is

intensive MCA on the catalyst surface, which then becomes less intensive because of the thermal softening of catalyst.

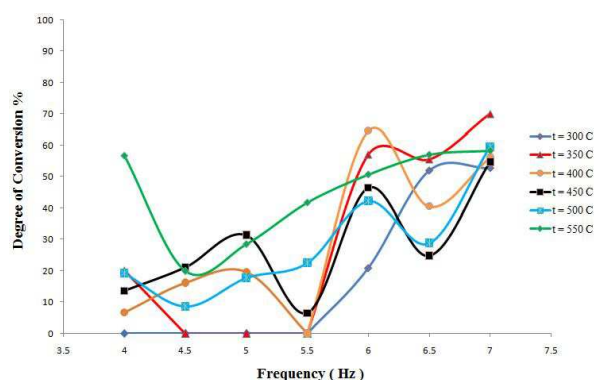


Fig. 3. Graphic degree of conversion (% weight) vs. frequency of vibration (Hz)

At frequency range MCA of 4 - 5.5 Hz and temperature 300-350°C, degree of conversion was 0%, with a gradual increase of frequency to 6 Hz, the degree of conversion increased to 64.6% at 400°C and then to 70% at 7 Hz and a temperature of 350°C (fig. 3). It is obvious that the catalyst has become more active by increasing the frequency of MCA, even at low temperatures.

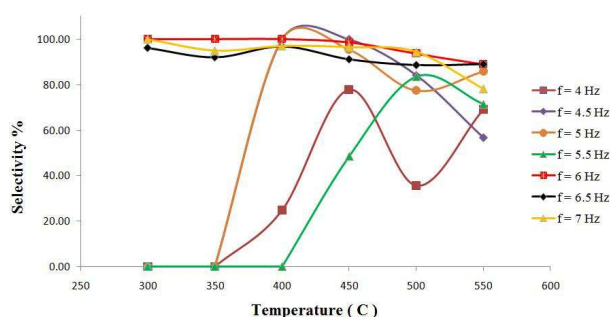


Fig. 4. Graphic selectivity (% weight) vs. temperature (°C)

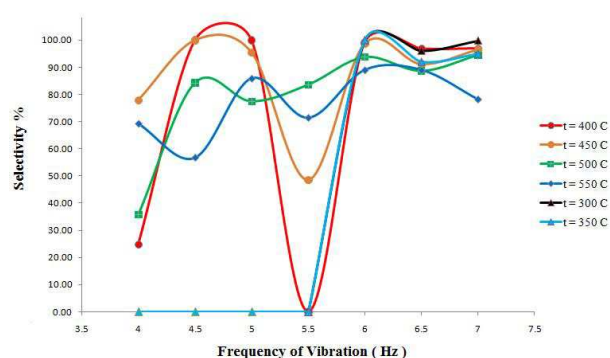


Fig. 5. Graphic selectivity (% weight) vs. frequency of vibration (Hz)

The selectivity (the amount of the produced gasoline and diesel fuel, divided by the amount of reacted gasoil) of light oilproducts was maximal at studied range of temperatures 300°C, 350°C, 400°C, 450°C, 500°C, 550°C and at a frequency MCA of 6 Hz. At 350°C and a frequency of 6 (fig. 4) selectivity reached 99.99 %.

At range of frequency 4-5.5 Hz and a temperature 300 - 350°C, the selectivity was 0%, at a frequency 4 Hz, the selectivity reached 77.88% at 450°C, at a frequency of 4.5 and 5 Hz, the selectivity was at a range 95 - 99.95% at 400 - 450°C, respectively (fig. 5). At 5 Hz the selectivity decreased from 71% at 550°C to 48% at 450°C, at a frequency range 6 - 7 Hz the selectivity was at a range 78 - 99.99% where at 6 Hz and 350°C was the higher value of selectivity.

Comparison of industrial process of catalytic cracking and AnCVB is shown in table. As seen from the table by using Si/Zr catalyst, reactor volume is reduced by 15 times in comparison with the heterogeneous catalysis and at 2.66 times in comparison with catalytic cracking at conditions of AnCVB on catalyst Nexus-345p and at 1.94 times in comparison with AnCVB on catalyst CaA zeolite.

Also on Si/Zr catalyst it was able to practically lower the process temperature, in comparison with the industrial indicators and at conditions of AnCVB on the catalysts: CaA zeolite and Nexus-345p.

Another important indicator is the high selectivity of process at conditions of AnCVB on Si/Zr catalyst of 98.7%wt, however due to the relatively low degree of conversion per one pass (67%wt) in the industrial conditions it requires a partial recirculation of raw material.

It should be noted that our studies (Si/Zr-catalyst, sample No:2) demonstrated improving the technological characteristics of cracking process in comparison with sample No:1. Despite a slight increase in temperature (the recommended value for the sample No: 2 is 350°C), the new modification allows to conduct the process with a conversion degree of 76.4 (at sample No:1 the value of X was 67%) with preservation of selectivity higher than 99.5%). This will allow in the industrial conditions to carry out the process of catalytic cracking at aerosol nanocatalysis on a new modification of catalyst without using the recirculation stage of the raw material.

Table. The comparison of industrial process of catalytic cracking and AnCVB technology

Parameter	Technology					
	Industry	AnCVB				
Productivity ton/day	6300	6300				
1. Temperature, °C						
In reactor	640 - 525	550	300	600	630	350
In regenerator	640	not needed				
2. Catalyst	Nexus-345p	Y-Zeolite	Si/Zr No:1	CaA	Nexus-345p	Si/Zr No:2
Concentration of catalyst in reactor, kg/m^3	300-700	$3 \cdot 10^{-3}$	$3 \cdot 10^{-3}$	$2 \cdot 10^{-3}$	$2 \cdot 10^{-3}$	$3 \cdot 10^{-3}$
3. Constant of cracking speed, s^{-1}	-	0,002	0,18	0,17	4,41	0,2
4. Selectivity of light products, % wt :	74,9	93,7	98,7	84,5	85,2	99,9
5. Degree of conversion, % wt :	with recycle	for one pass				
	85	15,7	67	95	89,1	76,4
6. Volume of reactor, m^3	800			306	420	158
regenerator, m^3	1600	Does not exist				

CONCLUSIONS

1. It was shown the possibility of obtaining light oilproducts using the technology AnCVB on a new modification of Si/Zr catalyst .

2. The perspective regime for designing an industrial unit working on Si/Zr catalyst, is a temperature 350°C, and a frequency of MCA 7 Hz at amplitude of MCA 12-14 mm, since in these conditions could reach the maximal degree of conversion of raw materials - 80%, and maintain a high output of light oilproducts - 76%wt.;

3. The organization of the catalytic cracking at technology of AnCVB on Si/Zr catalyst is promising at a number of parameters:

- It was shown that the process of catalytic cracking at conditions of AnCVB on Si/Zr, can be carried out at 300°C;

- The achieved selectivity of light oilproducts was more than 98%, due to the fact, that the gaseous phase is practically did not formed;

4. It was shown that applying of MCA at cracking process can intensify the speed of chemical reactions. So by using Si/Zr catalyst, it was possible to increase the degree of conversion of vacuum gasoil from 0 to 66.2% by increasing the vibration from 4 to 5.5 Hz at 300°C .

5. For gasoline fraction obtained on Si/Zr catalyst, the given indicators of octane numbers by research and motor methods were compliant with the standards of catalytic cracking gasoline.

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ПРИМЕНЕНИЕ АЭРОЗОЛЯ НАНОЧАСТИЧЕК
SiO₂/ZrO₂-КАТАЛИЗАТОРА ДЛЯ ПОЛУЧЕНИЯ
БЕНЗИНА И ДИЗЕЛЬНОГО ТОПЛИВА ИЗ
ВАКУУМНОГО ГАЗОЙЛЯ

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Аннотация: Рассмотрено применение технологии аэрозольного нанокатализа для осуществления нового высокоэффективного процесса каталитического крекинга с получением бензина и дизельного топлива из вакуумного газойля. Температура в новом процессе ниже на 250⁰С, чем в промышленных процессах крекинга, а количество катализатора снижается до концентрации 2,38 г/м³ реактора. SiO₂/ZrO₂-катализатор в условиях новой технологии показал селективность образования светлых продуктов свыше 99%.

Ключевые слова: крекинг, бензин, дизельное топливо, аэрозольный нанокатализ.

Analysis of the constructive features of railway brakes and methods of improving the process of their functioning

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Summary. The article provides the analysis of current situation in railway brake systems and provides new constructive solutions that optimize the use of disc brakes in the traction mode thereby increasing the effective power of the traction vehicle, increase the coefficient of friction for shoe brakes, stabilize the temperature in the tribocontact, reduce the wear of the friction nodes and improve safety.

Key words. Disc brake, shoe brake, shape memory alloy, porophore, pressed air.

INTRODUCTION

Due to the continuous rise of train speeds high requirements are placed to the brake systems. Application of the well-known shoe brake construction that provides interaction between the brake shoe and the surface of the wheels is limited by their allowed heat. The use of disc brakes becomes more common because the required braking power is not achieved with shoe brakes.

In operation, the rolling surface and ridges of wheels that contact with the rails and in case of braking shoe - with pads on the brake axle. Consequently, both the friction pairs mutually affect the process of wheel and rail wear, the formation of the contact zone between them and the arising contact stress level, and therefore the adhesion force, determining the magnitude of traction and braking forces of the rolling stock.

To improve braking efficiency of rail vehicles it is necessary to create adequate braking power for braking devices and provide a stable friction of the wheels and rails. The authors

propose new technical solutions that reduce resistance to movement of the vehicle, as well as improving the operational efficiency of frictional brake elements of the rolling stock.

BACKGROUND RESEARCH ANALYSIS

The efficiency of the frictional elements of the brake system of the rolling stock considerably influences traffic safety, the ability to increase the speed and increase of the capacity of the rail lines.

During braking the kinetic energy of the train is converted into other forms of energy, most of which - in the heat. This process is accompanied by a temperature increase of friction elements. Effective deceleration of the train depends on the friction coefficient, which is affected by the temperature changes in tribocontact. Another urgent issue in the operation of rolling stock is to stabilize the temperatures in the zone of interaction of the brake pad and wheel [1, 2, 5, 8, 19, 20].

All the energy that is produced by the traction vehicle is spent on overcoming the resistance forces and the forces of inertia. Annually for train traction a large amount of fuel and electricity is spent, the cost of which significantly affect the the cost of transportation [6-18, 21, 22]. Therefore, resistance reduction is as important as increasing the efficiency of the traction vehicle. Reducing the resistance can increase the weight of the rolling stock or the speed for the same locomotive, reduce wear and repair costs. The

problem of reducing resistance of movement is directly related to the need to optimize the aerodynamic of rolling stock [4].

OBJECTIVES AND PROBLEMS

The aim of the article is to develop recommendations and constructive solutions to improve the efficiency of operation of brake frictional elements of the rolling stock, as well as to reduce the resistance to movement of the vehicle by providing a construction of disc brakes with additional elements that allow you to remove the circulation of air in the air ducts on the move.

METHODS AND TECHNICAL SOLUTIONS FOR IMPROVING THE PROCESS OF FUNCTIONING OF THE RAILWAY BRAKES

At high speeds of the vehicle disc brake ventilation vanes creates additional resistance to movement which leads to a certain expense of locomotive power, especially for high-speed locomotives, for which the expense of significant speeds resistance increases. Thus is pumped through the ventilation channels 3000 - 4000 m³/h of air which cools the disc. This leads to expenditure of a certain power. For example, according to research by Turkov A. [18], for diesel trains of DR-type and electric trains of ER-type in which installed set of eight brake discs at a speed of 200 km/h will spend more than 19.1 kW and 48 kW respectively on the self-venting. For diesel train DR1 total capacity is reduced by 2.6%. Research conducted by the authors, the results of which are presented in Table 1 show that for modern high-speed trains, this amount increases by several times.

The proposed method for reducing the aerodynamic resistance of vehicles is implemented as follows.

To eliminate the self-ventilation of disc brakes, which causes a negative resistance to the movement of the train in the mode of the traction and freewheel, it is proposed to close ventilation holes of disc brakes.

During the motion the plates 4 of shape memory material (fig. 2) [3, 4] which are located on each blade 3 venting, ventilation ducts 5 overlap. During braking, rolling stock brake pads are pressed with a certain force to the friction rings 1 (fig. 1) of the brake disc. The result is a braking torque, which is through the friction ring 1 and connected with them with the circlet 3.

Table 1. Power expended by train in motion to overcome the resistance of the working disk brakes

Train	Power of the train, kW	Speed, km/h (m/s)	Ventilation power of brake disc, W	The total ventilation power of the train brake discs, kW
"Aurora" train (Russia)	609 2	200 (56)	2060	247
TVG (France)	225 00	574,8 (159)	31065	1988
Sapsan (Germany, Russia)	800 0	250 (69,4)	3599	432
Diesel train ADELANTE (ALSTOM)	280 0	200 (56)	2060	99
DR1 (Riga)	736	120 (33,3)	521	19
Fahrgestell Velaro CRH3	550	300 (83)	5731	733

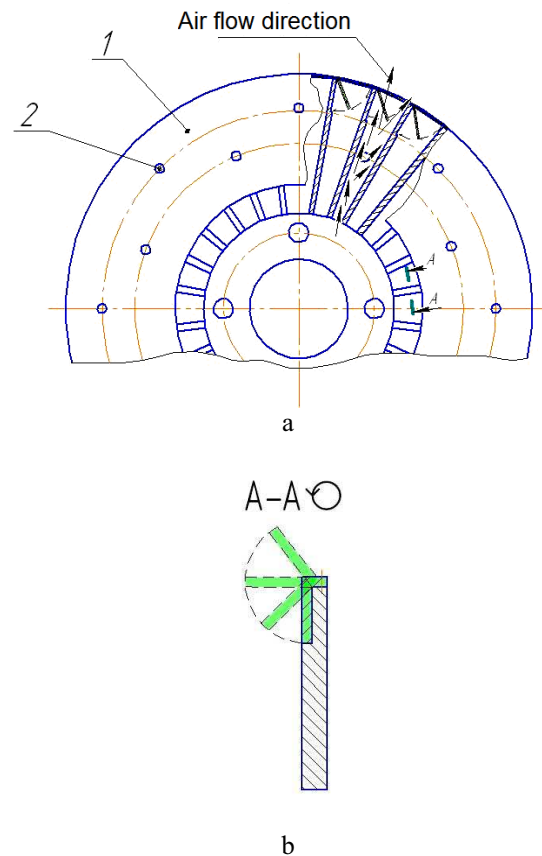


Fig. 1. a – the circulation of air in the brake disc, the plate at the outlet, b – a plate of shape memory material at the inlet

During braking the brake disc temperature increases. Under the influence of high temperature, the material of plate 4 moves from the martensitic state to austenitic (fig. 3). This changes the crystal lattice and shape of plate 4. Angle of inclination α of plate 4 to the ventilation blade 3 reduces from 90° to 0° - 5 ventilation ducts open. Under the influence of centrifugal forces the air that is in air ducts 5 moves from the brake disk to the periphery in the radial direction, this produces the ventilation air flow that provide the removal of heat from the disk. The plates may be arranged as at the inlet of brake disc (fig. 1 b, section A-A) as at the outlet (fig. 1 a).

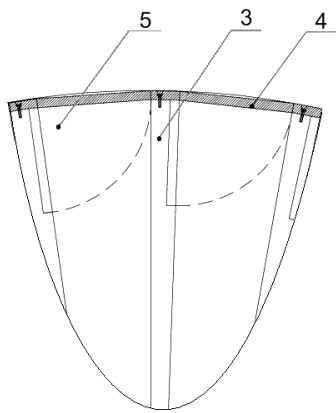


Fig. 2. The constructive scheme of the brake disc

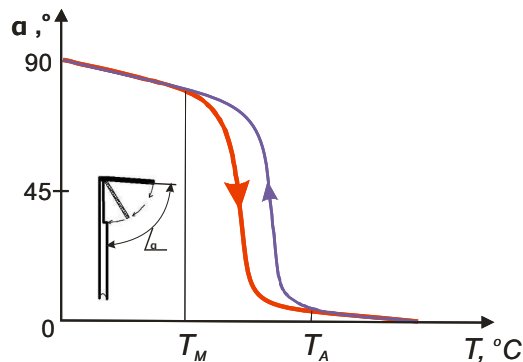


Fig. 3. The dependence of the angle of rotation of the plate relative to the ventilation blade on the temperature of brake disc

When the brake disc is cooled the reverse process occurs - the material of plate 4 changes from austenitic to martensitic state. When reaching by plate 4 temperature of martensitic state - it is unbent, occupying the initial position ($\alpha = 90^\circ$) - ventilation ducts 5 close (fig. 2, 3), due to this further loss of power because of the circulation of

air in the ventilation ducts of brake disc while moving decreases.

Thus, during movement ventilation ducts are closed, during braking - they are open. When reaching the ambient temperature of the plate brake disc returns to the initial position. In this case ventilation ducts close to the next braking.

Let us consider the question of temperature stabilization of frictional contact "brake shoes - the wheel." The existing method of increasing the efficiency and durability of brake pads using the section pad when braking that provides increased contact area of the interacting element and the pressure drop in the contact area, can not sufficiently ensure the effectiveness of braking. This is due to the fact that when braking tribological pair contact is heated and the method of cooling is not provided, thereby decreasing the friction pad possibility and increased wear of the friction pair happens.

Thus, there is the problem of increasing braking efficiency of and reduce brake pad wear.

The assigned task is achieved in that when braking to the contact zone of the friction pair a gaseous active environment is injected formed by reacting brake shoe elements which are provided with porophore and wheel of rolling stock. That is, the design of the brake pad is provided with holes, which have insertions of gas-forming materials - porophore to form between the interacting surfaces of the wheel and the braking pad the gas environment that can cool the contact and reduce wear of the working surfaces (fig. 4).

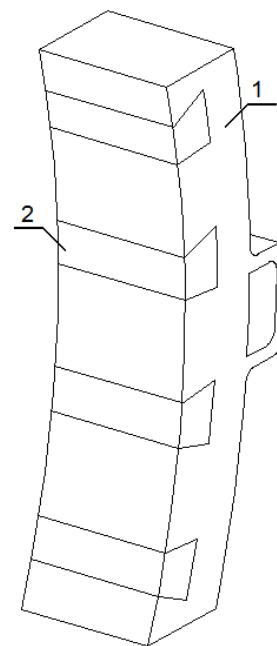


Fig. 4. Brake pad with inserts made of porophore: 1 - braking pad; 2 - porophore inserts

This solution allows to:

1. reduce the temperature in tribocontact;
2. increase the longevity of the brake pads;
3. increase the coefficient of friction of the interacting working surfaces providing braking efficiency of the vehicle;
4. improve traffic safety.

The proposed method of increasing the efficiency and durability of brake pad works as follows.

During braking rolling stock pads are pressed to wheels or brake disc. The temperature in the friction pair increases. Under the influence of the temperature in the shoe the process of thermal decomposition of porophore pad element begins, which leads to high speed release of significant amounts of gas products. One of the major decomposition products is a gas - nitrogen which reacts with thin surface layers of frictional units. This positively affects the frictional properties of the pair of friction - coefficient of friction increases sharply strengthens and stabilizes the material surface, thereby increasing their durability and wear resistance. Braking efficiency allows to increase safety of the vehicle.

The authors are also tasked with improving the efficiency of the locomotive braking method and constructing equipment for its implementation through the efficient use of compressed air, which is discharged from the brake cylinder and cooling brake pads and working surface of the wheel, placing the products of frictional wear out of the contact "brake shoes - the wheel" (fig. 5).

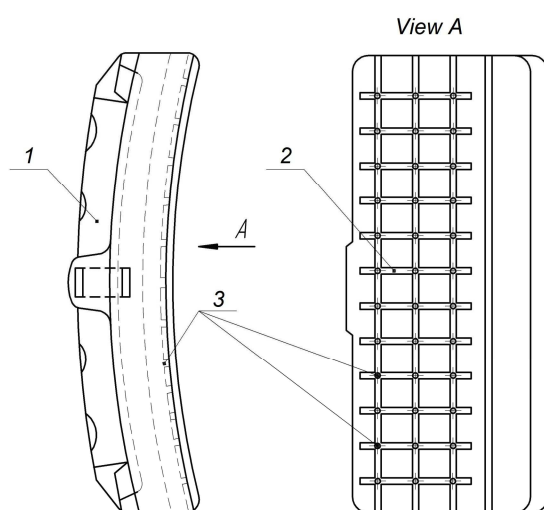


Fig. 5. Brake pad with holes for cooling: 1 – braking pad 2 – channels, 3 – holes

For this purpose compressed air is discharged from the brake cylinder through the air

distributor and a check valve in the bellows assembly, and on the next braking adjustable valve is activated connecting a brake shoe with bellows seal through which accumulated air on the rubber conduit through the holes made in the brake shoe and supplied to the channels to the contact zone "brake shoes - wheel", cools it and blows wear products into the environment.

CONCLUSIONS

Application of the proposed construction of brake disc will reduce the resistance to movement of the vehicle, optimizing the use of disc brakes in the traction mode thereby increasing the effective power of the traction vehicle to reduce the costs of energy and fuel.

The proposed method of increasing the efficiency and durability of the brake pad using the inserts of porophore will increase the coefficient of friction, stabilize the temperature in the tribocontact and reduce the wear of the friction nodes and improve safety.

The use of of the method of the locomotive braking with compressed air and equipping for its implementation will allow the following:

- Efficient use of compressed air, which is discharged from the brake cylinders;
- Cooling the contact zone "brake shoes - wheel" by supplying compressed air to the brake pad holes;
- To improve braking efficiency and reduce the intensity of the brake wear through the timely removal of products of frictional wear of the contact zone of the brake pads and the wheel roll surface and improve the temperature conditions of operation of the braking pads;
- Improve traffic safety by increasing the reliability of the braking.

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АНАЛИЗ КОНСТРУКТИВНЫХ ОСОБЕННОСТЕЙ ЖЕЛЕЗНОДОРОЖНОГО ТОРМОЗА И МЕТОДЫ СОВЕРШЕНСТВОВАНИЯ ПРОЦЕССА ЕГО ФУНКЦИОНИРОВАНИЯ

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Аннотация. В статье приведен анализ современных железнодорожных тормозов, а также представлены новые конструктивные решения, которые позволяют оптимизировать использование дискового тормоза в режиме тяги и выбега, тем самым увеличивая эффективную мощность тягового транспортного средства, повысить коэффициент трения для колодочных тормозов, стабилизировать температуру в трибоконтакте, уменьшить износ узлов трения и повысить безопасность.

Ключевые слова. Дисковый тормоз, тормозная колодка, сплав с памятью формы, порофоры, сжатый воздух.

Analysis of the influence of jet-abrasive flow parameters on wheel and rail friction coefficient

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S u m m a r y . Analysis of the influence of Jet-abrasive flow parameters on friction between wheel and rail is provided. The authors developed a computer program for planning of experiment and determine the regression equation based on experimental data obtained using modernized and developed stand equipment.

K e y w o r d s : adhesion coefficient, Jet-abrasive flow, planning of the experiment, the regression equation.

STATEMENT OF THE PROBLEM

The most important economic indicator of the railway transport is the cost of transportations, which is largely determined by the weight of the train, which greatly depends on the interaction of the wheel-rail system. Consequently, the quality of work the wheel-rail friction node determines the economic and operational performance of railway transport.

In the operation of locomotives it is necessary to adjust parameters of the friction wheels interacting with the rails, in accordance with specified operational characteristics. This allows a greater level of adhesion for the implementation of maximum traction or braking.

ANALYSIS OF RECENT STUDIES AND PUBLICATIONS

In the research schools and centers in England, USA, France, Japan and other countries, have been tested such methods to improve adhesion: laser, chemical and hydro-jet cleaning, supply on different characteristics abrasive

materials, and others [1, 2]. Despite the existence of a large number and variety of methods to improve adhesion promoting their designs on international exhibitions, the researchers are actively continuing to seek the most effective method.

In practice the operation of railway transport of Ukraine and foreign countries, the most common is the supply of sand under the wheels of the locomotive on the rails. The study of work of sand system has allowed to define its basic flaws [3], which demonstrate the relevance of solved by the authors tasks on creation an effective method of improving adhesion. It is also confirmed by a protocol number 6 STC of «Russian Railways», as the main consumer of Ukrainian locomotive products where it is decided to create an adaptable sand supplying construction under the driving wheel set or other ways to increase adhesion.

After complex theoretical and experimental studies [4, 5], the authors developed the construction of the new perspective method of improving adhesion of rail and wheels using impact of two-phase jet-abrasive flow on interacting surfaces [6, 7].

OBJECTIVES

The purpose of this paper is to analyze and then select the process parameters of the jet-abrasive effect on the area of the wheels in contact with the surface of the rail, on the basis of experimental stand research.

THE RESEARCH RESULTS

To assess the impact on rail wheels with coefficient of friction parameters of two-phase jet-abrasive flow method the theory of planning the experiment is applied [8-12], which allows to significantly reduce the number of experiments and mathematical model of the process to assess joint and independent effect of each factor (parameter) to the coefficient of friction of the wheels on the rail. Method of planning experiments involves the choice of factors and their levels and varying intervals, determination of system response, planning matrix and obtaining the regression equation.

Choice of factors, their levels and intervals of variation, based on an analysis of the literature [13-17], which allowed to choose for the experiment the next most significant factors: angle of attack of blasting jet α , speed of abrasive V_1 , the concentration of abrasive in the air stream K , its granularity d , speed of relative displacement of the nozzle and rail surface V_2 , length of blasting jet L .

One factor can take in the experience one or more values - levels. The number of experiments required to implement all possible combinations of factor levels is determined by the formula:

$$N = U^k, \quad (1)$$

U – number of levels;

k – number of factors.

For the model we choose two levels. Then in the solution of full factorial experiment (FFE) the number of tests required to get the model is $N = 2^6 = 64$. With so many tests FFE has a high redundancy of tests, especially when there is a number of factors more than four and leads to significant time and cost to conduct experimental research. It is advisable to reduce their number through the information, which is not significant in the model. Such a decision may make use of regular fractional replicas of FFE containing the appropriate number of experiments and preserve the basic properties of the matrix of planning. Replica comprising only half ($1/2$) of FFE experiments, is called half replica. In this case, we use a quarter-replica, which is $1/4$ of FFE experiments, then the number of experiments to determine the effect on the coefficient of friction parameters of jet-blasting process will be reduced to 16.

The boundary values of the variables are summarized in table 1. They were chosen on the

basis of the literature, as well as in accordance with the overall parameters of the locomotive and ensuring flow impact on the contact zone.

As a response is received the maximum coefficient of friction of wheel and rail f obtained experimentally by installing an upgraded stand «Friction machine for studying frictional properties of the contact of wheel-rail» [18, 19], represented in fig. 1.



Fig. 1. Stand «Friction machine for studying frictional properties of the contact of wheel-rail»

Table 1. The boundary values of the variables

Factor	Value
Angle of attack of abrasive jet, α , deg.	
X_1 minimum	5
X_1 average	25
X_1 maximum	45
Speed of abrasive V_1 , m/s	
X_2 minimum	30
X_2 average	50
X_2 maximum	70
Abrasive granularity d , μm	
X_3 minimum	250
X_3 average	425
X_3 maximum	600
The concentration of abrasive in the air stream K , %	
X_4 minimum	0.2
X_4 average	0.3
X_4 maximum	0.4
Speed of relative displacement of the nozzle and rail surface V_2 , m/s	
X_5 minimum	0.55
X_5 average	0.965
X_5 maximum	1.38
Length of blasting jet L , mm	
X_6 minimum	60
X_6 average	90
X_6 maximum	120

For convenience and flexibility of using the theory of experiment planning, the authors developed a computer program «Planning of

experiment with increasing traction in the wheel-rail system by the combined effect of the two-phase jet-abrasive flow» (cert. № 43748).

In the beginning of the work in program in the window (fig. 2) factors (parameters), their units, symbols and levels are inputted. After computing the variation interval experiment is planned (the matrix of planning), which with the help of a computer program is displayed on the screen of a personal computer, fig. 3.

Fig. 2. The developed software frame

In the plan $x_1, x_2, \dots, x_n$ are formalized or codified factors defined by the ratio:

$$x_i = \frac{x_i - x_{icp}}{x_{i \max} - x_{icp}} = \frac{x_i - x_{icp}}{x_{icp} - x_{i \min}}, \quad (2)$$

where: $x_{icp} = (x_{i \max} + x_{i \min})/2$; $x_{i \max}$, $x_{i \min}$ – are boundary values of the variation in the independent variables (factors).

№ эксп.	Фактор 1	Фактор 2	Фактор 3	Фактор 4	Фактор 5	Фактор 6
1	-1.0	-1.0	-1.0	-1.0	1.0	1.0
2	-1.0	1.0	1.0	-1.0	-1.0	-1.0
3	1.0	-1.0	1.0	1.0	-1.0	1.0
4	1.0	1.0	-1.0	1.0	1.0	-1.0
5	1.0	-1.0	-1.0	-1.0	-1.0	-1.0
6	1.0	1.0	1.0	-1.0	1.0	1.0
7	-1.0	-1.0	1.0	1.0	1.0	-1.0
8	-1.0	1.0	-1.0	1.0	-1.0	1.0
9	-1.0	1.0	-1.0	-1.0	-1.0	1.0
10	-1.0	-1.0	1.0	-1.0	1.0	-1.0
11	1.0	1.0	1.0	1.0	1.0	1.0
12	1.0	-1.0	-1.0	1.0	-1.0	-1.0
13	-1.0	-1.0	-1.0	1.0	1.0	1.0
14	-1.0	1.0	1.0	1.0	-1.0	-1.0
15	1.0	-1.0	1.0	-1.0	-1.0	-1.0
16	1.0	1.0	-1.0	-1.0	1.0	1.0

Fig. 3. A planning matrix

In coded system based on expressions (2) compliance will be respected: $x_{i \min} \rightarrow x_i = -1$; $x_{icp} \rightarrow x_i = 0$; $x_{i \max} \rightarrow x_i = +1$.

The mutual influence of factors is explained by paired interaction effects: $x_1 x_2, \dots, x_n x_m$ and tripple $x_1 x_2 x_3, \dots, x_n x_m x_k$. The total number of all possible effects including b₀, linear effects and interaction of all orders equal to the number of

experimentations in full factorial experiment. The number of possible interactions of certain order is determined by the formula [9]:

$$C_k^m = \frac{k!}{m!(k-m)!}, \quad (3)$$

k – number of factors; m – the number of elements in interaction.

Solution of the problem, finding dependence of the coefficient of friction on the factors studied was obtained in the form of equation:

$$y = f(x_1, \dots, x_k), \quad (4)$$

f – reply function; x_1, x_k – factors; $y = f$.

For the construction of experiment plan starting point is chosen (main or zero level), around which the experimental points are determined symmetric to the zero level. The results of the experiment with a selected set of factors allow us to construct the model used to determine the values at other points in the factor space.

When planning an experiment the developed program takes into account the mutual influence of binary and ternary interactions of factors. According to the obtained experiment the required tests (experimental studies of the impact of the two-phase jet flow of abrasive on friction of wheel and rail) were held on a stand «Friction machine for studying frictional properties of the contact of wheel-rail». For each interaction of factors experimental studies were carried out four times and the values of the coefficient of friction were entered into a computer program window (fig. 4). With this software the check for errors had been done, and deduced the mean value of the coefficient of friction had been found.

Search for mathematical model begins by examining of possible states of the system.

In accordance with the property of normalization of plan of FFE matrix expression for determining estimates of the coefficients of the regression equation can be written as [20]:

$$b_i = \sum_{j=1}^N x_{ji} y_i / N. \quad (5)$$

The results of calculations of the output values of the coefficient of friction in accordance with the plan of the experiment are displayed in the program window.

According to the formula (2) value of regression coefficients are determined and presented in the form of a diagram in fig. 5.

Fig. 4. The input window for the results of experiments

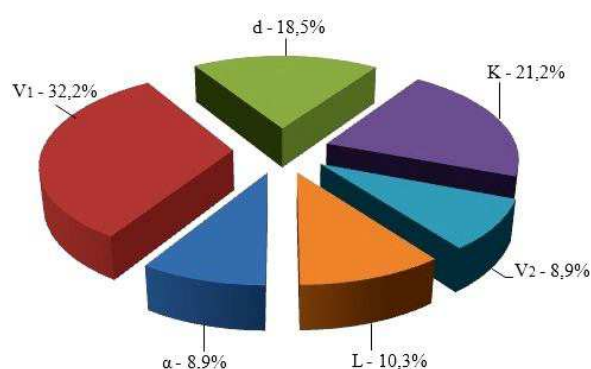


Fig. 5. The influence of parameters of abrasive jet stream on the coefficient of friction

The regression equation for coefficient of friction of wheel and rail on the parameters of the abrasive jet stream is derived first in coded form and looks like cumbersome equation, which is to be converted.

To convert the regression equation of a coded form to natural, use the formula of the converting (2). Substituting the actual values from the table. 1 according to the formula 2 in equation we obtain coded resulting regression equation:

$$f = 0.4306 - 0.1581 \cdot V_2 + 0.1523 \cdot K + 0.0015 \cdot V_1 - 0.0015 \cdot L + 0.0008 \cdot \alpha - 0.00015 \cdot d - 0.112 \cdot K \cdot V_2 - 0.0013 \cdot K \cdot L - 0.0005 \cdot K \cdot V_1 + 0.0015 \cdot L \cdot V_2 - 0.0002 \cdot V_1 \cdot V_2 + 0.0004 \cdot K \cdot \alpha + 0.0004 \cdot K \cdot d + 0.0005 \cdot V_2 \cdot \alpha \quad (6)$$

The resulting equation can predict the results of the effect of abrasive jet stream on the coefficient of friction, solve the problem of choosing a compromise technological parameters of the dispenser for a given coefficient of friction of wheel and rail.

The dependence of the coefficient of friction of the main technological parameters of the process is illustrated by the graph (fig. 6, 7, 8). From the graphs shown in fig. 6, the coefficient increases as the speed of abrasive material and abrasive attack angle of the jet.

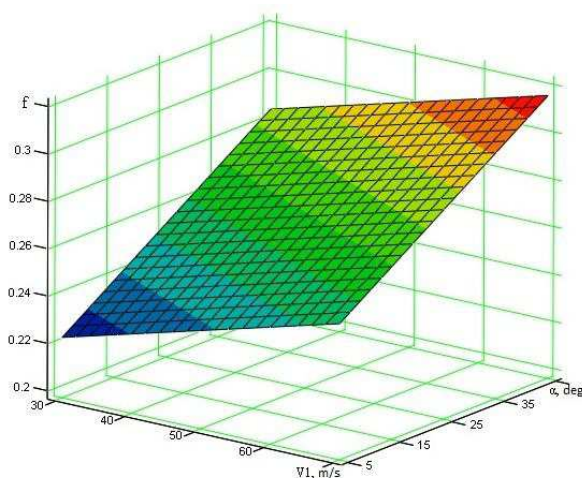


Fig. 6. The dependence of the coefficient of friction on the speed of the abrasive V_1 and angle of attack of abrasive jet α

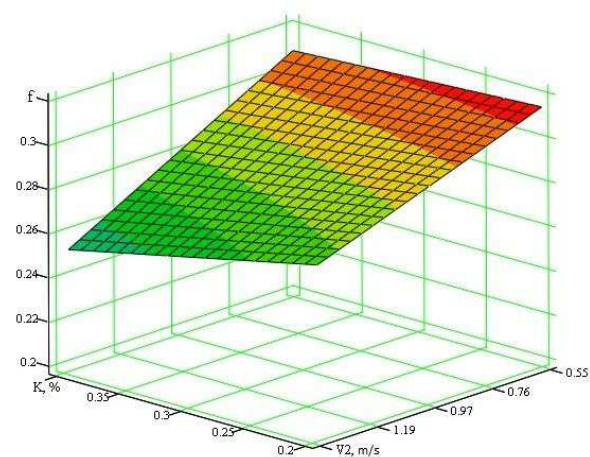


Fig. 7. Dependence of coefficient of friction on the concentration of abrasive in the air stream K and a relative movement speed of the nozzle and surface of the rail V_2

Dependence of coefficient of friction on the concentration of abrasive in the air stream K and a relative movement speed of the nozzle and surface of the rail V_2 is shown in fig. 7. There the coefficient of friction increases with increase in concentration and decrease in the speed of relative

movement. This is due to the increased productivity of the abrasive jet stream due to the maximum amount of particles in contact with the surface and the time of their contact.

With a decrease in length of jet granularity abrasive jet there is an increase of the friction coefficient, which is shown in fig. 8. Effect of abrasive granularity on the friction coefficient speaks that smaller granularity abrasive grains by injecting to jet pick up speed faster than the larger grains. The smaller length of the jet blasting, the more influent this effect is.

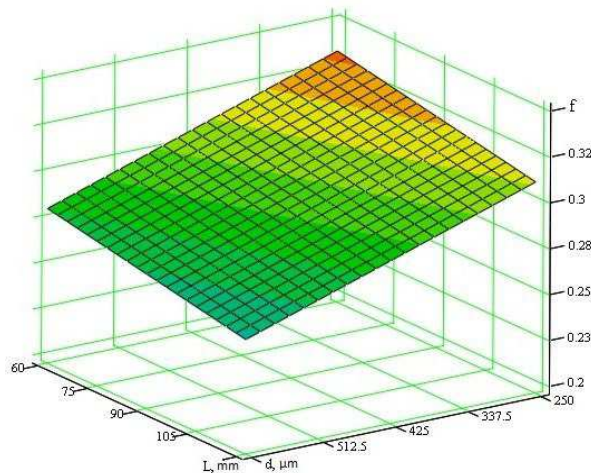


Fig. 8. Dependence of coefficient of friction on granularity abrasive d and length jet L

CONCLUSIONS

The resulting regression equation makes it possible to evaluate the effect on the coefficient of friction of wheel with the rail parameters of biphasic abrasive jet stream, and to predict the characteristics of supply device of abrasive material in its design and operation.

According to our experimental studies, and the resulting regression equation was found that the greatest effect at the coefficient of friction of wheel and rail of abrasive flow is of speed, and the least impact is of the angle of attack.

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АНАЛИЗ СТЕПЕНИ ВЛИЯНИЯ ПАРАМЕТРОВ СТРУЙНО-АБРАЗИВНОГО ПОТОКА НА КОЭФФИЦИЕНТ ТРЕНИЯ КОЛЕСА С РЕЛЬСОМ

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Владимир Ноженко, Ольга Просвинова*

Аннотация. В работе выполнен анализ степени влияния параметров струйно-абразивного потока на коэффициент трения колеса с рельсом. Разработано авторскую компьютерную программу для планирования эксперимента и определения уравнения регрессии по результатам экспериментальных данных полученных на модернизированном и разработанном стендовом оборудовании.

Ключевые слова: коэффициент сцепления, струйно-абразивный поток, планирование эксперимента, уравнение регрессии.

Stability analysis of the model describing the fractional composition of coal

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S u m m a r y . The paper analyzes the stability analysis of the model describing the fractional composition of coal. The numerical experiment was made in the neighborhood of each parameter optimum value. The analysis showed that in the neighborhood 0.05 of the parameters optimal values of the fractional composition describing model does not exceed the error of obtaining experimental data.

Key words: fraction composition, weight distribution function, stability analysis.

description of the fractional composition of coal. Due to the fact that this model has a stochastic nature, as well as the method of identifying the model parameters, one of the most promising areas for further research is to analyze the influence of errors in the determination of the model parameters on its stability [5-7, 9, 15].

INTRODUCTION

Raw materials information recovery [1-4], in particular the problem of the fractional composition information recovery [10,12,14], is one of the main objectives of coal preparation, as it directly affects the quality of all processes of coal preparation plant. In practice, the solution of the fractional composition recovery is an inevitable compromise between the price of the fractional analysis and accuracy, that is, the number of bundles. Therefore, the actual task of modern coal preparation is the problem of finding such a description of the information about the fractional composition of coal [18,19], which would allow much detail as possible to calculate output and the ash content of an arbitrary number of narrow fractions of the minimum volume sampling.

One solution to this problem is using a model for the description of coal fractional composition, based on the use of the boundary density weight distribution functions and of the boundary ash content in conjunction with the concept of enrichability surface. This model allows us to obtain an analytical solution that takes into account the physical limitations imposed on the

OBJECTS AND PROBLEMS

The purpose of this paper to analyze the experimental data to assess the impact of changes in the parameters straightening weight distribution functions of the boundary density and ash content on the stability of the model describing the fractional composition of coal [20-24].

The model parameters describing the fractional composition can be divided into physical (minimum and maximum boundary density), real (minimum and maximum ash content of the boundary) and the parameters of straightening, determined by the probability of paper [22]. The method of probability paper [8,11,13] is based on finding such a transformation of the distribution function, which turns it into a straight line. Then the question of finding the parameters of the distribution function is to find the coefficients of the line [16,17].

THE RESULTS OF RESEARCH

As is known, the distribution function of the density and ash content of coal fractions are [1].

Then, using the concept of enrichability [1] surface, the fractional composition can be written:

$$\text{as: } \Gamma(\rho) = \frac{1}{1 + (a_0 + a_1 t_p) \sqrt{1/t_p - 1}}, \quad t_p = \left(\frac{\rho - \rho_0}{\rho_1 - \rho_0} \right)^2$$

$$F(\lambda) = \frac{1}{1 + (b_0 + b_1 t_\lambda) \sqrt{1/t_\lambda - 1}}, \quad t_\lambda = \left(\frac{\lambda - \lambda_0}{\lambda_1 - \lambda_0} \right)^2$$

$$U(\rho_{i-1}, \rho_i) = \frac{\Lambda(\Gamma_i(\rho_i)) - \Lambda(\Gamma_{i-1}(\rho_{i-1}))}{\Gamma_i(\rho_i) - \Gamma_{i-1}(\rho_{i-1})}$$

$\Lambda(\Gamma) = \int_0^\Gamma \lambda(\Gamma) d\Gamma$, where: a_0, a_1, b_0, b_1 – parameters on the results of the experiment, ρ_0, ρ_1 – minimum and maximum boundary density, λ_0, λ_1 .

The model description shows that the modification of parameters b_0, b_1 influences the calculation of the average ash and does not affect the calculation of output values of narrow fractions.

Consider the experimental data on the fractional composition of the raw coal machine classes of mine "Almaznaya" (class 100 mm), by the identification of the model parameters and compare the experimental and theoretical results (table 1):

$$\begin{aligned} a_0 &= 0,09537594, a_1 = 0,28370233, \\ b_0 &= 0,26466792, b_1 = 0,64594815, \\ \rho_0 &= 1,58175342, \rho_1 = 2,00826073, \\ \lambda_0 &= 0,03893242, \lambda_1 = 0,93534468, \\ \beta_{ke} &= 45,402, \beta_k = 45,402 \end{aligned}$$

Table 1. Comparison of theoretical and experimental data describing the fractional composition of coal (mine «Almaznaya»)

$\gamma_e, \%$	$\gamma_t, \%$	$ \Delta\gamma $	$A_e^d, \%$	$A_t^d, \%$	$ \Delta A^d $
30,87	30,8693	0,0007	8,6	8,6	0
46,96	46,96	0	47,5	47,4991	0,0009
22,17	22,1707	0,0007	92,2	92,1992	0,0008

The comparison results (Table 1) shows that the relative error in determining outputs and the average ash content of narrow fractions does not exceed obtain experimental data error.

Let (speaking about the fractional composition description model):

$\varepsilon_1 = \max_{1 \leq i \leq n} |\gamma_{ie} - \gamma_{it}|$ – estimation of an absolute error of output value determination,

$\varepsilon_2 = \max_{1 \leq i \leq n} \left| \frac{\gamma_{ie} - \gamma_{it}}{\gamma_{ie}} \right|$ – estimation of an relative error of output value determination,

$\varepsilon_3 = \sum_{i=1}^n (\gamma_{ie} - \gamma_{it})^2$ – the sum of the narrow fractions outputs squared deviations,

$\varepsilon_4 = \sum_{i=1}^n \left(\frac{\gamma_{ie} - \gamma_{it}}{\gamma_{ie}} \right)^2$ – the sum of the narrow fractions outputs relative squared deviations,

where: γ_{ie}, γ_{it} – accordingly the output of the i narrow fraction by experimental and theoretical data,

$\varepsilon_5 = \max_{1 \leq i \leq n} |A_{ie}^d - A_{it}^d|$ – estimation of an absolute error of an average ash content determination,

$\varepsilon_6 = \max_{1 \leq i \leq n} \left| \frac{A_{ie}^d - A_{it}^d}{A_{ie}^d} \right|$ – estimation of an relative error of an average ash content determination,

$\varepsilon_7 = \sum_{i=1}^n (A_{ie}^d - A_{it}^d)^2$ – the sum of the narrow fractions ash content squared deviations,

$\varepsilon_8 = \sum_{i=1}^n \left(\frac{A_{ie}^d - A_{it}^d}{A_{ie}^d} \right)^2$ – the sum of the narrow fractions ash content relative squared deviations,

where: A_{ie}^d, A_{it}^d – accordingly the average ash content of the i narrow fraction by experimental and theoretical data.

Let's do the numerical experiment in a neighborhood of the parameter ρ_0 optimal value. Results analysis showed that estimation of an absolute error of output value determination (fig.1) and the sum relative squared deviations (fig. 3) close to 1,5816, estimation of an relative error (fig. 2) in the interval $[1,58064649; 1,5816651]$, the sum of relative squared deviations in the interval $[1,57623253; 1,58641859]$ is not more that 0,05. The behavior of the model in determining the average ash content (figures 5-8) has a similar character.

Let's do the numerical experiment in a neighborhood of the parameter ρ_1 optimal value. Results analysis showed that estimation of all types of calculated errors related to the output values (figures 9-12) in interval $[2,007017; 2,009007]$ are close to 0. The behavior of the model in determining the average ash content (figures 14-16) is almost the same excluding (figure 13) the estimation of the absolute error (which is not more than 0,05 in the neighborhood of the optimum value).

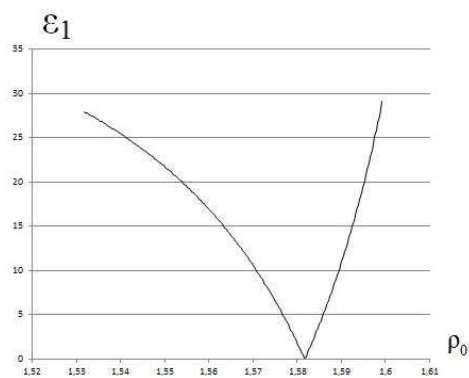


Fig. 1. A plot of $\varepsilon_1(\rho_0)$

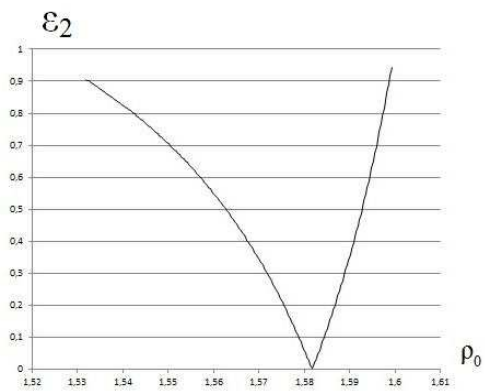


Fig. 2. A plot of $\varepsilon_2(\rho_0)$

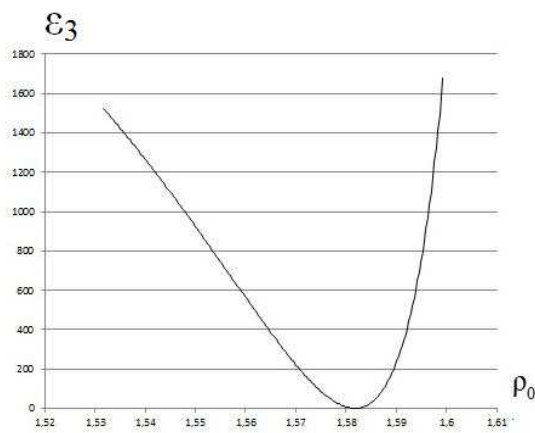


Fig. 3. A plot of $\varepsilon_3(\rho_0)$

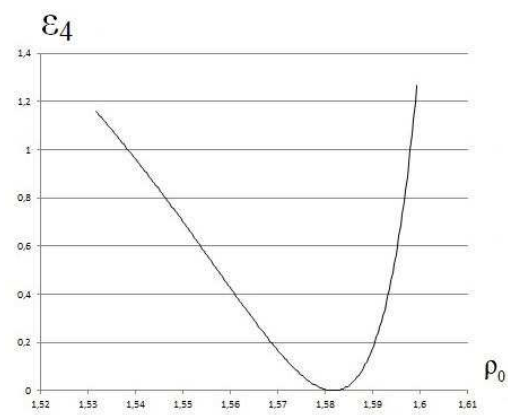


Fig. 4. A plot of $\varepsilon_4(\rho_0)$

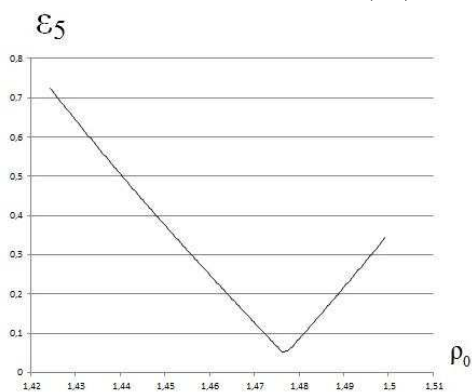


Fig. 5. A plot of $\varepsilon_5(\rho_0)$

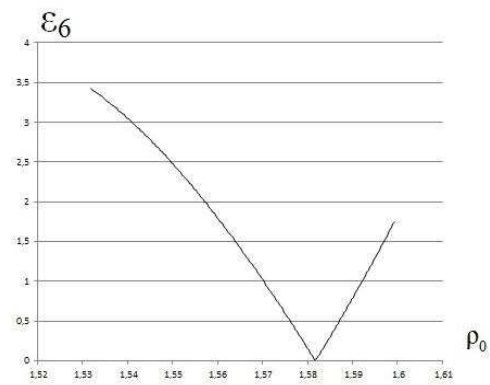


Fig. 6. A plot of $\varepsilon_6(\rho_0)$

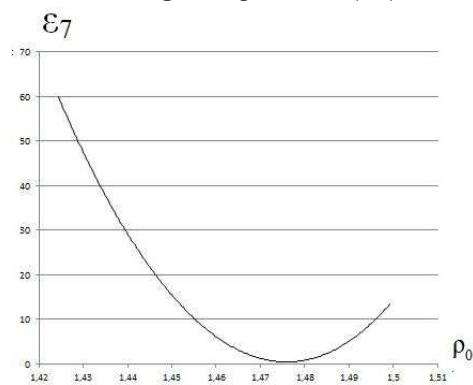


Fig. 7. A plot of $\varepsilon_7(\rho_0)$

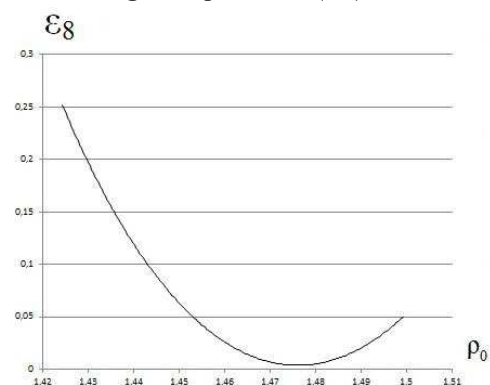
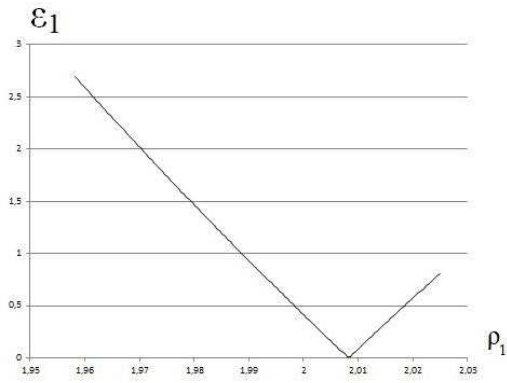
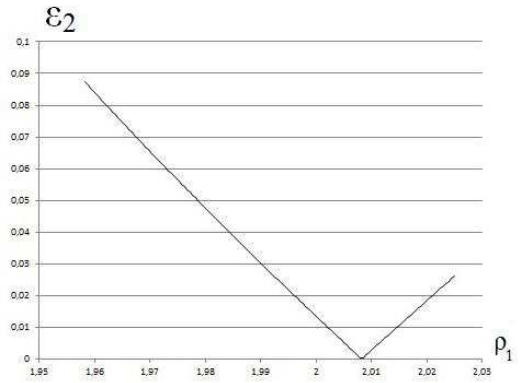
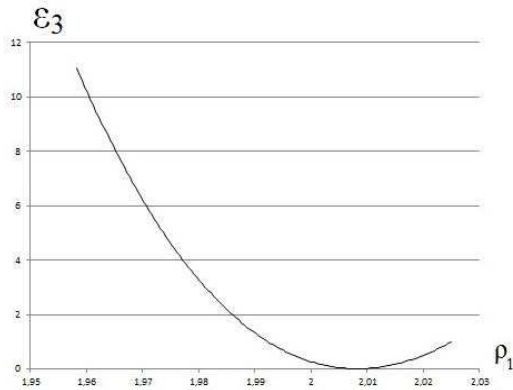
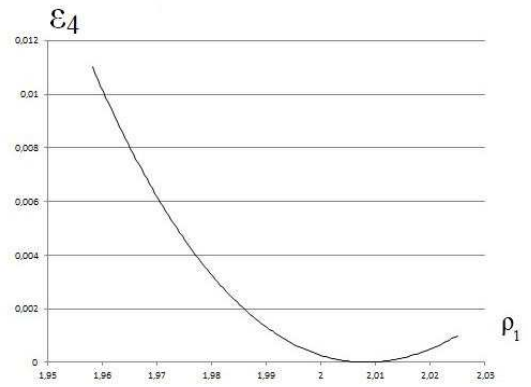
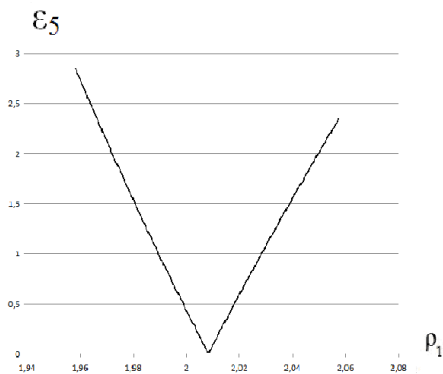
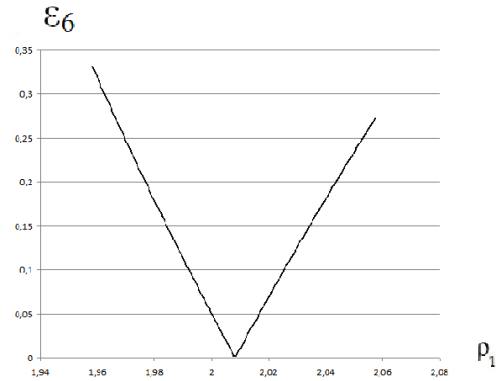
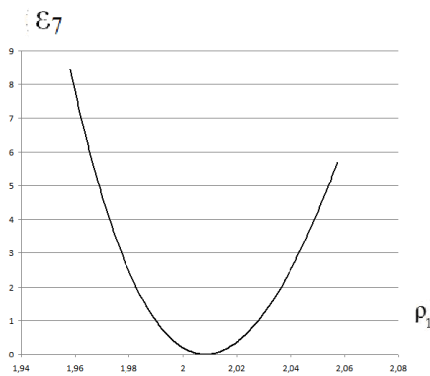
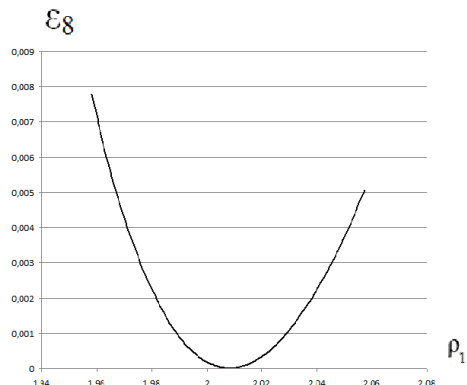
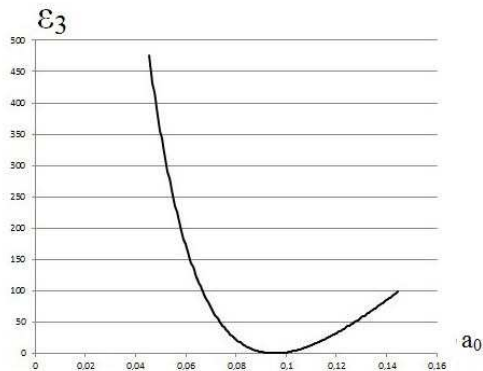
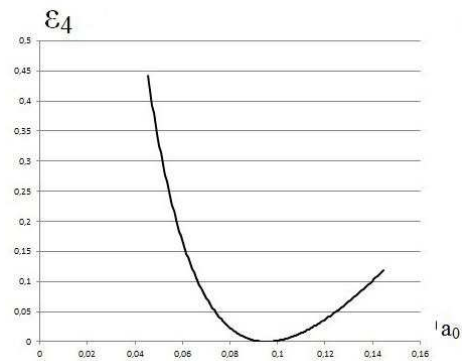
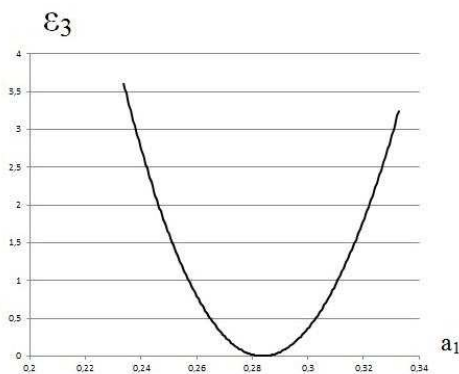
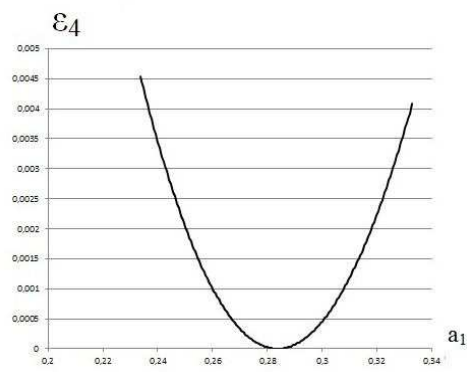


Fig. 8. A plot of $\varepsilon_8(\rho_0)$

Fig. 9. A plot of $\varepsilon_1(\rho_1)$ Fig. 10. A plot of $\varepsilon_2(\rho_1)$ Fig. 11. A plot of $\varepsilon_3(\rho_1)$ Fig. 12. A plot of $\varepsilon_4(\rho_1)$ Fig. 13. A plot of $\varepsilon_5(\rho_1)$ Fig. 14. A plot of $\varepsilon_6(\rho_0)$ Fig. 15. A plot of $\varepsilon_7(\rho_1)$ Fig. 16. A plot of $\varepsilon_8(\rho_1)$

Fig. 17. A plot of $\varepsilon_3(a_0)$ Fig. 18. A plot of $\varepsilon_4(a_0)$ Fig. 19. A plot of $\varepsilon_3(a_1)$ Fig. 20. A plot of $\varepsilon_4(a_1)$

Let's do the numerical experiment in a neighborhood of the parameter P_1 optimal value. Results analysis showed that estimation of all types of calculated errors related to the output values (figures 17-18) in interval $[0,09462967;0,09612221]$ are close to 0, excluding the estimation of the absolute error (which is not more than 0,05 in the neighborhood of the optimum value). The behavior of the model in determining the average ash content (Figures 19-20) is almost the same excluding the estimation of the absolute error (which is not more than 0,05 in the neighborhood of the optimum value).

CONCLUSIONS

The analysis showed that in the neighborhood 0.05 of the parameters optimal values of the fractional composition describing model is not very sensitive to changes in parameter values, and almost always (except, perhaps, the values at the boundaries of the range) does not exceed the error of obtaining experimental data.

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АНАЛИЗ УСТОЙЧИВОСТИ МОДЕЛИ ОПИСАНИЯ ФРАКЦИОННОГО СОСТАВА УГЛЯ

Олег Грачев

А н н о т а ц и я . В статье выполнен анализ устойчивости модели описания фракционного состава угля. Численный эксперимент проведен в окрестности оптимальных значений каждого параметра. Анализ результатов численного эксперимента показал, что в окрестности 0,05 оптимальных значений параметров модели описания фракционного состава не превышает погрешности получения экспериментальных данных.

Ключевые слова: фракционный состав, весовые функции распределения, анализ устойчивости.

Workplace organization problems of the industrial machine employees research

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Summary. The question of normalization in the workplace in machinery construction industry with considering comprehensive anthropometric approach is studied. Fig. 3. Tabl. 1. Ref. 20.

Key words. Labor safety, workplace, ergonomic requirement, machine

INTRODUCTION

Known that the management system of privacy labor in various industries of Ukraine [2, 11, 15, 16, 18] depends on variety of factors, including: the status and level of maintenance in equipment, organization and discipline of labor, availability qualified personnel and equipment safety. In turn, automatic production processes and modern technology control state of working environment with out leading to what is often pr and workers are unable to see some areas that are involved in the manufacturing process because they are guided by signals on the scoreboard or video picture on screen that captures operational information comes.

The technical condition of the workplace ought to provide working ability of operator [4, 6-10, 12, 17, 19], which should be quickly and true perceived as you and process the information that depends on its physiological properties are affected as individual features of senses involved in the analysis and response characteristics their anthropometric indicators, constructive parameters of his workplace.

RESEARCH OBJECT

Normalization of the operator systems and automatic using computer technology and improve the robot by parameters of human interaction with technology within a single system "human – machine – environment" requires changes relating to the establishment optimal to allocate and environment for the employee by another studies adoption projects are making tons and need action and conducted research terms and condition of labor and with values above ergonomic requirement.

RESULTS OF EXPERIMENTAL RESEARCH

Comprehensive systematic approach to these problems is solved at the study opportunities and the functioning of the body and workers in the labor force in order to create such conditions, methods and organization of labor activities that contribute to its comprehensive spiritual and physical development, providing comfort and safety in process in the workplace, health safety and working ability.

A specific object of this study is not a separate in equipment, or man and as a subject and production, not a separate environment, and the system "human – machine – environment", all elements are considered in conjunction with physical and mental consistency extended features and board for all types of people, their aesthetic

and other qualitative indicators with parameters of modern hardware and allocate and environment.

Main methods used in the study of human activity: psychologist, physiological and modeling techniques (fig. 1).

Psychological experiments are divided into research (questionnaires, observation) and testing, allow to estimate degree of development in humans and certain psychological qualities. With and control methods overall of work. For pulse rate, electrical activity of the heart, brain, electric poles and skin, etc., you can judge the degree of intensity and severity of the operator. In the simulation creates a matrix of key parameters typical state employee, at in broadcast employment.

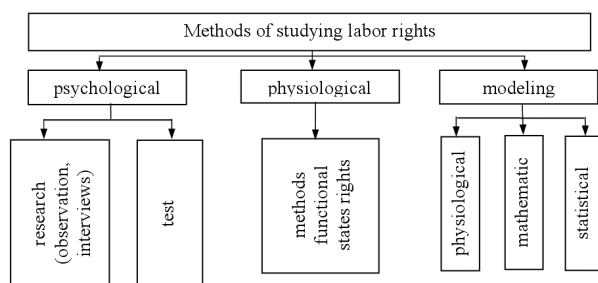


Fig. 1. Block diagram of the study work operator

In modern manufacturing a priority for cottages organization working operator's seat is to create safe working conditions in all areas of production and auxiliary enterprises and units for normal products in labor without unnecessary physical and psychological stress, any harmful and local environmental influences using different tools and information. The latter must satisfy three important measurements at scales: the content they have quite clearly reflect the state of objects in the environment, and for several centuries information provided - ensure optimal watch is visually, mental and muscle load operator, form - meet with villas and operator processing and responding to information that comes.

In our time of growth psychological stress experienced by employees several professions. One of its main reasons - a large amount of information perceived, including, and with vision. Therefore, and in the exclusion of superfluous information needed careful filtering of character and volume. Psycho and physiologists no congestion arising in the process and labor may increase absence of professional selection, particularly for the type of higher nervous activity, emotional overload, which appear as a result of

incompatible individual employees in the team, uncomfortable at fixed working posture of operator, location and means of obtaining information identical remotes with various controls, including their ergonomic and color characteristics.

Using data anthropometric studies can determine the impact of physical factors on which provided time and reliable. The main ways to do this - this automatic control systems and instrumentation technology, reliable virtue in equipment, creating a comfortable with colored clearance surfaces of equipment and facilities, and decreasing their levels of noise and vibration.

The workplace should be adapted to a particular employee with definite qualification, taking into account the physical and psychological capabilities as well as the following requirements [1, 5, 13, 14, 17, 20]:

- adequacy of working space (the so-called motor field) that allows at exigencies make all necessary movements and moving in the operation and maintenance of a hundred tons of forging;
- adequacy of physical, visual and auditory and connections between operator equipment and other employees;
- optimal location of jobs in the premises, and presence of safe passage for employees;
- ergonomic elements of the workplace, equipment and premises;
- the need for adequate implementation of this work natural and artificial lightening;
- acceptable level of noise and vibration in the workplace;
- the necessary collective and individual means of protection of workers from the effects harmful factors and.

In terms of workplace machinery companies use visual elements in the form of tablets. These boards and control panels, under optimal view, should be placed on the same or different panel, they must meet the optimal conditions for angle of viewing without moving sight - $30^\circ \dots 40^\circ$, with movement - $50^\circ \dots 60^\circ$, but with a twist of the head - 90° (fig. 2).

Knowledge of the characteristics of the human visual field provides an opportunity for necessary visibility control device or equipment for the parameter dimensional mechanism of its position relative to the user. Definitive here is the field of view and its boundaries are defined capabilities of optical systems and people, size and distribution of photoreceptor in the retina and protrusions of the head [3].

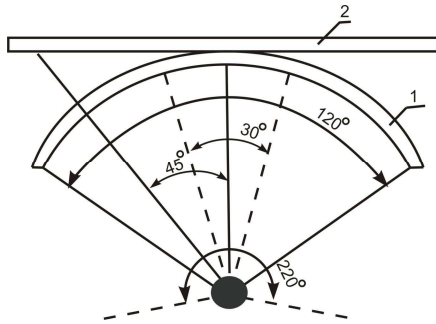


Fig. 2. Normative condition of scoreboard angle (in the background) semicircular (1) and frontal (2) forms

To calculate the total size of the panel and the zone location of major appliances that are used most frequently for different distances observable, use the formula

$$L = k_p \cdot d, \quad (1)$$

where: L the distance from the center of the appliance to the relevant area; k_p the coefficient accounting options and disposition panel of equipment shown in the table. 1; d the distance from the operator to the panel.

In the zone observations affect anthropometric and specifications: human operator labor intensity, state of sight and mind. At the same time, we must remember that the tension on the labor affects the degree monotony and separate ability as susceptibility and action (monotone), the negative consequences of which is fatigue, with its various degrees of fatigue, loss of interest in the work, which leads to poor quality and slow performance, loss of orientation in time. Size of boards and their location (or semicircle in front) depends on the amount of information entering the control panel.

Table 1. The coefficient k_p

Panel options	Right and left from the center	Top from center	Down from the center
Total dimensions in panel, m	1.35	0.90	1.45
The most use zone location of equipment, m	0.60	0.425	0.625

The most convenient is the location desk and control panel on one side, the main dimensions of the workplace are shown in fig. 3.

However, this scheme has limited capacity for several centuries and information processed by operator. On panels positioned at different controls that can be divided into four groups. The first group includes agencies turning on and shutdown, start exercising and soups control object, the

second - the bodies tossing from one type of work to others and also the third - the bodies in regulation and the fourth - emergency controls that should have minimum time for abrasion.

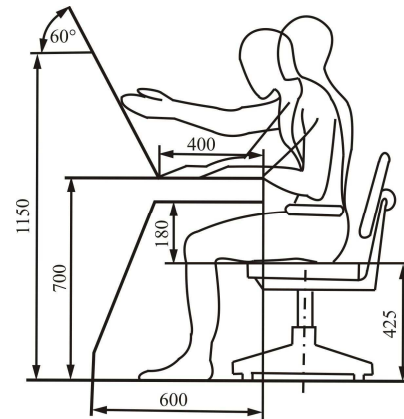


Fig. 3. Basic supervisory control panel

All controls should be easily accessible, must have different colors, moreover, color design depends on what situations and significant their use - regular (working), dangerous, critical or emergency. Searching time ought to be minimal, and effort for action on ought not to depend on which area of the motor field of person and which organ is at work "sitting" or "standing".

CONCLUSIONS

Our studies indicate that the counting requirements of the organization and design of workplace human operator to the presence of display information to create safe working conditions and open new opportunities for determining when latent reasons of emergency and with fluctuations in the business machine industry.

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ИССЛЕДОВАНИЕ ПРОБЛЕМ ОРГАНИЗАЦИИ РАБОЧИХ МЕСТ РАБОТНИКОВ НА ПРОМЫШЛЕННОМ ТРАНСПОРТЕ

Николай Касьянов, Александра Андрианова

Аннотация. Рассмотрены вопросы нормализации труда на рабочих местах в отрасли машиностроения с учетом комплексного антропометрического подхода. Ключевые слова. Охрана труда, рабочее место, эргономические характеристики, машины.

Assessment of the natural and energy resources utilization in the transportation flow chart of the industrial production

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Summary. There is a consideration on modeling of the assessment of the natural and energy resources utilization and losses of raw materials on the industrial transport of the blast-furnace production aiming to reveal the most unprofitable objects and processes of the transport as well as to protect the environment.

Key words: transport, energy resources conservation, ecology.

INTRODUCTION

One of the most important problems in the modern conditions of the technical, competitive and economic development of the industrial transport of metallurgical sector is the issues of reducing the costs of natural, energy resources and labor resources as well as the protection of the environment from its harmful influence [3].

It is discovered that in the total discharge of contaminants into the atmosphere by all anthropogenic sources the mass fraction of the transport is 60%, metallurgy – 13-20%, power engineering – 10-15%. Metallurgy and transport make more than 80 % in total [11, 19].

The transportation flow chart (TFC) of metallurgic raw materials transfer to the blast furnace (BF) and movement of the ready products and waste products of the blast-furnace production is one of the most energy consuming schemes in the complex structure of the metallurgic sector transportation system. The share of the

transportation flow chart of the blast furnace production (TFC BFP) at the enterprises with the complete metallurgical cycle is 76% for energy consuming, 40% for water consuming, 70% for waste products by mass of the raw materials [2].

These conditions bring out the necessity of the adequate assessment [6] of natural and energy resources and labor resources (NE and LR) utilization at the stages and on the objects of the transportation flow chart of the blast furnace production.

It will facilitate to reveal the most resource-consuming processes and objects, reserves of resources conservation and reserves to increase the efficiency of energy utilization, to define the priority in improving the objects and processes of the industrial transport [9].

We present the blast furnace production as a cybernetic process constructed on the “black box” principle with the analysis of outputs and inputs according to the cybernetic scheme [12], fig. 1.

“The black box” is the blast furnace itself with physical and chemical process going in it and providing the required conditions and factors of its operation.

Transportation flow objects with their processes and operational outcomes which are to ensure the required conditions and required factors of the blast furnace operation are supposed as the input factors.

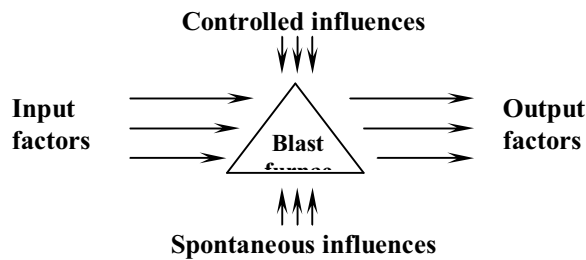


Fig. 1. Cybernetic scheme of the full blast furnace production cycle

The outcomes of the processes inside the blast furnace and the outcomes of the industrial transport operation with their processes and objects are supposed as the output factors.

Requirements to NE and LR, BF operation, its product – cast iron, etc., are treated as controlled influences. Natural factors of the environment, force-majeure circumstances, etc., are treated as spontaneous influences.

Life cycle of the objects and processes of TFC BF production can be presented as a dynamic graphic-topological model where certain natural, energy and labor resources are used variably at all of its stages (fig. 2).

Utilization of NE and LR in the transportation flows [Gabler 1983] on the preparation stage of the blast furnace production raw materials can be presented in the form of a matrix as a peculiar form of inter-object balance of NE and LR consumption [18].

NE and LR consumption indices per unit of the goods of the transported raw materials, ready products and waste products of the production are taken as the basis of the balance.

When analyzing the utilization of NE and LR in the transport flow chart of the industrial enterprises, three kinds of balances: active, passive and net-balance (estimated) are taken into account.

Net balance presupposes the acceptable levels of harmful influence (NE and LR utilization) of the transport flow chart of the blast furnace production on the environment which include the appearance of the human peril in the industrial region [7]: unfavorable environmental conditions [13].

The assessment of NE and LR utilization in the industrial transport of the blast furnace production concerning the environmental protection should be attributed to the passive balance as damaging the environment more than net balance.

Opposed to the passive balance, the active balance implies the reduction of natural, energy and labor resources consumption in comparison with the net balance and aims to the minimum utilization of the resources and maximum environmental protection [4, 14].

In this case the balance matrix can serve as a basis for modeling the inter-object utilization of the natural, energy and labor resources in the transport flow chart of the blast furnace production.

	1	2	3	4	5	6	7	8
Stages and dynamics of the life cycle	Production	Keeping of the reserve fund	<i>i</i> –th operational cycle	Maintenance and overhaul	Keeping of repair stock	<i>i</i> –th operational cycle	Demounting	Renovation and utilization
Structure of NE and LR used (j):								
1. Atmosphere	+	+	+	+	-	+	+	+
2. Hydrosphere	+	+	+	+	-	+	+	+
3. Lithosphere	+	-	+	+	+	+	+	+
4. Territories	+	+	+	+	+	+	+	+
5. Phytosphere	+	-	+	+	-	+	+	+
6. Biosphere	+	-	+	+	+	+	+	+
7. Energy	+	+	+	+	+	+	+	+
8. Labor resources	+	+	+	+	+	+	+	+

+ NE and LR are used; - NE and LR are not used

Fig. 2. Graphic and topological model of the life cycle dynamics of the transportation flow chart objects of the blast furnace production and natural, energy and labor resources (NE and LR) utilization

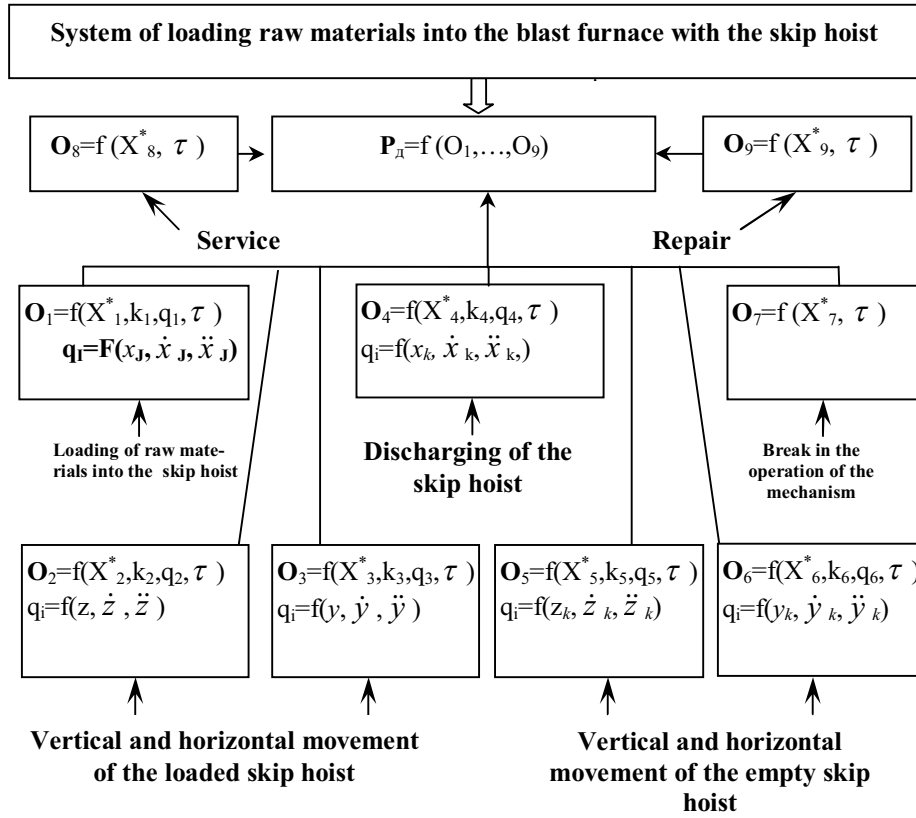


Fig. 3. The flow diagram of loading the blast furnace with the raw materials using the skip hoist

Letters in the figure show: P_d – the functional of NE and LR expenditure at the stage of the object's life cycle; O_i – functional of NE and LR consumption of the corresponding element of the loading process; X_i^* – cost coefficients; k_i – constructive characteristics of the object including geometry, mass, efficiency coefficient, etc.; q_i – independent generalized coordinates, τ – time.

Cost coefficient X_i^* , including the consumption of the corresponding NE and LR as well as the consumption of c_{pi} : the energy c_{en} , materials c_m , repair c_p , labor force c_3 , wear-and-tear c_a , management c_{ynp} and other c_{np} , makes:

$$X_i^* = \sum_{i=1}^p c_{pi} \cdot \quad (7)$$

On the operational stage, when discharging the skip hoist, the following example of the functional of the consumption for vertical and horizontal movement of the loaded skip hoist can be presented:

$$O_2 = f(X_2^*, K_2, q_2, \dot{q}_2, \dots, \tau), \quad (8)$$

or in the particular expression:

$$O_2 = J_n + J_y + J_m + J_o, \quad (9)$$

where:

J_n, J_y, J_m, J_o – are the functional showing the consumption at the stages of the start, movement, braking and stops of the mechanism correspondingly.

Thus, the requirement for the i -th resource for the j -th process of loading can be defined [16]:

$$x_{ij}^* = \sum_{s=1}^4 \frac{b_s^i}{C_i^p} \cdot d_s^{cn}, \quad (10)$$

where:

C_i^p – are mean prices for the i -th resource;

b_s^i – the coefficient of the utility function of the i -th resource for the equipment of S group which is defined when identifying the model;

d_s^{cn} – financial assets for fulfilling the demand for the i -th resource of S group defined as follows [Richter 1975]:

$$d_s^{cn} = \alpha_{cn} \cdot d_{s\Sigma}^H + \beta_{cn} \cdot d_s, \quad (11)$$

where:

α_{cn} , β_{cn} - coefficients representing the shares of the financial resources accumulated and received after the sales of the product which are directed toward the consumption of the i -th resource and defined when identifying the model of demand for the i -th resource,

$d_{s\Sigma}^u$ - total financial resources intended for the consumption of the i -th resource of S group,

d_s - aggregated financial resources for the consumption of all i -th resources of all S groups.

CONCLUSIONS

The suggested approach to the modeling of the assessment of natural, energy and labor resources in the transportation flow chart of the industrial production allows to define the most consuming objects and processes of the chart, determine the priority for their improvement as well as to develop the corresponding environmental protection procedures.

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ОЦЕНКА ИСПОЛЬЗОВАНИЯ ПРИРОДНЫХ
И ЭНЕРГЕТИЧЕСКИХ РЕСУРСОВ В
ТРАНСПОРТНО-ТЕХНОЛОГИЧЕСКОЙ
СХЕМЕ ПРОМЫШЛЕННОГО ПРОИЗВОДСТВА

Ольга Хлестова, Иван Берестовой

А н н о т а ц и я . Рассматривается моделирование оценки использования природно-энергетических ресурсов и потерь сырьевых материалов на промышленном транспорте доменного производства с целью выявления наиболее затратных объектов и процессов транспорта, а также защиты окружающей среды.

К л ю ч е в ы е с л о в а . транспорт, энергоресурсосбережение, потери сырья, экология.

Application of optimal planning methodologies for investigation of echnological processes, devices and systems

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Summary: The optimal planning of experiments methodology by cost and time-consuming expenses has been developed. Hardware and software have been proposed for its implementation. The developed methodology has been tested in the investigation of a number of processes, devices and systems.

Key words: methodology, cost, time, optimal experiment plan, software and hardware.

INTRODUCTION

The problem of obtaining mathematical models appears in solving problems of optimization and control of various objects. At that, naturally, researchers aspire to develop these experimental models at minimal cost and time expenses. For this purpose, the optimal planning of experiments methodology by cost and time-consuming expenses has been worked out [2, 3, 9, 10, 15, 20].

MATERIALS AND RESEARCH RESULTS

The developed methodology includes a complex of methods for experimental plans, software and hardware optimization and their implementation (fig. 1).

The complex of methods allows to synthesize experiment plans that are optimal by cost and time-consuming expenses. Moreover, at that the method of iterative optimal by cost and time-consuming expenses experiment planning [1,

11-14, 17] is appropriate for objects with a number of significant factors $k \leq 4$, the method of sequential optimal by cost and time-consuming expenses experiment planning [4, 5, 8, 16] - for objects with the number of factors $k > 4$ and branch and bound method [6, 21, 22] and the method of successive approximations [7] should be used for $k > 3$. Optimal by cost and time-consuming expenses experiment planning method [18] is used to study dynamic objects. Which is a modification of the iterative experiment planning for static objects.

To implement the proposed methods, a complex of software systems have been developed, which are granted certificates of registration of product copyright at the State Department of Intellectual Property of Ukraine.

To implement the optimal plans on the research object which have been obtained by software, hardware has been worked out, which is protected by patents of Ukraine.

Fig.2 shows the list of the developed software and hardware for the synthesis and implementation of optimal by cost and time-consuming expenses experiment plans. The following methods are used: analysis of the permutations rows of the matrix of experiment planning, random search [23], branches and bounds [24], successive approximation [19, 25] to optimize the experiment plans by the specified criteria.

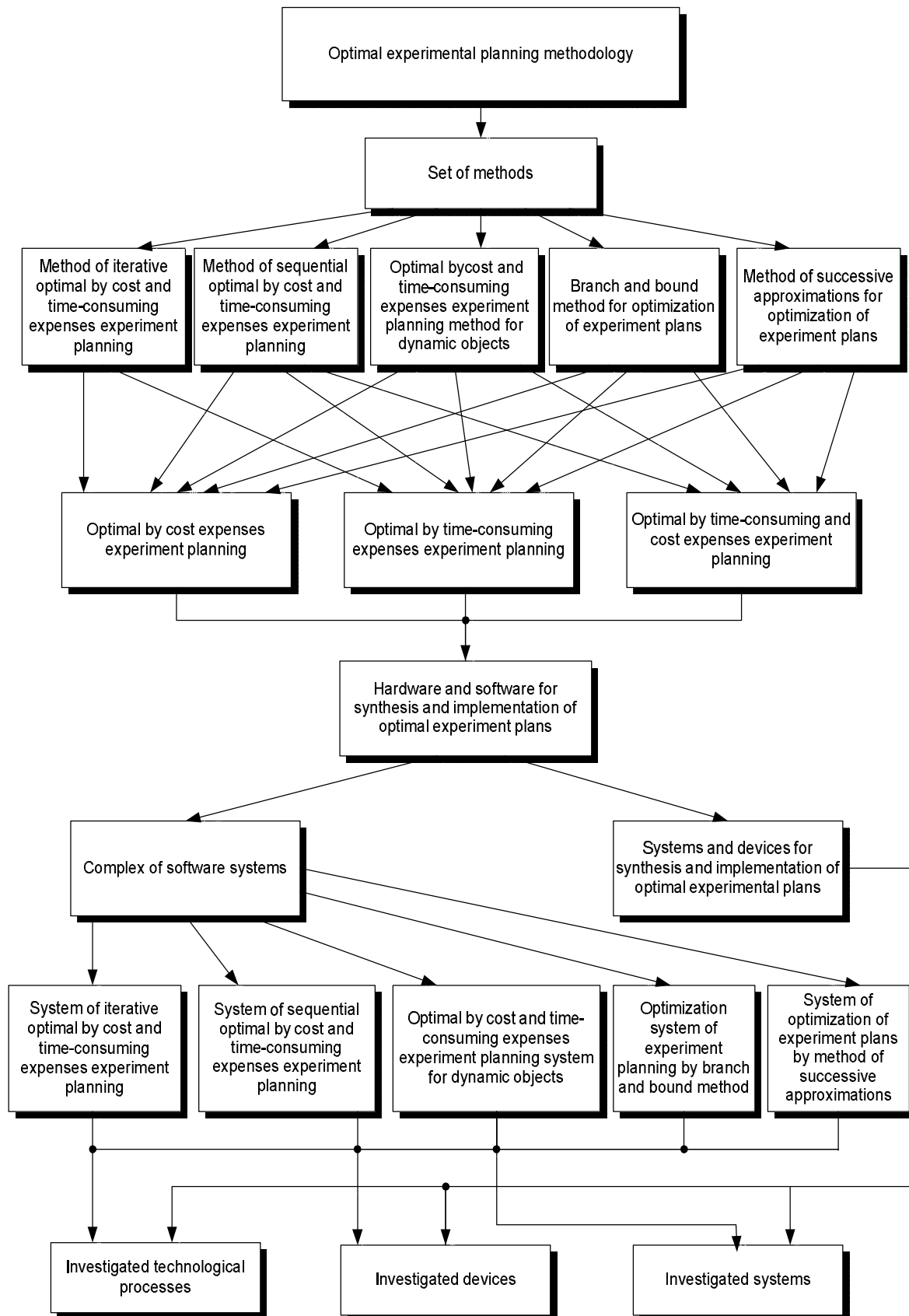


Fig. 1. Methodology for optimal planning of experiments

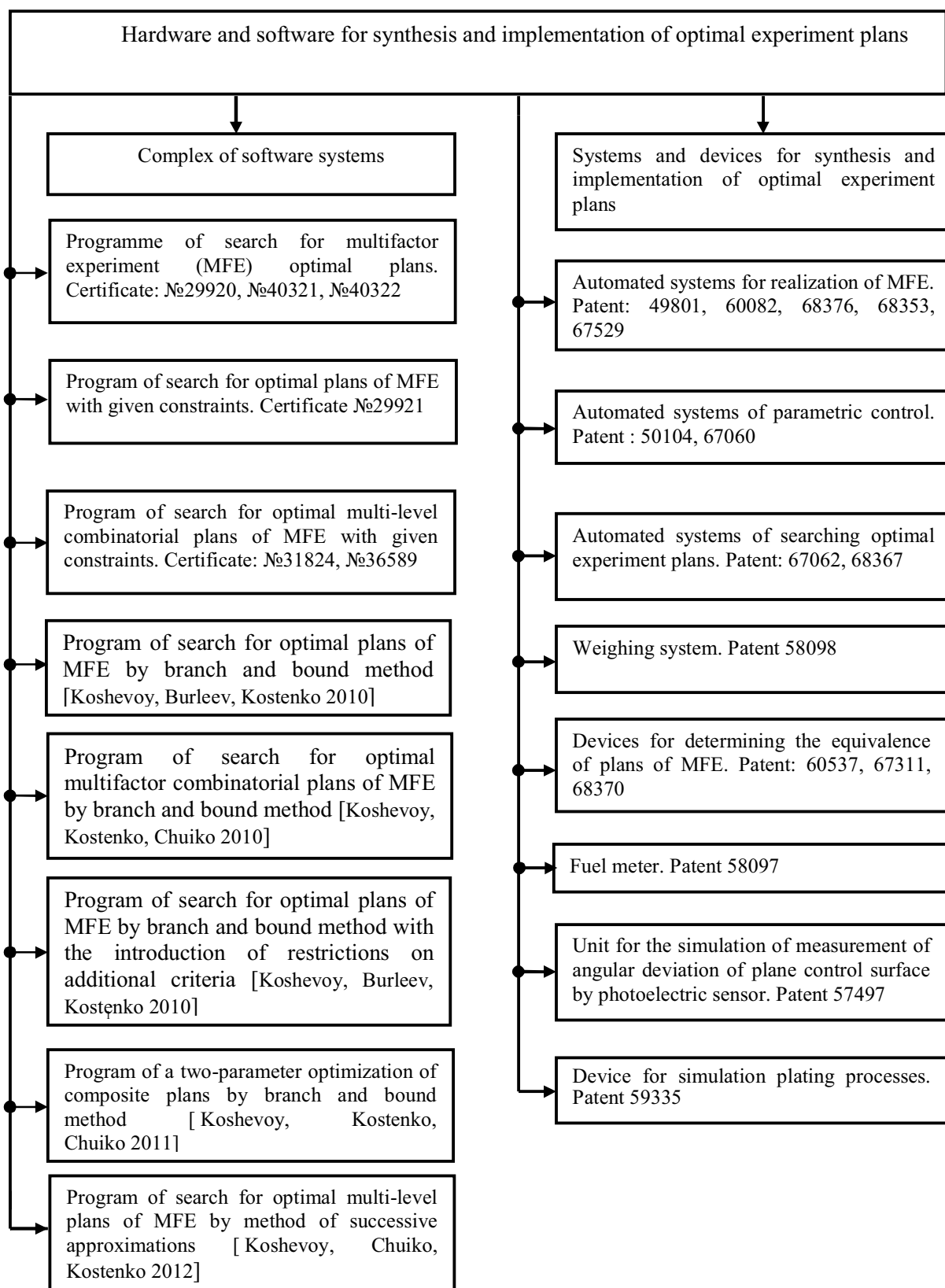


Fig. 2. Software and hardware of optimal experiment planning methodology

Table. Results of investigating software on a number of real and simulated devices

Object of study		Plan of the experiment	Number of factors K and experiments N	Optimization method	Gain in cost or time (times)
1		2	3	4	5
TECHNOLOGICAL PROCESSES	Calibration process of hydrometers [Koshevoy, Kostenko, Zabolotny, Pavlik, Tsehovskyy, Knish 2010]	Complite factor experiment (CFE)	K=2; N=4	Analysis of permutations	cost 1,14
	Process of electroplating copper plating of printed circuit boards [Koshevoy, Kostenko, Zabolotny, Pavlik, Tsehovskyy, Knish, 2010]	CFE	K=4; N=16	Analysis of permutations	cost 1,5
				Random search	cost 1,9
	Process of measuring the metallization area of printed circuit boards [Koshevoy, Kostenko, Zabolotny, Pavlik, Tsehovskyy, Knish, 2010]	Fractional factor experiment (FFE)	K=4; N=8	Analysis of permutations	cost 1,5
	Production of semiconductor devices [Koshevoy, Kostenko 2009]: process of ultrasonic cutting of plates; fusion crystal process; etching process	CFE	K=3; N=8	Analysis of permutations	cost 1,6
		FFE	K=4; N=8	Analysis of permutations	cost 1,4
		Rotatable central composite planning (RCCP)	K=2; N=13	Analysis of permutations	cost 1,77
				Branch and bound:	
				algorithm 1;	cost 2,54
				algorithm 2	cost 3,06
	Process of forming the body cutters [Koshevoy, Kostenko 2009]	FFE	K=5; N=8	Analysis of permutations	cost 1,5
	Process of manufacture of the reinforced parts [Koshevoy, Kostenko, Gordienko, Syroklyn 2011]	FFE	K=4; N=8	Analysis of permutations	cost 2,21
	Process of testing electronic devices [Koshevoy, Kostenko, Gordienko, Syroklyn 2011] stage 1 stage 2	Plakett-Berman	K=7; N=8	Analysis of permutations	
					cost 3,37
					cost 3,24
	Work of the radar station operator [Koshevoy, Kostenko 2010]; modes of operation; resistant performance	RCCP	K=5; N=32	Branch and bound:	
				algorithm 1;	time 3,8
				algorithm 2	time 3,95
		FFE	K=5; N=16	Analysis of permutations	time 1,64
				Random search	time 7,40
	Work of the radioelectronic station operator [Koshevoy, Kostenko 2010]	RCCP	K=5; N=32	Branch and bound:	
				algorithm 1;	time 1,67
				algorithm 2	time 1,73

1		2	3	4	5
	Machines service with numerical program control [Koshevoy, Kostenko 2010]: modes of operation;	RCCP	K=5; N=32	Branch and bound:	
	productivity of the plant site			algorithm 1;	time 1,36
				algorithm 2	time 1,38
		CFE	K=4; N=16	Analysis of permutations	time 1,17
				Random search	time 1,00
	Process of deep plasma-chemical etching [Koshevoy, Burleev, Kostenko 2010]	CFE	K=3; N=8	Branch and bound T _{lim} =150 min	cost 1,28
	The process of producing porous materials [Koshevoy, Chuiko, Kostenko 2011]	Orthogonal central composite planning (OCCP)	K=4; N=25	Branch and bound	Cost 5,47
					Time 7,33
	The process of preparation of mince [Koshevoy, Kostenko, Rozhnova 2010]	CFE	K=2; N=4	Analysis of permutations	Cost 2,57
	The process of making popcorn [Koshevoy, Dergachev, Burleev, Kostenko, 2011]	FFE	K=5; N=18	Successive approximation	Cost 3,36
Analysis of permutations				Cost 1,37	
Random search				Cost 2,26	
DEVICES	Contactless gauges of direct currents [Koshevoy, Kostenko, Zabolotny, Pavlik, Tsehovskyy, Knish 2010]:	CFE	K=2; N=4	Analysis of permutations	Cost
	voltage of 9 V;				1,33
	voltage of 5 V				1,34
	Eddy current gauges dielectric coatings [Koshevoy, Kostenko, Zabolotny, Pavlik, Tsehovskyy, Knish, 2010]	CFE	K=4; N=16	Analysis of permutations	Cost 1,81
				Random search	Cost 2,01
				Iterative planning	Cost 1,78
	Device for monitoring the quality of dielectric materials [Koshevoy, Kostenko, Zabolotny, Pavlik, Tsehovskyy, Knish 2010]	CFE	K=4; N=16	Analysis of permutations	Cost 1,2
				Random search	Cost 1,0
				Iterative planning	Cost 2,13
				Branch and bound	Cost 1,44
Photoelectric transducers of angular displacements: placement of optical fibers [Koshevoy, Burleev O.L., Kostenko, 2010];	CFE	K=3; N=8	Analysis of permutations	Cost 1,3	
	output parameters [Koshevoy, Kostenko, Zabolotny, Pavlik, Tsehovskyy, Knish 2010]	OCCP	K=3; N=15	Branch and bound	Cost 1,67
Moisture meters of bulk materials [Koshevoy, Kostenko, Zabolotny, Pavlik., Tsehovskyy, Knish 2010]				CFE	K=3; N=8

1		2	3	4	5
Semiconductor thermo-regulator [Koshevoy Kostenko, 2009]		CFE	K=4; N=16	Analysis of permutations	Cost 1,5
				Random search	Cost 2,48
		Addition to RCCP	K=4; N=15	Analysis of permutations	Cost 1,99
				Random search	Cost 2,31
		RCCP	K=4; N=31	Branch and bound: algorithm 1;	Cost 3,05
				algorithm 2	Cost 4,19
Weighing system [Koshevoy, Kostenko, Zabolotny, Pavlik., Tsehovskyy, Knish 2010] System for determining fuel consumption of internal combustion engine [Koshevoy, Kostenko, Zabolotny, Pavlik., Tsehovskyy, Knish 2010] Ship power plant unit [Koshevoy, Kostenko 2009] Complex of technical systems [Koshevoy, Kostenko, 2010]: maintenance; shutdown system Tracking system [Koshevoy, Kostenko 2009]	Weighing system [Koshevoy, Kostenko, Zabolotny, Pavlik., Tsehovskyy, Knish 2010]	CFE	K=3; N=8	Analysis of permutations	Cost 1,61
	System for determining fuel consumption of internal combustion engine [Koshevoy, Kostenko, Zabolotny, Pavlik., Tsehovskyy, Knish 2010]	CFE	K=2; N=4	Analysis of permutations	Cost 1,2–1,3
	Ship power plant unit [Koshevoy, Kostenko 2009]	CFE	K=3; N=8	Analysis of permutations	Cost 1,5
	Complex of technical systems [Koshevoy, Kostenko, 2010]: maintenance; shutdown system	RCCP	K=4; N=31	Branch and bound: algorithm 1;	Time 1,5
				algorithm 2	Time 1,55
	shutdown system	FFE	K=5; N=16	Analysis of permutations	Time 1,35
				Random search	Time 2,85
	Tracking system [Koshevoy, Kostenko 2009]	CFE	K=3; N=8	Analysis of permutations	Cost 3,78

The developed methodology has been tested in the studying of a number of technological processes, devices and systems. In all the cases, while study the said objects cost and time-consuming expenses benefit has been gained compared with the initial plans of the experiment (table).

CONCLUSIONS

1. A methodology by the optimal cost and time-consuming expenses of experiment planning has been developed, which improves the efficiency of experimental studies aimed at modeling and optimization of real objects.

2. Software and hardware have been developed that enable to effective by use the developed methodology of optimal planning experiments.

3. The efficiency and effectiveness of the proposed methodology have been proved by testing it on a number of technological processes, devices and systems.

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ПРИМЕНЕНИЕ МЕТОДОЛОГИИ
ОПТИМАЛЬНОГО ПЛАНИРОВАНИЯ
ДЛЯ ИССЛЕДОВАНИЯ ТЕХНОЛОГИЧЕСКИХ
ПРОЦЕССОВ, ПРИБОРОВ И СИСТЕМ

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Елена Костенко, Виктория Рожнова*

А н н о т а ц и я. Разработана методология оптимального планирования экспериментов по стоимостным и временным затратам. Для ее реализации предложены программно-аппаратные средства. Разработанная методология апробирована при исследовании ряда процессов, приборов и систем.

К л ю ч е в ы е с л о в а. методология, стоимость, время, оптимальный план эксперимента, программно-аппаратные средства.

Improving efficiency of train traction operational standards: an approach with usage of simulation

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Summary. The paper gives the results of the research on the correction of the train operation model by means of test data. Simulation makes it possible to replace long-term test cruises by relevant calculated data, allowing to reduce the fuel and energy consumption, improve transportation of cargo and passengers.

Key words. Train traction, efficiency improvement, operation standards, test cruises, simulation.

INTRODUCTION

The introduction of the new series of locomotives is connected with forecasting the train traction operational standards. Such standards include the train weight standards Q , train schedule $\{T\}$ and train control modes by the established schedule $\{u\}$, and their corresponding rates of traction fuel and energy consumption E .

The effectiveness of transportation process is highly dependent on the values of the given standards. This accounts for the objective of efficiency improvement of these standards. It can be formulated as a specific energy resource discharge function minimization:

$$e = \frac{E(Q, \{T\}, \{u\})}{Q} \rightarrow \min. \quad (1)$$

This objective is topical for the replacement of engine stock by new series, for which the set of standards must be specified for the first time. Under conditions of Ukraine's railways, such

objective is still topical both for the existing and the modernized locomotives.

RESEARCH ANALYSIS

The solution of the given objective is based on the identification of the actual traction and power characteristics of locomotives in operation. Besides it is necessary to know the operational conditions of a specific site, which causes a choice of driving modes of trains.

Traditionally the solution of similar objectives have relied on two approaches. According to the first one, models with various specifications which then were used for estimation and optimization of standards of train traction were formed.

Train movement simulation leans on classical postulates of the theory of locomotive traction [11, 18]. More detailed models for the solution of specific objectives are known as well: efficiency specifications [7], mode of electrodynamic braking [15], for diesel engine with sequential turbocharging [2] and for two units system locomotives [12].

Researchers have accumulated high scientific potential with the solution of train dispatching optimization tasks [1, 8, 20]. It led to adaptation of specific technical systems for locomotives performance improvement [4, 16].

However researchers note considerable divergence in the results of simulation, which can

be explained by deviations in the real train characteristics [14]. Therefore a skilled control of the results in the course of test cruises is required [17, 21]. The technological level of modern measuring systems allows obtaining exhaustive data about the traction-energy processes in the train [19].

But in the long-term perspective a great number of test cruises is economically inefficient. Besides, the necessity of the modes and conditions constancy during the test is still difficult to achieve.

RESEARCH OBJECT

Therefore the authors of the article assumed that the efficiency of train traction process experimental studies can be increased by the addition of computer simulation to the full-scale tests, which simulate the conditions of test cruises. For this purpose it is necessary to correct the design model, in order to achieve its adequacy, and then to use this model in simulation.

In order to determine the optimum train locomotives operational standards a new approach has been developed [9]. According to it a set of correcting factors is used as an assessment of divergence between ideal (passport) and actual model characteristics. These factors are found out as a result of measurement data processing. The approach, stated in [3], can be used for measurement database processing.

In order to estimate the divergence of power characteristics (traction power, specific resistance and braking forces) the external parameter as of the train system has been chosen as a reduction factor, while the correction factors are to be calculated under condition of a minimal divergence line between the estimated and the actual profiles of the site [12].

The advantage of such a method is a linear accumulation of divergences, estimated to determine if the adjustment is necessary, and the calculation of correction coefficients with the use of simple algebraic operations. This makes it possible to control parameters of the train in real time during a cruise which is essential for the onboard locomotive decision support systems.

The corrected model of the train taking into account correction coefficients is the following: upon transition from step n to $n+1$:

$$f_k(v_n, u_n) = \frac{F_k(k_I(u_n) \cdot I_d(v_n, u_n), u_n)}{(P + Q)g}, \quad (2)$$

$$\left. \begin{aligned} s_{n+1} &= s_n + \Delta s, \\ v_{n+1}^2 &= v_n^2 + 2\Delta s \zeta [k_f f_k(v_n, u_n) - k_w w_o(v_n) - \\ &\quad - k_b b(v_n, u_n) - i(s_n)], \\ \Delta t_n &= \frac{2 \cdot 60 \Delta s}{v_{n+1} + v_n}, \quad t_{n+1} = t_n + \Delta t_n; \end{aligned} \right\}, \quad (3)$$

$$\tau_{n+1} = \tau_\infty (k_I(u_n) \cdot I_d(v_n, u_n)) \frac{\Delta t}{T(k_I(u_n) \cdot I_d(v_n, u_n))} + \\ + \tau_n \left(1 - \frac{\Delta t}{T(k_I(u_n) \cdot I_d(v_n, u_n))} \right), \quad (4)$$

$$E_n = \left[\frac{k_I(u_n) I_d(v_n, u_n) U_e(s_n) p(u_n) \Delta t_n}{6 \cdot 10^4}, \right. \\ \left. G(u_n) \Delta t_n, \right] \quad (5)$$

where: P – locomotive weight [t]; k_I – engine characteristic change correction coefficient; k_f , k_w , k_b – traction change, resistance and braking correction coefficients; I_d – engine current [A]; s – train track [km]; v – speed [kmph]; ζ – proportionality coefficient [kmph²/(N/kN)]; w_o and b – specific resistance and braking forces [N/kN]; t and Δt – operation and move out time [min]; τ – engine superheat temperatures [°C]; T and τ_∞ – engine thermal characteristic; U_e – supply voltage (for electric locomotive) [V]; p – the number of engine bypassing; G – fuel consumption (for diesel locomotive) [kg/min].

At each “run” of the model, the optimum mode of train operation is used according to the criteria:

$$H^* = E + \lambda_1 T + \lambda_2 M + \lambda_3 \tau \rightarrow \min, \quad (6)$$

where: T – travel time through the site; M – the number of controller switches by train-operator; λ_1 , λ_2 , λ_3 – corresponding factors estimation coefficients.

The discrete variant of dynamic programming was used as a working optimization method, as it does not require the models simplification. According to this method the authors developed the corresponding computing algorithms.

RESULTS OF RESEARCH

Basing on numerous calculations the authors have found out that the results for the corrected model differed from the data of full-scale measurements within 1,5%. For the same operation

modes calculations for ideal model gave divergences to 5% on energy consumption and 7% on track time [10].

Thus the implemented correction of the model allowed achieving its adequacy to specific operational conditions, and then the model can be used for train traction power optimization.

The simulation process can be presented as follows:

1. Estimation of the train weight critical norm Q ,
2. Distribution of the train diagram between spans $\{T\}$,
3. Efficiency improvement of the operational modes on every span $\{u\}$,
4. Calculation of the fuel and energy consumption.

Such program includes all tasks defined by the regulatory requirements.

According to the methods [Enterprise standard 2010 “Arranging rolling stock operational tests”], the estimation measure for train weight critical standard is the rates for the locomotive wheel creep on the calculated ascent. They were estimated with the simulation results depending on the coefficient:

$$k_{\psi} = \frac{F}{1000\mu P_g}, \quad (7)$$

where: F – traction force implemented without critical creep;

μ – creep coefficient of traction.

The example of k_{ψ} coefficient distribution according to two train weights is shown in fig. 1.

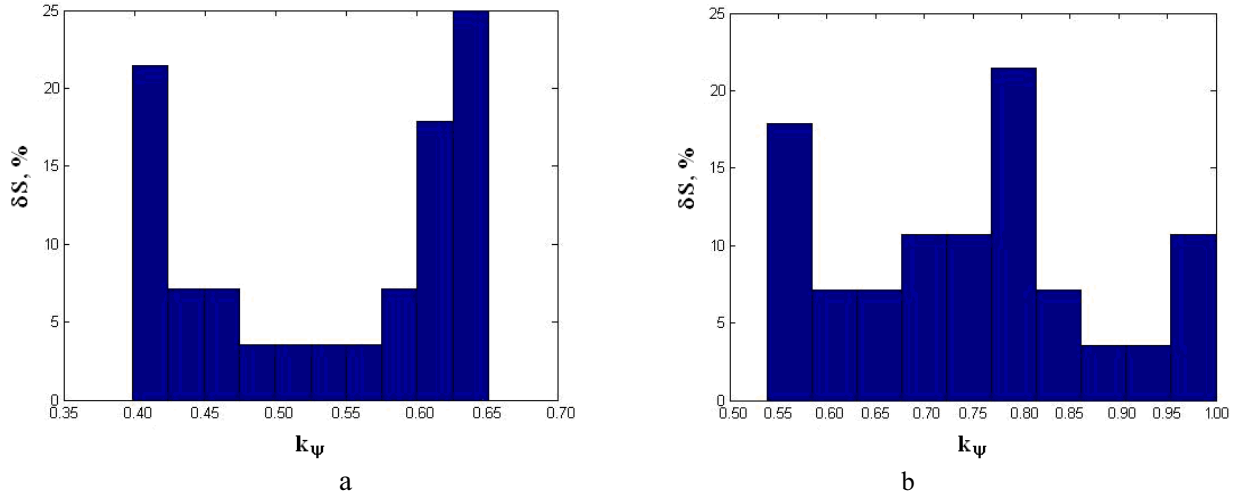


Fig. 1. The k_{ψ} coefficient distribution along the length of ruling gradient for train with $Q=4200$ t (a) and $Q=5400$ t (b)

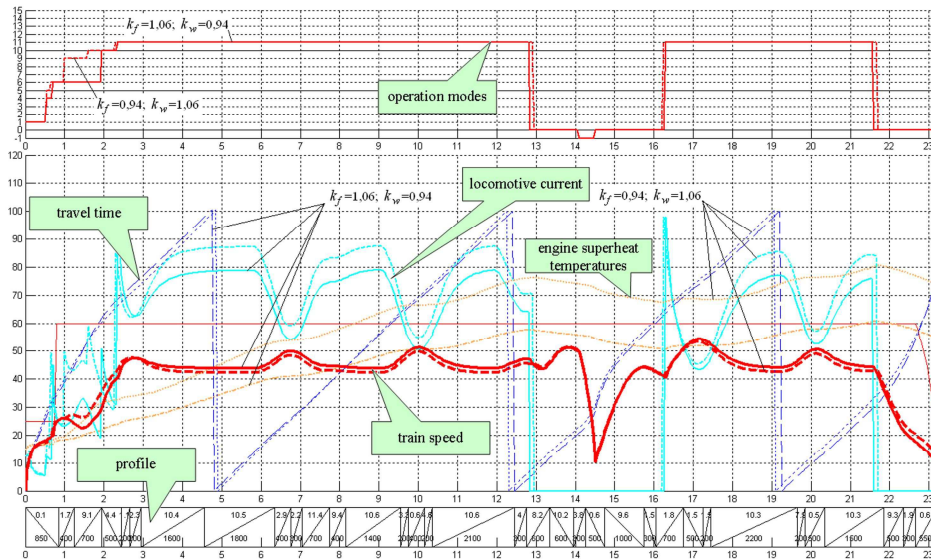


Fig. 2. Determination of optimum operation modes for different operational conditions

As you can see, for the train weight of 4200 t (existing standard) the k_{ψ} coefficient has values up to 0,65, which considers a reserve on locomotive traction force. With the increase of train weight up to 5400 t, on the most part of calculated ascent (about 54%) the locomotive goes with $k_{\psi} > 0,75$, and site extent with $k_{\psi} > 0,85$ and $k_{\psi} > 0,95$ doesn't exceed respectively 22% and 10% of the calculated ascent. The results of the simulation were confirmed during test cruises, thus the model yielded reliable result.

The application of simulation with estimation of the influence by variation of operational factors can be especially effective (in comparison with full-scale tests). In fig. 2 the optimum operational modes for tow extreme possible variants of combination k_f and k_w coefficients are presented. According to calculation results, this optimum operation mode can be recommended as stable.

For the research on the stability of optimum operation modes for this site the simulation was carried out for various combinations of coefficients of k_f , k_w and λ_I , that corresponds to various technical condition of the locomotive, train and the time taken (fig. 3, 4). The real-life cruises would require considerable time and constancy adherence of all external conditions.

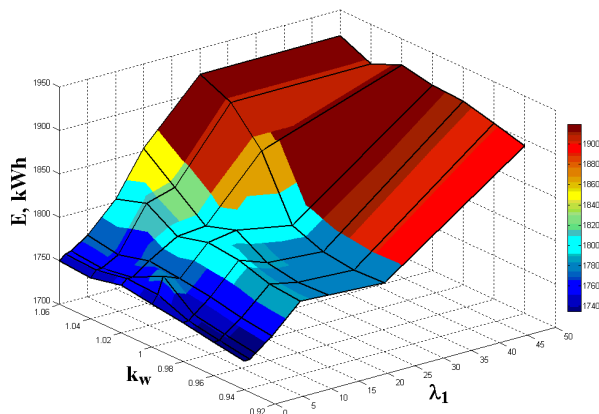


Fig. 3. Power consumption E depends on λ_I and k_w (with fixed value $k_f=0,99$)

It has been stated that at fixed values of λ_I of time table and k_f coefficient value e can change due to the resistance characteristics of structure up to 3%. On the other hand, due to the change of k_f coefficient (a technical condition and locomotive tracking characteristics) the divergence of consumption e (at preservation of optimum operation mode) can reach 16%. The obtained data allow to specify local traction power consumption

standards and analyze the results of introducing the train automated control system.

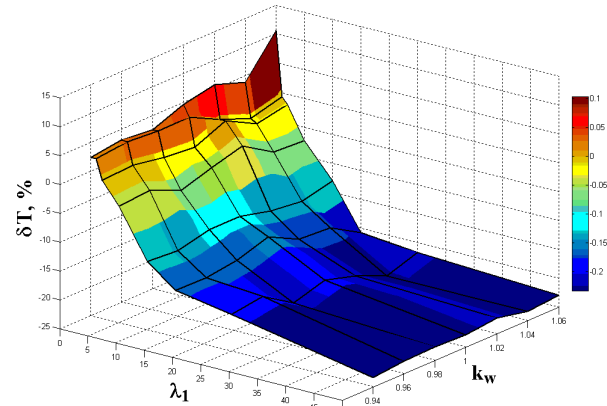


Fig. 4. Timetable lag δT depends on λ_I and k_w (with fixed value $k_f=0,99$)

CONCLUSIONS

1. General principles, algorithms and software have been developed to make corrections to the characteristics of ideal train model by test results and calculate the optimal operational standards for trains.
2. This method can be applied to improve efficiency of train traction standards at certain parts of Donetsk Railway.
3. The simulation according to the programme of test cruises showed positive results, making it possible to reduce the fuel and energy consumption.
4. Moreover the test quality improves, because the simulation determines the use of modes and parts of the railway to study during the real cruises.

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ОПТИМИЗАЦИЯ ЭКСПЛУАТАЦИОННЫХ ПОКАЗАТЕЛЕЙ ТЯГИ ПОЕЗДОВ: ПОДХОД С ИСПОЛЬЗОВАНИЕМ МОДЕЛИРОВАНИЯ

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Сергей Матвиенко*

А н н о т а ц и я . Изложены основные принципы построения адекватной модели тяги поезда, скорректированной на основании данных опытных поездок. Использование такой модели позволяет определить рациональные значения эксплуатационных показателей и нормативов тяги поездов с учетом местных условий, и, следовательно, повысить эксплуатационную и энергетическую эффективность перевозочного процесса.

К л ю ч е в ы е с л о в а . Тяга поездов, оптимизация, эксплуатационные показатели, опытные поездки, моделирование.

Determination of traction and dynamic qualities of the electric train with operated pneumatic suspension

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Summary. The purpose of this article consists in research of traction and dynamic indicators of an electric train with operated pneumatic suspension. The object of research is pneumatic suspension of a high-speed railway transport. Work is performed by a method of theoretical research of control systems of pneumatic suspension. In article the algorithm of work of a control system is considered by pneumatic suspension. And traction and dynamic indicators of an electric train with operated pneumatic suspension are also defined. The developed control system is recommended for use on passenger high-speed railway transport.

Key words: pneumospring, sensor, servomotor, GPS navigator, dynamic indicators.

INTRODUCTION

The future of control systems is connected by pneumatic suspension with control of geometry of a way and parameters of interaction of a wheel and a rail [1, 2]. Therefore the management development of systems with using of GPS is the actual task demanding the decision [18]. Proceeding from told above, the control system of pneumatic suspension which differs from standard ER-200 established on an electric train was developed. The offered system allows to make management of damping of fluctuations, to regulate floor level depending on a static deflection, from the speed of movement and a condition of a way, using GPS system data [12, 17]. It represents the module in structure of which three classical subsystems enter: measuring, decisive (managing director) and executive. The measuring subsystem consists of the sensor of height of level of a floor, a global system of positioning, the switchboard and the analog-digital converter [19]. The decisive subsystem is presented to the computer. It has the external

(system) interface. The executive subsystem consists of two electric air gates. And also from a servomotor and a three-stage throttle which regulate air supply from the additional tank in a pneumospring. The object of management is the pneumospring [20].

The algorithm of work of system is described as follows, at the movement of the vehicle there is a vertical relative movement of a magnet along a plate to gerkonov's sensors [14, 15]. At a deviation of a magnet of rather initial situation the signal Δ which arrives on the computer (up-down) is formed. In a case excess of level it is necessary to turn on dumping electric air gate which will let out a quantity of the compressed air, and at level reduction, it is necessary to turn on the electric air gate of the forcing highway via which the compressed air in a pneumospring moves. Set turn of a shaft of a servomotor establishes the section of a throttle necessary for damping [13].

For definition of traction and dynamic indicators of an electric train AYR 200 with the developed control system the software developed on chair of railway transport of VNU of V. Dahl and adapted for the solution of problems of this work was used. The system consists of 27 bodies (bodies 1, sides 4, cross beams of carts 2, ATED 4, an anchor of ATED 4, wheel steam 4, and rails 8), each of which has six degrees of freedom [13]. Rails under each wheel have two degrees of freedom (the discrete model of a way is considered). Dynamic indicators of an electric train were determined for the range of speeds of movement from 5 to 45 m/s with in a draft mode by a direct site of a way. The settlement scheme of an electric train of ER-200 is submitted in (fig. 1.)

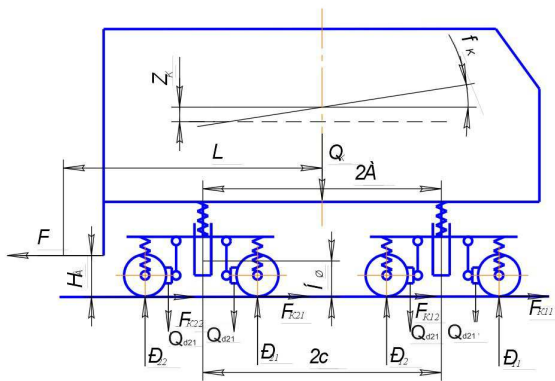


Fig. 1. Settlement scheme of an electric train of ER200

Calculations were carried out for four options of a rigidity of the second step of spring suspension: for spring 5518 kN/m, for pneumatic 3200, 3400, 3600 kN/m. And also for four conditions of a way: excellent, good, satisfactory and unsatisfactory which in the program are characterized by amplitudes of vertical roughnesses, respectively 0.01, 0.014, 0.02, 0.025 m (fig. 2) [6, 7].

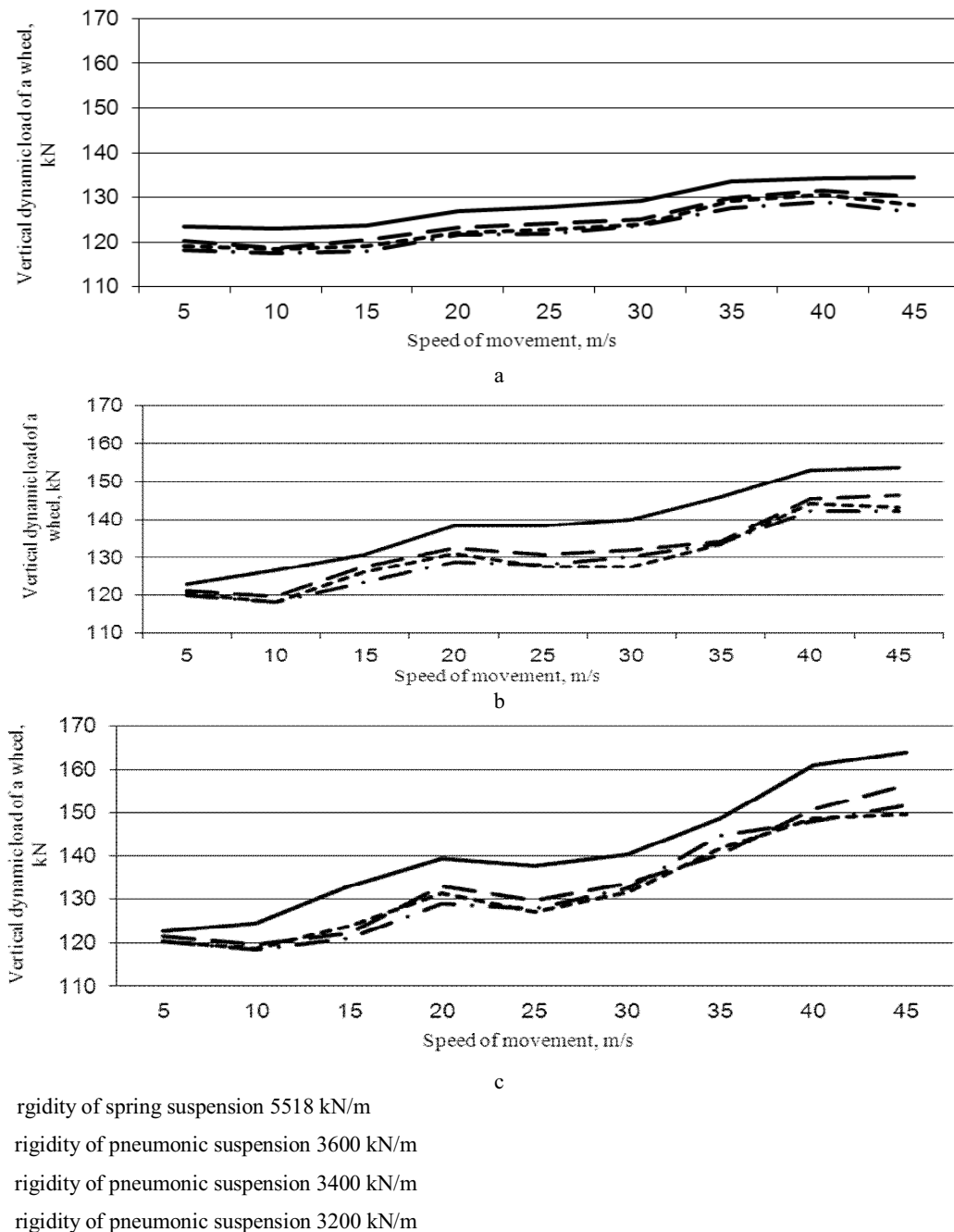


Fig. 2. Theoretical dependences of dynamic vertical loading on a wheel on a rail from the speed of movement and rigidity of suspension for an electric train: a) excellent condition of a way; b) satisfactory condition of a way; c) unsatisfactory condition of a way

As showed calculations for mathematical model of movement of an electric train application of pneumatic suspension allows to reduce dynamic influence from a wheel by a rail in the range of speeds from 5 to 45 m/s twice in comparison with spring suspension with 17,3 to 9,8%.

Deterioration of a condition of a way leads to increase in dynamic loading from a wheel on a rail: at a speed of 20 m/s for PS (pneumatic suspension) to 3%; for a spring set to 4,2%; at a speed of 40 m/s for PSS to 5,6%; for a spring set to 8,5% (fig. 2).

With change of vertical rigidity of pneumatic suspension with 3200 to 3600 kN/m the increase in dynamic loading from a wheel on a rail to 2% for a way in an unsatisfactory condition is observed.

Proceeding from told above, it is possible to draw the following conclusion that pneumatic suspension application with possibility of regulation of its rigidity allows to reduce dynamic impact on a way in comparison with spring RP and to increase the speed of movement of the rail vehicle with preservation of satisfactory qualities on indicators of vertical dynamics [9, 10]. We carried out an assessment of change of indicators of dynamics from regulation parameters. The virtual site of movement (5000 m long) is generated for this purpose. The site is randomly broken into 6 pieces, to each of which the condition of a way corresponds there. For the set way a series of calculations in the range of speeds of movement from 5 to 45 m/s was carried out.

As results of calculations showed, at speeds of movement up to 30 m/s spring suspension rather well carries out vibroprotective function. However at movement over 30 m/s are desirable to regulate rigidity of suspension that allows to do pneumatic suspension.

In order that on all generated site the coefficient of vertical dynamics didn't exceed an indicator with level "well" it is offered on each of sites of a way to regulate rigidity. Recommended parameters of regulation of rigidity of the second step of suspension are presented in table 1.

Table 1. The control parameters of pneumatic suspension

The indicator bumps, m	0.01	0.014	0.02	0.025
The rigidity of the 2nd stage spring suspension, kN / m	3600	3400	3400	3200

Results of regulation are presented in fig. 3 and they show that at movements of a rolling stock with a speed over 30 m/s improvement of coefficient of vertical dynamics at regulation of

rigidity of pneumatic suspension on the average for 25%, in comparison with spring suspension, for 5% in comparison with unregulated pneumatic suspension is observed.

Thus regulation of rigidity of pneumatic suspension in the range from 3200 to 3600 kN/m allows us to achieve indicators of dynamic qualities with level "well" on way pieces with various limit parameters of roughnesses. While for traditional spring suspension the dynamic indicator corresponds to an assessment badly.

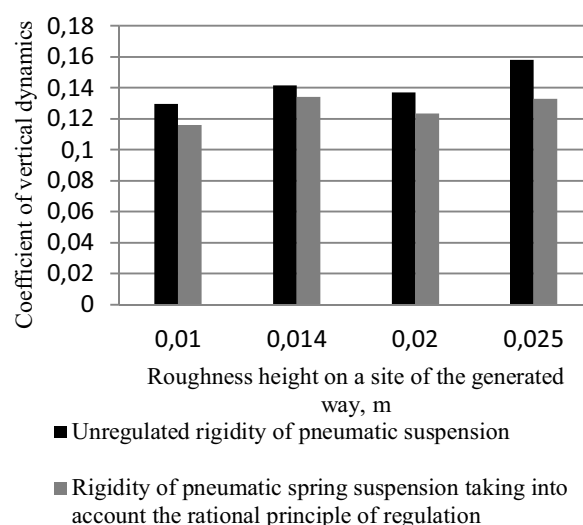


Fig. 3. Change of coefficient of vertical dynamics depending on a condition of a way at a speed of 40 m/s

In design and design practice as criterion of an assessment of traction properties of the locomotive the concept use of coupling weight is accepted η_u [3, 8]. The coefficient η_u qualitatively characterizes change of vertical loading of wheel couple at development by the engine of force of draft. For the biaxial engine of value of coefficient of unloading of wheel couple are defined by base of a body and full wheel base and don't depend on height h_u . We carried out an assessment of application of pneumatic suspension for regulation of traction indicators of an electric train. The design of a pneumospring provides placement in a rubber-metal element, or a metal spring. Vertical rigidity of these elements is higher, than pneumosprings [11]. Therefore for increase in efficiency of coupling weight we offer to adjust at the time of start-off pressure in a pneumospring so that the body of the locomotive leaned on springs or rubber-metal elements. It allows to reduce turning moment of a body in the vertical plane and

more ravnonomerno to distribute loading between wheel couples. For an assessment of influence of such redistribution on efficiency of coupling weight a series of calculations is carried out [16].

For calculations the Mathcad package was used. Calculations showed that regulation of rigidity of pneumatic suspension allows to improve efficiency of coupling weight at the time of start-off on the average to 2,5%.

CONCLUSIONS

The analysis of calculations for mathematical model of movement of an electric train showed that application of pneumatic suspension allows to reduce dynamic influence from a wheel by a rail, in the range of speeds from 5 to 45 m/s of two in comparison with spring suspension (with 9,8 to 17,3 %)

At deterioration of a condition of a way the increase in dynamic loading is observed at a speed of 40 m/s for pneumatic suspension to 5,6%, for spring to 8,5%.

With change of vertical rigidity of pneumatic suspension with 3200 to 3600 kN/m the increase in dynamic loading to 2% for an unsatisfactory condition of a way is observed.

At movement of a rolling stock with a speed over 30 m/s improvement of coefficient of vertical dynamics at regulation of rigidity of pneumatic suspension on the average for 25% in comparison with unregulated spring suspension, for 5% in comparison with unregulated pneumatic suspension is observed.

The principle of regulation of rigidity of pneumatic suspension for the purpose of improvement of traction characteristics is offered at start-off. That allowed to improve efficiency of coupling weight for 2,5% in relation to a standard electric train.

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ОПРЕДЕЛЕНИЕ ТЯГОВО-ДИНАМИЧЕСКИХ
КАЧЕСТВ ЭЛЕКТРОПОЕЗДА С УПРАВЛЯЕМЫМ
ПНЕВМАТИЧЕСКИМ РЕССОРНЫМ
ПОДВЕШИВАНИЕМ

Краснобрыжева Юлия

Аннотация. Цель данной статьи заключается в исследовании тягово-динамических показателей электропоезда с управляемым пневматическим рессорным подвешиванием. Предметом исследования является пневматическое рессорное подвешивание скоростного железнодорожного транспорта. Работа выполнена методом теоретического исследования систем управления пневматического рессорного подвешивания. В статье рассмотрен алгоритм работы системы управления пневматическим рессорным подвешиванием. А также определены тягово-динамические показатели электропоезда с управляемым пневматическим подвешиванием. Разработанная система управления рекомендуется для использования на пассажирском скоростном железнодорожном транспорте.

Ключевые слова: пневморессора, датчик, серводвигатель, трехступенчатый дроссель, электропневматические вентили, GPS-навигатор, динамические показатели.

Modeling of construction spindle's nodes machining centre

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Summary. The decision of the problem of the determination to softness formative spindle's nodes machining centre tools with NC drill-milling-bore of the group, equipped module complete set of the equipments is present. They are received correlations (the accounting cards, nomogram), allowing to model design two support spindle's nodes with changing complete set of the equipments. The analysis of the influence deformation of supports on two-set rolling bearing on balance of softness of the under investigation nodes tool within their worker of the zone. The order of the using the offered procedure is shown on tool - a representative drill-milling-bore of the group.

Key words: spindel, instrumental block, softness, 3D-modeling.

INTRODUCTION

The Analysis trend developments metal cutting production has shown perspective such design tool, which possess the raised technological possibility on the base machining centre and multi operation tools with NC. Efficiency of the introduction of such equipment is connected with system development of the cutting and auxiliary instruments on module principle. The variety of the types instrumental's block, including auxiliary and cutting instruments on the one hand and increasing of the requirements to quality product does necessary undertaking the studies on provision of stiffness of formative spindle's nodes.

PUBLICATION AND METHOD ANALYSIS

The study to stiffness of formative nodes processing centre average standart size conducted [20]. The Influence of the type, amount and

locations bearing on efficiency spindle's node has considered [11]. The analysis of the springy system "chuck-piece" in turning automatic machine tool on criterion of stiffness has realized [10]. The analytical dependency of the features of the moving the executive organ from constructive parameter tool-hexapod is presented in [14]. The detailed analysis of the influence supports on rolling bearing light series on accuracy and stiffness to speed precession spindel's nodes has conducted [3]. The advantage of the use the noncontact drive tool for increasing technical level are considered in work [6, 13].

Author [20] brings the experimental estimation of the change to stiffness in worker space machine system and her relationship with layout factor and standard size. The study relative to fixed variant of the adjustment main drive and does not take into account the influence instrumental block on value of stiffness that particularly characteristic for machining tool.

The springy system "equipment tooling-instrument" or "equipment tooling - piece" occupies In balance of stiffness tool significant place. The great study of the springy system "chuck-piece" is presented in work [10]. It is offered united model chuck - "beam with restraint" in the manner of springy-friction joint, allowing raise accuracy in calculation strain features of the springy systems tool. Together with that, unlike turning automaton tools in multi-objective tool vastly enlarges the types of the applicable equipment tooling.

OBJECTS AND PROBLEMS

The purpose given work is increasing to efficiency of the process of the designing formative nodes to account of the building unified solid and analytical models (the formula-trench), as well as algorithm of the determination springy-strain features spindle's nodes (SN) multi-objective tool, rig with by module equipment tooling.

THE MAIN SECTION

The modern formative nodes machine tool present itself closed-loop dynamic systems, using module equipment tooling. [2, 8, 16, 19]. Final accuracy and stiffness made product is defined constructive feature of the instrumental equipment, including its are founded- size: lengths to cantilever, diameter to cantilever and others [15].

For study tense-deformed conditions and use the finite element methods [9, 12] necessary to

build 3D-models of the separate piece and assemblies SN [4, 5].

As base design is considered SN ram-type drill-milling-bore machine with NC models SF68VF4 [7], built-in in two-stage drive main motion. In mode of the co-ordination with swivelling table provides processing the pieces with all sides, as well as coaxiality boring hole without reline up pieces. Designed by 3D-model of the drive tool SF68VF4 with use resource KOMPAS-3D on task of the parametric relationships and associations between separate component 3D-assemblies was submitted for fig.1.

Spindle's node given machine centre is considered as beam on two elasticity support, each of which is assembled on two-set radial and thrust bearing, is installed on scheme "Tandem-O" with preliminary preloading in the manner of distance sleeves. Author's are designed by 3D-model of the assembly cored SN with mechanism of the automatic clamp of the instrument in system KOMPAS-3D (fig.2)



Fig. 1. 3D-assembly of the drive main motion

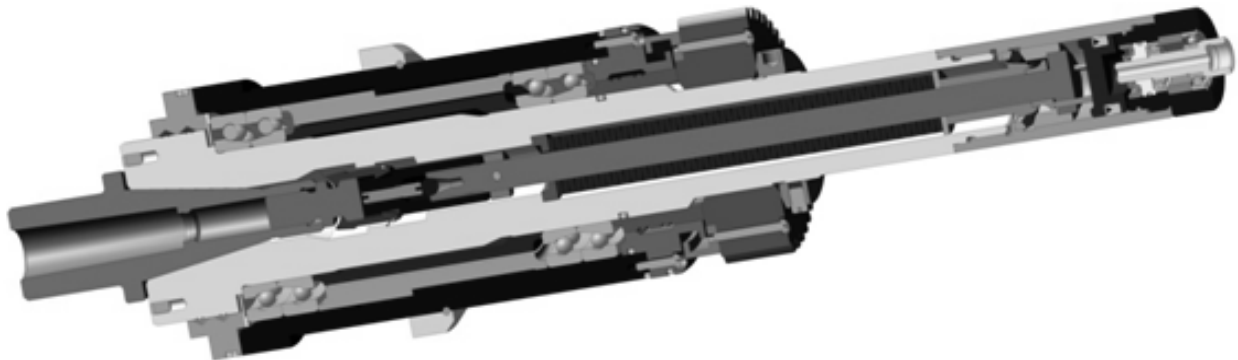


Fig. 2. 3D-assembly spindle's node

For performing the complex engineering analysis, both separates pieces, and assemblies wholly use the module APM FEM [17, 18, 21], equiped SAE - library, realizing decisions of the engineering problems by final element method (FEM). In time of the decision are assigned fastening and put loads; they are assigned coinciding face (for FEM-analysis of the assembly); the generation FEM-nets is realized; the calculation and viewing result in type of the cards of the stress and displacement.

By means of module APM FEM are executed all afore-mentioned actions and are received field of stress (fig. 3) and field of the displacement (fig.4) on ensemble of the sections of the spindle as beam.

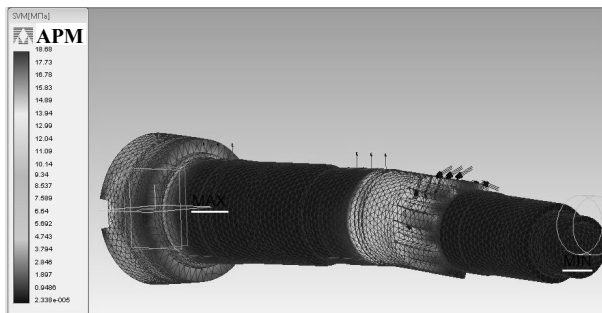


Fig. 3. Fields of the strenth of the horizontal spindle

For study of stiffness we shall form the elasticity-deformation model an two support spindle's nodes with set of the module equipment tooling (the cantilever) different standard size. The

Particularity of the under investigation object is presence two components:

the unified two support SN, which can be used in distinguish machining centre;

the instrumental block - a changeable component, oriented on different range of product.

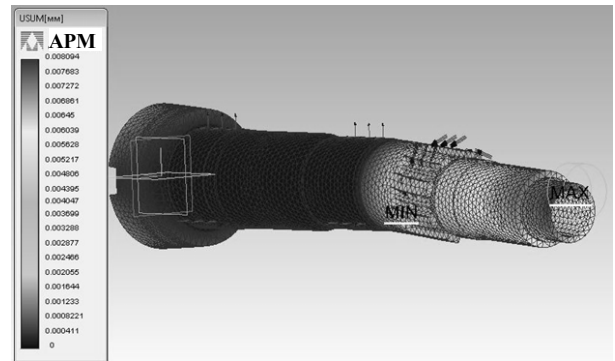


Fig. 4. Fields of the moving the horizontal spindle

The First component (fig. 5) is presented in elasticity-deformation models in the manner of steady-state card $\delta = (\Delta_2 + \Delta_3)$ [12] i.e. in the manner of analytical dependency of the displacement supports Δ_2 and strictly spindle Δ_3 from length of the cantilever ℓ_k . System is used from four linear equations with border condition. As example shall consider spindle's nodes (fig. 5) it is enough wide-spread ram-type specialized tool to models SF68VF4.

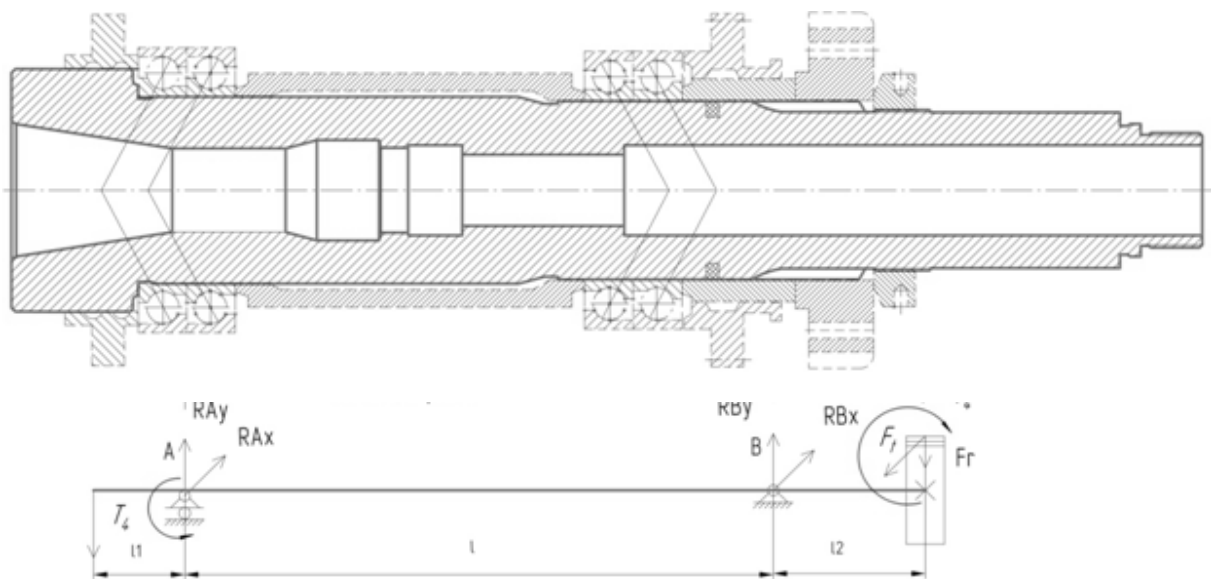


Fig. 5. Constructive and accounting scheme spindle's nodes

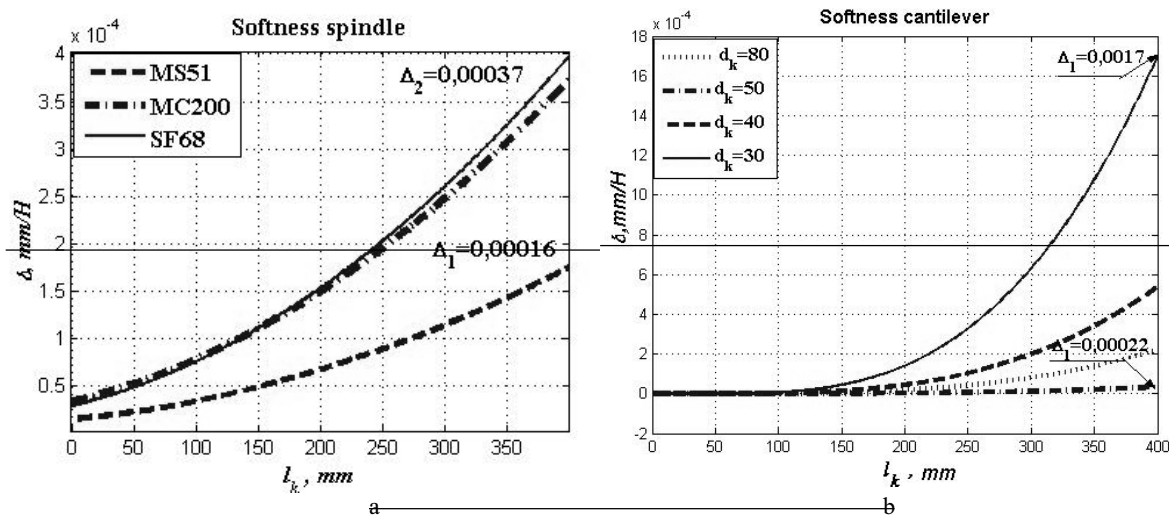


Fig. 6. Softness spindle's nodes (nomogram): a – steady-state cards; b – softness cantilever

In mathematical ambience MAPLE are received values of reactive power and moments on back (z) and front (r) support:

$$R_z = 0,0573 - 0,0028 l_k; R_p = 0,943 + 0,0028 l_k; \\ m_z = 24,97 + 0,098 l_k; m_p = 51,51 + 0,488 l_k.$$

Computable value reaction allow to define deflection and corner of the rotate on the end of the spindle ($x = l + l_1$) depending on lengths l_k instrumental block. The tool-representatives drill-milling-boring group: mode- MS51 with cone of the spindle 30 AT5 on GOST 15945-82; the models SF68VF4 with cone 40 on GOST 936-82; the models MC200PF4V with cone 40AT5 on GOST 15945-82 are selected.

Got in work steady-state cards for tools MS51, SF68, MC200 are provided in table 1.

Table 1. Steady-state cards spindle's nodes

Model	State card
MS51	$(-85,25 - 2,00 l_k + 0,11 l_k^2) \cdot 10^{-8}$
SΦ68	$(30,37 + 0,61 l_k + 0,042 l_k^2) \cdot 10^{-8}$
MC200	$(66,75 + 4,85 l_k + 0,069 l_k^2) \cdot 10^{-8}$

For undertaking express - calculation of one or another adjustment is designed nomograms, consisting of two parts: steady-state card (fig.6, a), built on formula tabl.1 and graphics to softness of the instrumental block Δ_1 (fig.6, b), built for cantilever of the constant section and different importances diameter d_k . The cantilever is considered as beam, restraint in supporting section and loaded in place of the cutting by single power.

Nomogrammy allow quickly to define brought about place of the cutting softness spindle's node, for what it is enough to know the overhang of the instrumental block l_k and diameter d_k cantilever. Softness beside cutter is defined by sum founded on nomogram values ($\Delta_2 + \Delta_3$) and Δ_1 .

In row of the events inaccuracy determinations to general softness SN is connected with absence in accounting model given about springy character bearing support. We shall consider, what influences upon results of the steady-state calculation inaccuracy in determination of linear softness of one bearing [1, 15]. For spindle's nodes tool to models SF68VF4 design value to softness $A_z = 3,99 \cdot 10^{-6}$ and $A_p = 3,93 \cdot 10^{-6}$, mm/N. We shall take else two values of linear softness with deflections:

1. $A_{z1} = 2,59 \cdot 10^{-6}$ and $A_{z2} = 5,39 \cdot 10^{-6}$, mm/N;
2. $A_{p1} = 2,55 \cdot 10^{-6}$ and $A_{p2} = 5,305 \cdot 10^{-6}$, mm/N, and angular softness of one bearing:
 1. $a_{z1} = 0,039 \cdot 10^{-8}$ and $a_{z2} = 0,081 \cdot 10^{-8}$, 1/(N mm);
 2. $a_{p1} = 0,039 \cdot 10^{-8}$ and $a_{p2} = 0,081 \cdot 10^{-8}$, 1/(N mm)/

In this case cards will be of the form of :

1. $\delta = (-71,05 + 0,62 l_k + 0,044 l_k^2) \cdot 10^{-8}$;
2. $\delta = (161,67 + 1,148 l_k + 0,043 l_k^2) \cdot 10^{-8}$.

Dependencies is built on fig. 7 δ from l_k , from which follows that even significant (before 35 %) from-bending to linear softness A_0 one bearing in both sides (overestimate or understatement) from nominal of value little

influences upon softness of the system spindle-cantilever as a whole.

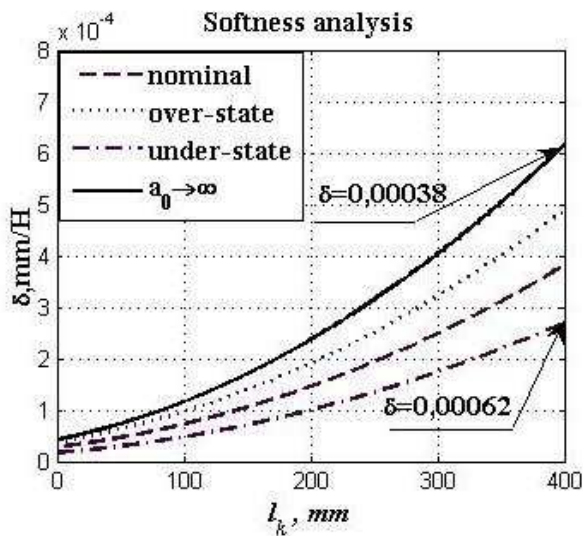


Fig. 7. Study of the steady-state card SN tool SF68PF4

On the other hand unless take into account angular stiffness of the single bearing ($a_0 \rightarrow \infty$) then received following steady-state card (fig. 7, curve, noted utter line):

$$\delta = (1093 + 16.09 l_k + 0.097 l_k^2) 10^{-8}.$$

Obviously, account to angular softness of the single bearing turns out to be necessary since races-even importance SN increases more than 50%. Besides as can be seen from calculation, change to linear softness A_z and A_p support of the spindle in it is enough broad limit without corresponding to from-changing of its diameter does not contribute the essential changes to softness SN (not exceeded 35%).

CONCLUSIONS

As a result offered approach to analysis and modeling to designs spindle's nodes on criterion of stiffness is executed building 3D-models of the separate parts and full 3D-assemblies SN and is organized complex study tense-deformed conditions to designs of the spindle. Built analytical model two-support spindle's nodes (for gamma tool), taking into account general characteristic these design on radial and thrust rolling bearing. By means of such models is realized express-calculation steady-state card in symbol type (tabl.1) for tool drill-milling-boring of the group. This vastly reduces working hours of the design work and opens the prospects of the

scale studies in the field of modeling and improvements modern design spindle's nodes.

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МОДЕЛИРОВАНИЕ КОНСТРУКЦИЙ ШПИНДЕЛЬНЫХ УЗЛОВ МНОГООПЕРАЦИОННЫХ СТАНКОВ

Олег Кроль, Виталий Осипов

А н н о т а ц и я. Приведено решение задачи определения податливости формообразующих шпиндельных узлов многооперационных станков с ЧПУ сверлильно-фрезерно-расточной группы, оснащенной модульными комплектами оснастки. Получены соотношения (расчетные формулы, номограммы), позволяющие моделировать конструкцию двухопорного шпиндельного узла с изменяющимися комплектами оснастки. Проведен анализ влияния деформационных характеристик опор на сдвоенных подшипниках качения на баланс податливости исследуемых узлов станков в пределах их рабочей зоны. Порядок применения предложенной процедуры показан на станках – представителях сверлильно-фрезерно-расточной группы.

К л ю ч е в ы е с л о в а: шпиндель, инструментальный блок, податливость, 3D-моделирование.

3D-modeling and optimization spindle's node machining centre SVM1F4

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S u m m a r y . The considered procedure of the building 3D- models spindle's heads with mechanism of the grip of the instrument and hydraulics block for orientation of the spindle in process of the change the instrument.

Stated problem of searching for of the optimum correlation parameter cantilever and interlinear support of the parts of the spindle specialized machining centre, providing maximum stiffness of the designed node

K e y w o r d s : machining centre, spindle's nodes , cantilever part, stiffness, 3D-modeling.

INTRODUCTION

Spindle's nodes (SN) is one of the main element processing centre, in significant measure defining accuracy and capacity of the process of the processing. Constant searching for of the new decisions for achievement of the high technical-economic factors brings about frequent change the models processing centre. So creators of the new technology must use all achievements in the field of analysis trend developments, 3D- modeling and optimization part of designed tool.

PUBLICATION AND METHOD ANALYSIS

Efficiency of the process of the creation machining tool depends on level quality formative nodes [1, 7, 9, 17]. Spindle's node (SN) being executive organ of the carrying system machining centre, renders the solving influence upon stiffness, vibration resistance and capacity tool as a whole [2, 13, 14, 20]. The Estimation to

accuracy spindle's node is realized with provision for that part, which contributes SN in total inaccuracy of the processing [12, 14]. These studies have shown that in shaping the factors to accuracy of the mutual location of the surfaces and accuracy of the form influence шпиндельного of the node forms accordingly 50... 80% and 60... 90 in general distribution to accuracy tool.

The Known work [3, 4], denoted consideration formative nodes tool as complex mechanical systems by means of complex of the models, including:

- elasticity-deformation, defining loads, deformation and stiffness SN;
- dynamic, defining own frequencies and transmission functions of the system;
- vibratory, defining amplitude spectrum of the velocities and displacement.

But all these models considered SN in 2D-format and did not give the full belief about field of the stress and displacement in space 3D and did not expect use the FEM- method.

On the other hand work [10, 11] use technologies and toolbox 3D-modeling without consideration of the procedures of the taking the optimum decisions.

OBJECTS AND PROBLEMS

The purpose given work is increasing to level of the procedure of the designing formative nodes to account of the building unified solid and

analytical models for optimization constructive parameters of spindle's nodes machining centre and finding the best relation between its cantilever and interlinear support parts.

THE MAIN SECTION

Modeling spindles node shall consider on example vertical multiprocessing tool with automatic change the instrument to models SVM1F4, which is intended for large powered processing the gamma of the details from ferrous, alloying and light metals. He is equipped operated by additional thumb table, used for rotary indexing of the work, as well as for processing the details with constant or variable circular feed. The main unit, specifying efficiency and accuracy of the processing is spindles head with mechanism of the clamp of the instrument, equipped hydraulics block, intended for orientation of the spindle in process of the change the instrument.

Increasing of the requirements to increase of accuracy and quality of the processing does necessary undertaking the complex calculation stress-deformed conditions of the spindle, as the main formative node spindles heads. Efficiency of such calculation depends on full nesses 3D-presentations in system KOMPAS-3D [5, 6].

In process of the study is built solid model spindle's heads (fig.1) and two support spindle's node (fig.2). In lower bearing of the spindle is installed high accuracy radial-thrust dual in-line cone-shaped roller bearing, which perceives radial and two-way axial loads and is characterized by possible radial load in 1,7 times above, than beside corresponding to single-in-line bearing [2]. Except this, he provides raised stiffness support.

In upper support is installed radial-thrust cone-shaped bearing, which allows the separate montage an rings and its construction provides preload spring type (fig.3). The building 3D-models of the details was executed designing complex 3D-assemblies and nodes, falling into spindle's head (fig.3).

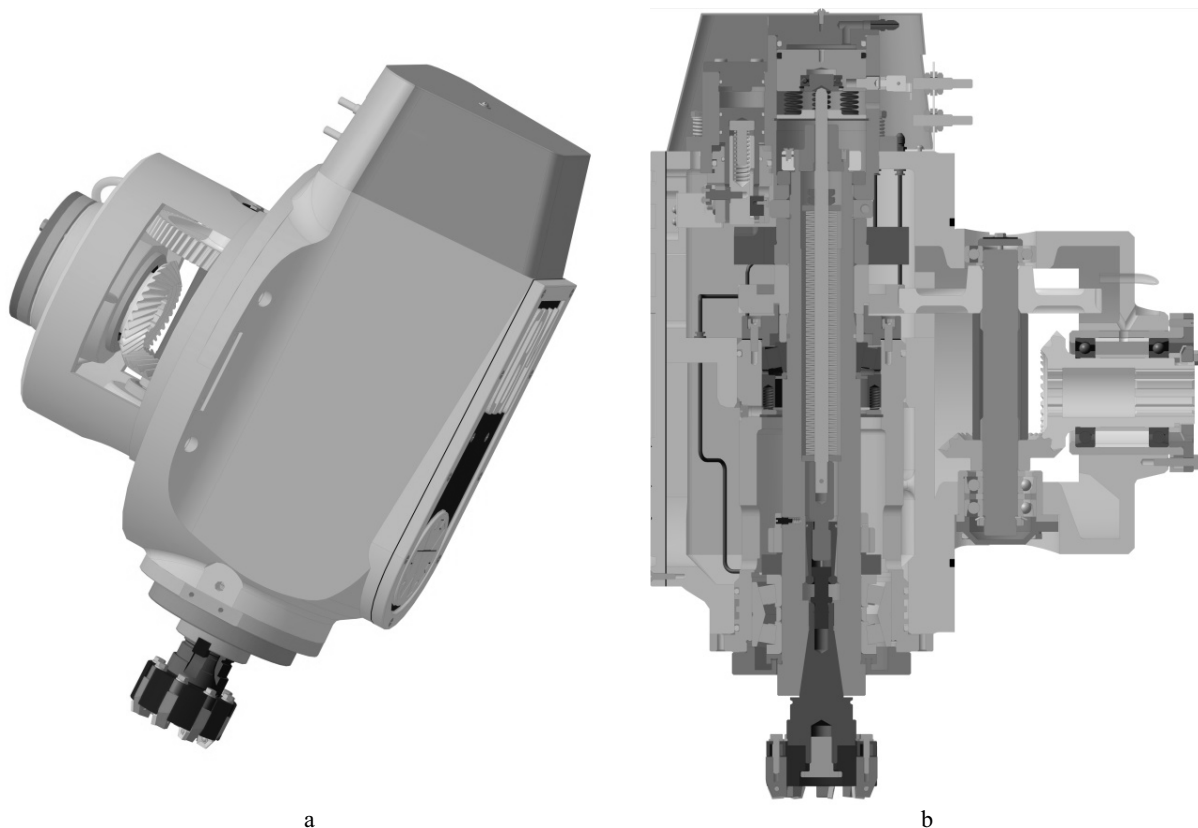


Fig. 1. Spindle's head machining centre SVM1F4: a – general view of unit; b – cross-section of head

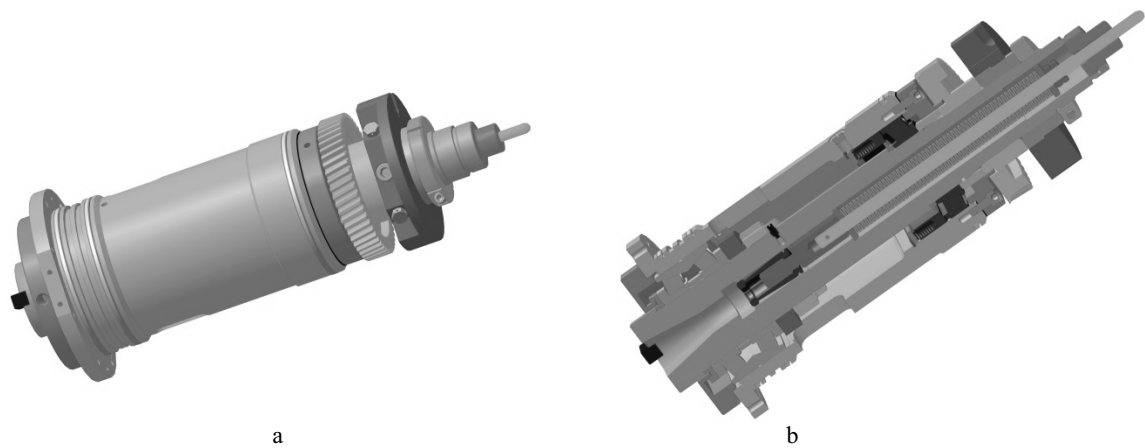


Fig. 2. Spindle's node of spindle's head: a – general type of the node; b – a cross-section of the spindle

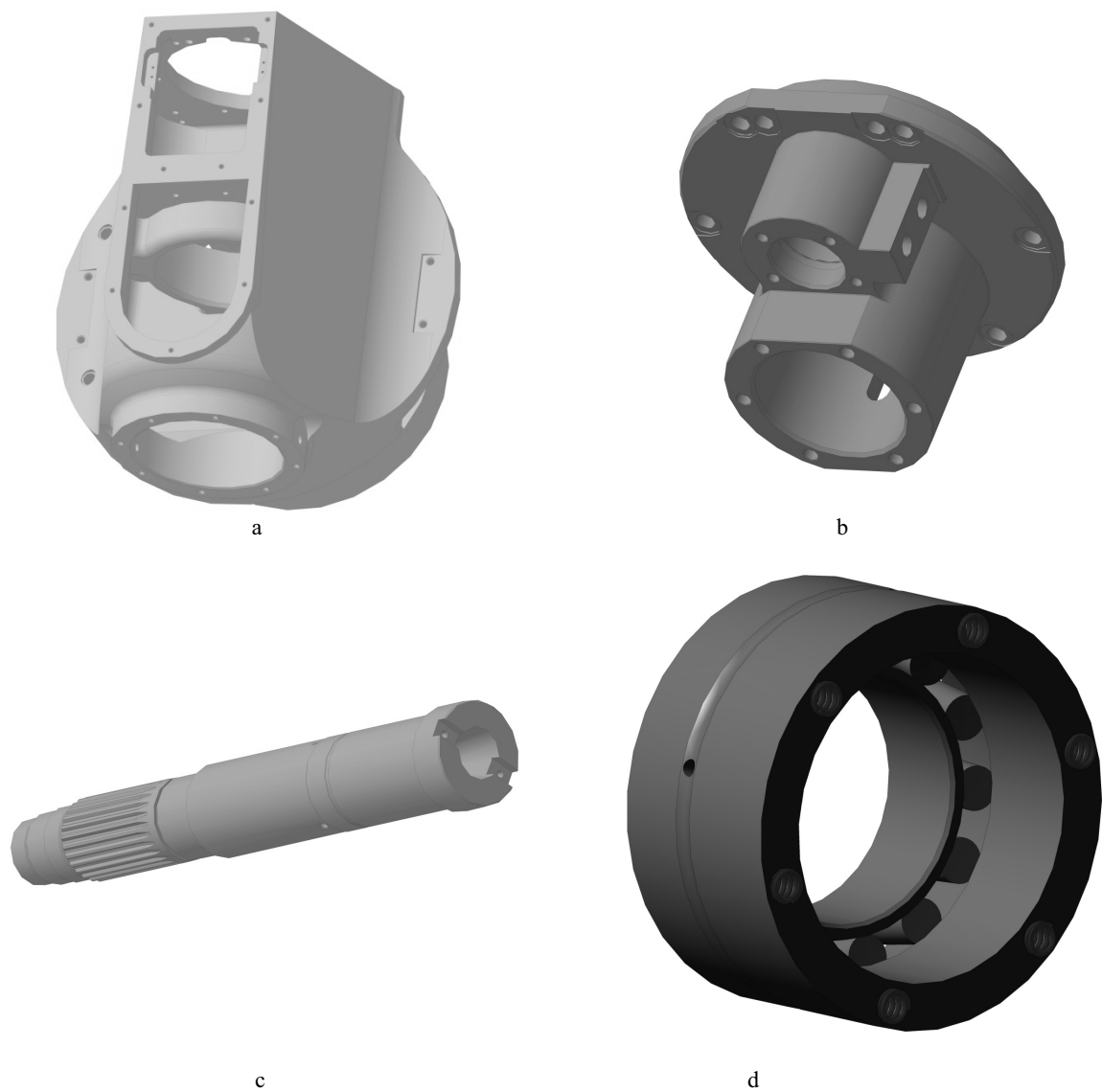


Fig. 3. The three-dimensional models of the details spindle's head: a – case of the head; b – case hydraulics block; c – spindle; d – a special roller bearing with spring preload

The Complex engineering analysis tense-deformed conditions of the spindle tool shall realize by means of module APM FEM [15, 16, 19], equipped by generator finite-element net, falling into CAE-library, which realizes the decisions of the engineering problems by method final element (FEM). Fastening is realized in process of the designing in upper and lower supports and are assigned put loads; they are defined coinciding face (for FEM-analysis of the assembly); it is realized generation FE-nets by method MT Frontal (with using multicore processor); it is executed calculation and viewing result in type of the cards of the stress and displacement.

Within the module APM FEM are realized all afore-mentioned actions and are received:

- a field of the equivalent stress on Mizes (the quarter theory to strenght), submitted for fig. 4;
- a field of the displacement (fig.5) on set of the cross- sections of the spindle.



Fig. 4. Fields of the stress in cross-sections of the spindle

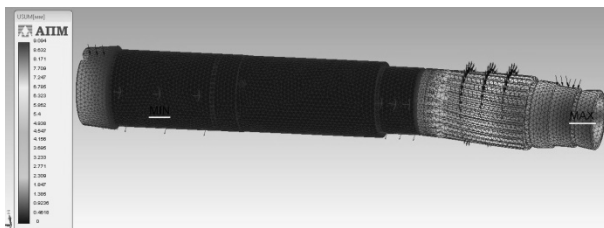


Fig. 5. Fields of the displacement of spindle

Efficiency to designing tool, taken optimal decisions is defined criteria to stiffness and vibration resistance. On optimal level such designs most influence render the sizes cantilever l_1 and interlinear support l parts.

For searching for of the optimum variant spindle's node on criterion of stiffness we shall build the mathematical model to designs SN, in the manner of systems of the expressions, linking different variable and controlling parameters of the node.

Two support spindle with console load by power P is displaced because of own deflection

and because of deflection rolling contact bearing. Shift of spindle's end, conditioned deformation its bearing as support, possible present in the manner of [12, 18]:

$$y_1 = \frac{P}{j_a} \frac{(\lambda+1)^2}{\lambda^2} + \frac{P}{j_b} \frac{1}{\lambda^2},$$

where: j_a , j_b – stiffness accordingly upper and lower support; δ_a , δ_b – a deformation accordingly upper and lower support of the spindle;

$\lambda = \frac{l}{l_1}$ – parameter of the relative length of the span.

Deflection spindle's end as springy beam possible to present in the manner of:

$$y_2 = \frac{Pl_1^2 l}{3EJ_1} + \frac{Pl_1^3}{3EJ_2} = \frac{P}{j_0} \left(1 + \lambda \frac{J_2}{J_1}\right),$$

where: $j_0 = \frac{3EJ_2}{l_1^3}$ – conditional stiffness of

the cantilever part of spindle.

Adding separate softness end spindle, shall get general softness an spindle's node:

$$\delta = \frac{1}{j} = \frac{(\lambda+1)^2}{j_a \lambda^2} + \frac{1}{j_b} \frac{1}{\lambda^2} + \frac{1}{j_0} \left(1 + \lambda \frac{J_2}{J_1}\right).$$

For spindles on rolling contact bearing of the entered restriction on the least distance between supports ($\lambda_{min} \geq 2,5$). This is connected with that running bearing under the most further reduction interlinear support distances intensifies running an spindle's end [8, 14]. In modern designing spindle's nodes on rolling contact bearing parameters to stiffness of the spindle in span are provided not below 250... 500, N/mkm.

On example vertical machining centre with automatic change the instrument to models SVM1F4 shall define the optimum correlation of the lengths console and interlinear support parts. Spindle's node of this centre is loaded by console power $P = 400$ N and presents the hollow shaft ($d = 65$ mm; $d_0 = 28$ mm) with standard end of the spindle. The upper and lower support are characterized following parameter to softness:

- linear: $A_p = A_z = 4,21 \cdot 10^{-6}$ mm/N;
- angular: $a_p = 0,42 \cdot 10^{-8}$, 1/N·mm; $a_z = 0,48 \cdot 10^{-8}$, 1/N·mm.

By means of core symbol mathematicians systems MAPLE, shall define displacement an spindle's end, conditioned deformation its support, which possible present in the manner of

$$y_1 = \frac{0,001668(\lambda + 1)^2}{\lambda^2} + \frac{0,001668}{\lambda^2}.$$

Running spindle's end as springy beam possible to present in the manner of:

$$y_2 = 0,0008533 + 0,000547\lambda.$$

General softness spindle's node, brought about console part, will form:

$$\delta = \frac{0,001668(\lambda + 1)^2}{\lambda^2} + \frac{0,001668}{\lambda^2} + 0,0008533 + 0,000547\lambda.$$

Forming softness and the general softness designed spindle's node was submitted for fig.6.

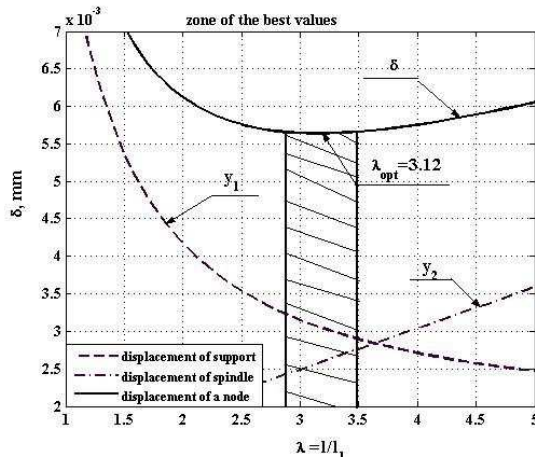


Fig. 6. Optimum correlations between linear size of the spindle

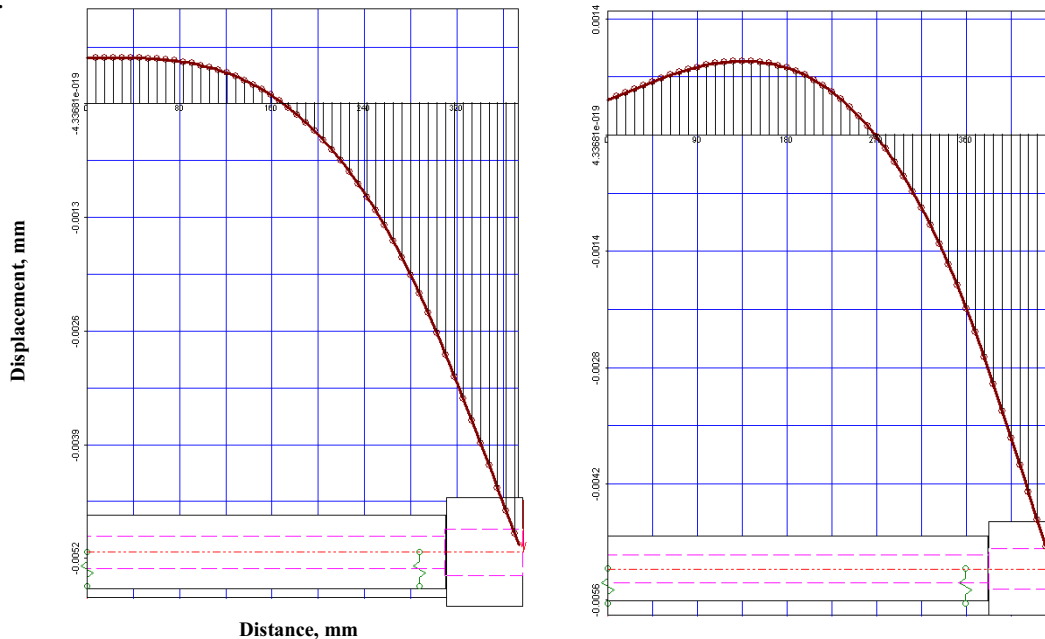


Fig. 7. Softness of the spindle under different interlinear support distances

The value of the relative length of the span ($\lambda_{min} \geq 2,5$) is a restriction, but constructor necessary to take the optimum decision. For designing spindle's node tool SVM1 optimum correlation in accordance with fig.6 is $\lambda_{opt} = 3,12$. In most cases, the constructor uses the half-way decision so it is important alongside with proper values of the optimum, form the range of values, for which general softness will be excess small. The studies have shown that rational range of values of the correlations between linear feature forms the interval $2,6 \leq \lambda \leq 3,9$.

For estimation of the change the value of the shift of the spindle when increase interlinear support distances, is used module APM Shaft systems computer aided design APM WinMachine [19]

On the base epures interlinear support distances a conclusion about increase degree to deformation with growing interlinear support distances l . When increase λ on 20% (with 3,2 before 4) value displacement the spindle on consoles increases approximately on 8% (with 0,0052 before 0,0056 mm). Together with that, necessary to note that with reduction of the length of the console part optimum value correlation λ_{opt} increases. In these cases optimum strategy will be an increase interlinear support distances, which can be limited from constructive considerations.

CONCLUSIONS

In given work is presented procedure 3D - modeling spindle's node specialized machine centre with vertical spindle's head. Constructed by 3D-models of the separate details and assemblies spindle's node in CAD KOMPAS-3D is given estimation of the optimum correlation between size console and interlinear support parts. The formed model to softness spindle's node, allowing on stage of the draft designing to value the size designing node and optimum correlations. Numerical values of the optimum correlation are given between linear size and corresponding to value of softness of spindle's node.

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3D-МОДЕЛИРОВАНИЕ И ОПТИМИЗАЦИЯ
ШПИНДЕЛЬНОГО УЗЛА
МНОГООПЕРАЦИОННОГО СТАНКА
СВМ1Ф4

Олег Кроль, Иван Сухорутченко

Аннотация. Рассмотрена процедура построения 3D-модели шпиндельной головки с механизмом зажима инструмента и гидроблоком для ориентации шпинделя в процессе смены инструмента.

Изложена задача поиска оптимального соотношения параметров консольной и межопорной частей шпинделя специализированного многооперационного станка, обеспечивающего максимальную жесткость проектируемого узла

Ключевые слова. многооперационный станок, шпиндельный узел, консольная часть, жесткость, 3D-моделирование.

Research and analysis of informational flows in the enterprise management system (on the example of "Lugansk cartridge works")

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Summary. This article reviews informational flows of manufacturing enterprise in order to reveal dubbing points, information excess or lack, the reasons of its failure or delays and documentation flow further optimization for management efficiency increase. The two level technology with the application of matrix model and networks graphs is being used for the analysis. This article analyses management logical structure for the matter of lack of contradictions.

Key words. Informational flow, documentation flow, intensity, network model, matrix model, logical structure.

INTRODUCTION

The issues of management board timely provision with required information are mainly defined by the shortcomings of informational flows at the company [12, 13, 14, 18]. The informational flow is the information physical transfer from one department to another [1, 19]. The informational flow intensiveness and speed make direct influence over company management efficiency [4, 16]. The company heads (general director, financial director, department directors) should have up-to-date information and in case of deviation from plan, concerning costs most of all, should have the possibility to make timely corrections. The basis for informational flow researches lies at the existing documentation flow at the company [8, 15, 17].

OBJECT, SUBJECT AND AIM OF RESEARCH

The article business research units' lies at business processes related to the management of Lugansk cartridge works. Lugansk cartridge works is the only company in Ukraine which manufactures bullets taking into account international standards [9]. Such level is being provided by the work of powerful engineering department and modern manufacturing base. Currently the concept of Lugansk cartridge works is to widen the nomenclature of manufactured products, which have demand at international market, including the products manufactured in accordance with the standards of leading international bullets manufacturers using rotor technology potential capacities.

The company activity scope lies not only at the manufacturing of wide range of bullets, manufacturing and supplying of rotor type equipment, instruments and technologies, required for bullets manufacturing.

Lugansk cartridge works has the license for the manufacturing and supplying of bullets for small arms (SAB), sport- small arms (SSAB) and bullets elements. The research subject lies at informational flows, accompanying manufacturing process.

The analysis goal lies at the detection of dubbing points, information excess or lack, the reasons of failures and delays and the company documentation flow further optimization for management efficiency growth.

RESULTS OF RESEARCH

The following multi level technology of informational flows presentation is applied for the analysis:

- matrix model, allowing to formalize the company documentation flow in general;
- allowing clear reflection both departments interconnection via informational flows and used types of documents.

Matrix model (table. 1) reflects the company departments interconnections via informational flow movement. The informational flow from the source to the receiver is defined as IP (i, j), where:

i – number of line in the table (information source);

j – number of column in the table (information receiver).

Explanations to table. 1:

-  – information flow within department;
-  – information flow between departments;
-  – not considered information flow.

Using network model (fig. 1) [3] we can calculate the departments load for the processing of incoming (management) and forming of outgoing information about performance and/or condition. The company department are displayed in form of nodes, informational flows are presented in form of graph arcs. Besides this in case of the availability of data on time consumption the model allows the assessment of documents processing terms and the time of their passing from operational level of management to the tactical and strategic management level.

Table 1. The matrix model of information flows involved in the production process

Source information departments of the enterprise, involved in the manufacturing process)		Recipient of the information											
		Store №10	Pantries	3 area (sleeve)	5 area (sleeve)	7 area (bullet)	1 area (assembly, packaging)	2 area (assembly, packaging)	Store FG №20	Quality control department	Accounting department	Planning department	Dispatching department
		1	2	3	4	5	6	7	8	9	10	11	12
Store №10	1												
Pantries	2												
3 area (sleeve)	3												
5 area (sleeve)	4												
7 area (bullet)	5												
1 area (assembly, packaging)	6												
2 area (assembly, packaging)	7												
Store FG №20	8												
Quality control department	9												
Accounting department	10												
Planning department	11												
Dispatching department	12												

The network model division into two informational subsections with various tops (departments) and two multitudes of informational connections: management and report ones allows the construction of hierarchy structure of manufacturing management and informational support (fig. 2, 3).

The informational flow content (arcs) is presented below in form of documents types list [10]:

- IP (1,1) – 1) incoming orders registration register,
2) cards of stocktaking,
- IP (1,10) – 1) incoming orders,
2) incoming invoices,
3) intrashop requirements,
- IP (2,1) – 1) intrashop requirements,
2) consignment note for materials interior transfer,
- IP (2,2) – 1) stocktaking cards,
2) register for incoming order registration,
- IP (2,10) – intrashop requirements,
- IP (2,11) – bill of materials consumption,
- IP (3,2) – 1) intrashop requirements,
2) consignment note for materials interior transfer,
- IP (3,4) – order for product elements manufacturing,
- IP (4,4) – register of manufacturing assessment (sleeve),
- IP (4,6) – paper note on cartridge cases receipt;
- IP (4,9) – Submission,
- IP (4,12) – report on the performance of daily norms on sleeve manufacturing,
- IP (5,2) – 1) intrashop requirements,
2) consignment note on materials interior transfer,
- IP (5,5) – manufacturing amount registration register (bullet),
- IP (5,9) – Submission,
- IP (5,12) – report on the performance of daily manufacturing norm on bullets,
- IP (6,2) – 1) intrashop requirements,
2) consignment note on materials interior transfer,
- IP (6,6) – 1) register on the stocktaking of obtained sleeves,
2) manufacturing amount registration register,
- IP (6,7) – task and schedule of products manufacturing,
- IP (7,7) – 1) party forming register,
2) stocktaking register,
3) manufacturing amount register,
- IP (7,8) – approval register stub note,
- IP (7,9) – submission,

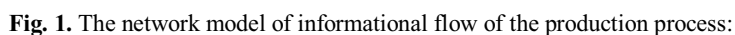
- IP (7,12) – report on the performance of daily norm on cartridge,
- IP (8,8) – ready products stocktaking register,
- IP (8,10) – Invoice,
- IP (9,8) – quality control department master's resolution on dropping party,
- IP (9,9) – 1) passport of approved products,
2) passport for disapproved products,
3) accompanying sheet "conditionally disapproved",
4) submission,
5) register of stocktaking and approval on the flow conditional waste,
6) register of stocktaking of final waste at waste isolator,
7) control cards,
8) register for registration of control cards processing results,
9) register of final stocktaking of the waste at the area,
10) report of the final waste,
11) register of waste reports registration,
12) information about waste and technological losses,
- IP (9,10) – 1) waste report,
2) report on the write off of final waste;
- IP (11,8) – acceptance and delivery act (commissioning report),
- IP (12,3) – task on the manufacturing of product elements,
- IP (12,5) – task and schedule of bullets manufacturing,
- IP (12,6) – task and schedule of products manufacturing.

Having analyzed the monthly documents amount of each type, we can define the informational flow intensiveness (table. 2).

The overall intensiveness of informational flow accompanying manufacturing process at the plant is equal to 3798 documents per month.

The incoming and outgoing informational flows for each network model arcs are summed for the definition of the most loaded departments participating at the processing of the documentation flow [11, 20] accompanying manufacturing process. The amount of monthly documentation processed by the departments is displayed in table. 3.

Total makes 4263 documents. The overall flow intensiveness and the amount of processed documents differ from each other as one document can be used at the activity of several departments and these departments employees spend their time for its processing.



- | | | | | |
|-------------------------|-------------------------|---------------------------------|-----------------------------|-----------------------------------|
| ① – material store №10; | ④ – area №5 (sleeve); | ⑦ – area №2 (assembly); | ⑩ – accounting department; | ⑬ – leadership; |
| ② – pantries; | ⑤ – area №7 (bullet); | ⑧ – store FG№20; | ⑪ – planning department; | → – movement of information flow; |
| ③ – area №3 (sleeve); | ⑥ – area №1 (assembly); | ⑨ – quality control department; | ⑫ – dispatching department; | |

Table 2. The intensity of the documents flow per month[illegible]

Table 3. The volume of documents by department and per employee

Departments	Volume		Volume per employee	
	pcs	pp.	pcs	pp.
Material store №10	780	399	780	399
Pantries	596	238	99	40
Area №3 (sleeve)	94	23	94	23
Area №5 (sleeve)	155	76	155	76
Area №7 (bullet)	160	58	160	58
Area №1 (assembly)	67	10	67	10
Area №2 (assembly)	163	75	163	75
Store FG № 20	191	101	191	101
Quality control department	1190	429	70	25
Accounting	713	464	238	155
Planning department	41	42	41	42
Dispatching department	113	58	57	29
In total:	4263	1972	2114	1032

Table 4. Comparison of informational flows intensiveness at network model of managed informational flow network and network model of informational flows about condition

Departments	Management documents amount	Amount of documents about the condition
Material store №10	0	119
Pantries	119	279
Area №3 (sleeve)	93	1
Area №5 (sleeve)	110	1
Area №7 (bullet)	137	1
Area №1 (assembly)	94	23
Area №2 (assembly)	98	1
Store FG № 20	40	60
Quality control department	66	110
Accounting department	0	769
Planning department	10	1
Dispatching department	3	110
In total:	770	1475

The network models (subsections) with two types of informational connections: management and informational one about the changes and conditions of the manufacturing are constructed for the research of manufacturing process management structure [5] (fig. 2, 3). The results of the first subsection analysis (fig. 2) allowed to construct hierarchy structure and information provision for decisions making process. As the first subsection base and anti base of the second one are similar [2] we can say about the absence of contradictions at management logical system.

Moreover it is important to calculate time parameters of informational flows passing from informational sources to management strategic level besides material and labor costs. In order to do this we need data on the time of documents processing and storage. From these two indices we need to select the maximum one it is applied to the arc of information condition (fig. 3). Taking into account this hierarchy model data we calculate the

length of all possible ways from information sources arcs to management arcs and select the maximum one [6]. It is impossible to conduct manufacturing process complete analysis at strategic level without the data from lower position levels (tactical and operational ones). In accordance with the aforementioned information we find critical way corresponding informational flow with maximum passing time. Critical way is equal to 50 days.

The comparison of management information intensiveness and informational flows on the manufacturing process condition (table 4) allows making the conclusion that the intensiveness of informational flow about the condition is twice more than management flow intensiveness.

It doesn't contradict to the theoretic notions about manufacturing management organization. On the other hand it emphasizes the amount of excess information about manufacturing process condition at the works.

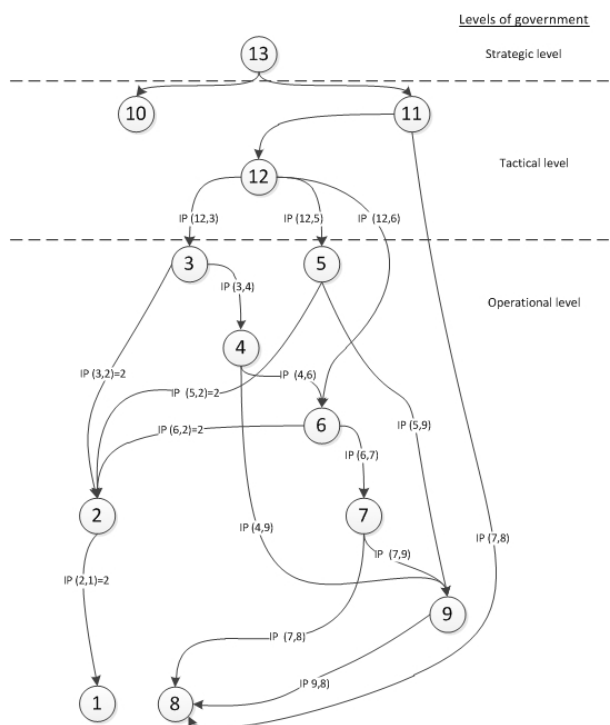


Fig. 2. Network model of managed informational flow network of the production process:

- | | | | | |
|-------------------------|-------------------------|---------------------------------|-----------------------------|-----------------------------------|
| ① – material store №10; | ④ – area №5 (sleeve); | ⑦ – area №2 (assembly); | ⑩ – accounting department; | ⑬ – leadership; |
| ② – pantries; | ⑤ – area №7 (bullet); | ⑧ – store FG № 20; | ⑪ – planning department; | → – movement of information flow; |
| ③ – area №3 (sleeve); | ⑥ – area №1 (assembly); | ⑨ – quality control department; | ⑫ – dispatching department; | |

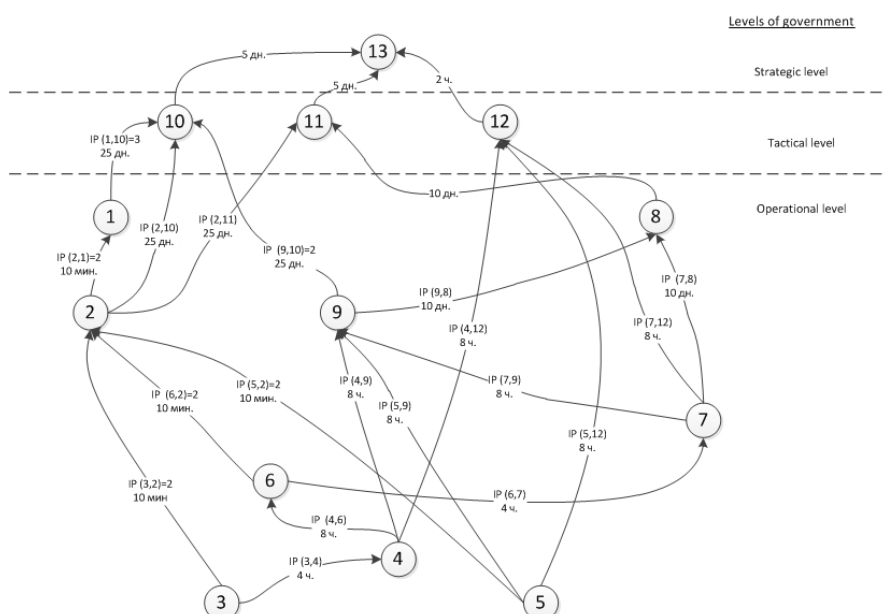


Fig. 3. Network model of informational flows about condition:

- | | | | | | | | | | |
|---|-----------------------|---|-----------------------|---|-------------------------------|---|---------------------------|---|---------------------------------|
| ① | – material store №10; | ④ | – area №5 (sleeve); | ⑦ | – area №2 (assembly); | ⑩ | – accounting department; | ⑬ | – leadership; |
| ② | – pantries; | ⑤ | – area №7 (bullet); | ⑧ | – store FG №20; | ⑪ | – planning department; | → | – movement of information flow; |
| ③ | – area №3 (sleeve); | ⑥ | – area №1 (assembly); | ⑨ | – quality control department; | ⑫ | – dispatching department; | | |

CONCLUSIONS

Thus, the application of matrix and network models of informational flows research and analysis at Lugansk cartridge works allowed making the following conclusions:

- the overall intensiveness of documentation flow accompanying the company manufacturing process is equal to 3798 documents a month; overall load to one employee is equal to 118 documents a month, material costs are low – about 178,6 UAH per month, the time of documents passing from operational to strategic level is equal to 50 days;

- the most loaded departments relatively to documentation flow are: engineering department (1190 documents a month), material store № 10 (780 documents), stowages (596 documents), accounting department (713 documents);

- the manufacturing management logical structure is without contradictions i.e. without transitive dependency and recurrence in management influences interchange;

- the informational flows are excessive, they are dubbed and parallelly processed;

- currently the accounts closing, the current months cost and financial forming is done to 20 of the following month. The most up-to-date information is the information on the amount of issued products (daily reports from the departments) and money flow on the account. The company management board uses the information of two month up-to-date for strategic solutions taking.

In order to increase the information obtaining speed from operational to tactical and strategic levels it is required to implement the automated system of manufacturing process management. This automation means first of all, the presence of electronic the data storage (DS) [7]. Having one single DS allows enterprise to allocate a number of advantages:

1. The DS contains the information the required for the entire time period – up until a few decades in a unified information space. This opens up opportunities for in-depth analysis of industrial, business and economic activities of the enterprise.

2. DS will eliminate inconsistencies in the data at the stage of collecting information before plunging into one database.

3. The universalization of access to data. DS provides the opportunity to receive any reports and analyze them based on a single source of information that allows users to integrate data

entered and accumulated in various operational systems for further comparison and analysis.

4. Solves the problem of conflicts that occur when users attempt to get simultaneous access to change and/or add data.

5. Allows the construction reports based on relevant, reliable and not conflicting data.

6. Acceleration of obtaining analytical reports, without expenses for aggregating (calculation of the total, average, minimum, maximum performance).

Thus, the introduction of ACSME will create a single information space for display of financial and economic activity of the enterprise, covering the main business processes. This will give the company's management and managers ample opportunity for analysis, planning and flexible management of resources to enhance its competitiveness, will improve the efficiency of daily work in the production area.

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ИССЛЕДОВАНИЕ И АНАЛИЗ
ИНФОРМАЦИОННЫХ ПОТОКОВ В СИСТЕМЕ
УПРАВЛЕНИЯ ПРЕДПРИЯТИЕМ
(НА ПРИМЕРЕ ЛУГАНСКОГО
ПАТРОННОГО ЗАВОДА)

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Анна Воронова*

А н н о т а ц и я . Исследуются информационные потоки промышленного предприятия с целью выявления точек дублирования, избытка и недостатка информации, причин ее сбоев и задержек, а также дальнейшей оптимизация документооборота для повышения эффективности управления. Для анализа используется двухуровневая технология с применением матричной модели и сетевых графов. Анализируется логическая структура управления предприятием на предмет непротиворечивости.

К л ю ч е в ы е с л о в а . Информационный поток, документооборот, интенсивность, сетевая модель, матричная модель, логическая структура.

Methods of increase of operating properties of transport vehicles in the conditions of low temperatures

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Summary. The methods of increase of operating properties of transport vehicles are described in the conditions of exploitation at the low temperatures of surrounding air. The results of researches of process of heatexchange are resulted in the bunches of finned tubes. Criterion dependences are got for the calculation of process of heatexchange. The rational construction of fuelpreheater of diesel transport vehicles is chosen.

Key words. Temperature, fuel, coefficient of heat transfer, fuelpreheater.

INTRODUCTION

Viscosity and density fuel define the processes of the evaporation and formation of mixture in diesel. More Low density and viscosity provide best atomization fuel. At reduction of the temperature fuel that is accompanied increase to density and viscosity, increases the diameter of the drop (fig. 1) and falls the fullness of their combustion with the result that increases the specific consumption a fuel, grows the opacity of exhaust gases [5, 10, 18].

With reduction of the temperature viscosity diesel fuel increases, obstructing filling section pump of the high pressure; however, practically breach of the presenting fuel approaches only at the temperature below the temperature of its clouding (before 268K). The Clouding fuel is connected with formation in him when cooling microchip the paraffin, having high temperature of a hardening. At clouding crystals paraffin gradually ram the filters, and presenting fuel stops. The Fault in functioning the system of the feeding

by fuel cause the reduction to powers and economy of the diesel, scale in the cylinder, sticking piston rings and other phenomena's. [1, 5, 6].

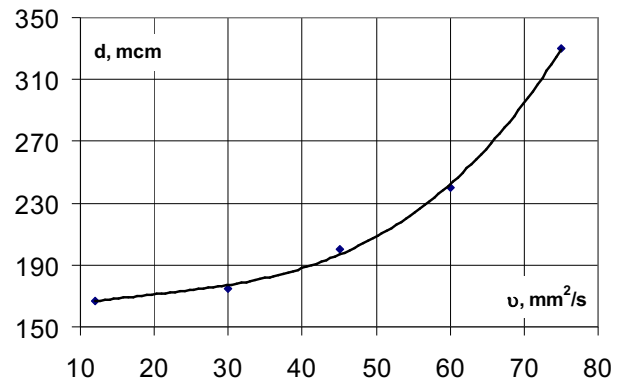


Fig. 1. The relationship between the subtleties spray fuel (average diameter of droplets d_p) on the viscosity

Viscosity fuel also influences upon filling the pump of the high pressure and on drains fuel through clearances plunger pair. With increase of viscosity fuel increases the resistance of the fuel system, decreases filling the pump of the high pressure that can bring about fault in its work. Raised viscosity promotes increasing an amount injected fuel in consequence of reduction drain it through clearances plunger pair in the course of нагнетания. Simultaneously increases the advance angle впрыска from kinematics of viscosity fuel.

With increasing of viscosity, because of spottiness of the sizes of the drop fuel, changes the depth of the penetration and corner of the cone of the fuel torchlight. Particularly sensitive to change of viscosity fuel to engines with indivisible camera of combustion, the form and sizes which are coordinated with the form and direction torchlight fuel [12].

Under constant moisture with increase the temperature fuel solubility water in he increases, and humid from air moves over to fuel. At reduction of the temperature fuel process goes in inverse direction: solubility water in fuel is lowered, and excess its partly falls out in the manner of emulsions and precipitation.

The Most amount of water falls into fuel at condensations it on cool surface of the tank fuel by autumn and in winter, when daytime fuel is warmed, but in the night is vastly cooled. At, the vapours of water condensing on wall fuel tank in the manner of drop of water or rime, which, haved in fuel, partly open in him, but partly settle on bottom of the tank. Than fuel less in tank, that more water in fuel system. Besides, presence of water in fuel is conditioned technology of the conversion to oils. Water in fuel may be free and emulsion.

Free water agglomerates in defender of the tank and pocket tube line, whence in fluid aggregation condition can be drainage easy, in crystalline aggregation condition disturbs the discharge отстоя and possible admixtures.

Emulsions water, freezing, forms the crystals rime, blocking fuel filters, but at hit in fuel equipment brings about freeze valve regulating unit and breakage of the drive of the pump.

At pumping fuel through filter occurs not only postponing weighted crystal ice on its surfaces, reducing (with miscellaneous by intensity, depending on amount of water) reception capacity filter, but also formation new crystal, being centre to crystallizations, around which occurs forming the hard phase.

Analysis of the influence of operating conditions of power systems of diesel vehicles led to the following conclusion: the performance of diesel engine vehicles in extremely low temperatures, typical of much of the territory of the CIS, largely depends on the efficiency of the power system operation which depends not only on the choice of the type of fuel, but mostly from fuel heater [2, 3, 11].

OBJECTS AND PROBLEMS

The Heaters oils (the heaters fluid fuel have a general name - a heaters of the viscous liquids) have found broad using in chemical, oil-processing, food industry, energy and on transport. On transport of the heaters fluid fuel have got broad spreading on court, diesel locomotive, to a lesser extent - on car transport.

Fuelpreheaters, as equipping the transport vehicle, being main by system element fuelpreheater, on the most typical particularity reasonable to classify as follows:

- a consumers to energy i.e. equipment, on operation which is spent efficient energy of the power installation [8, 21];
- utilizer energy i.e. equipment, using cast-off heat.

The electric heaters fuel pertain To the first group, to the second - gas and liquid. Moreover preferably organize the heating a fuel in pathway of the system of the power supply.

The Main action, reducing separation from fuel of the precipitation, is a heating fuel not in fuel tank, but in heatexchangers, disposable in system, which must:

- provide steady presenting a fuel in cylinders of the engine in given range of the temperature fuel regardless of the temperature surrounding ambiances;
- have a possible hydraulic resistances under minimum mass and size and high heat efficiency;
- be charaterized by required reliability and lifetime;
- have a minimum expenseses on fabrication and installation in system of the feeding, high maintainability and simplicity in service.

The Preceding studies теплообменных device has shown that the most efficient surfaces, sending heat, are formed from thick bunch finned tubes, made by method накатки on technologies VNIIMETMASH (the fig. 2). On result of the analysis result preceding studies and author data (the curve 6 on fig. 2) the most efficient are a bunch finned tubes with the following geometric parameter: diameter of the tube on rib $d_r = 10,22$ mm; the diameter of the tube, carrying rib $d_{cr} = 5,8$ mm; the internal diameter of the tube $d_1 = 4,4$ mm; the step rib $t_r = 1,59$ mm [7, 9, 17].

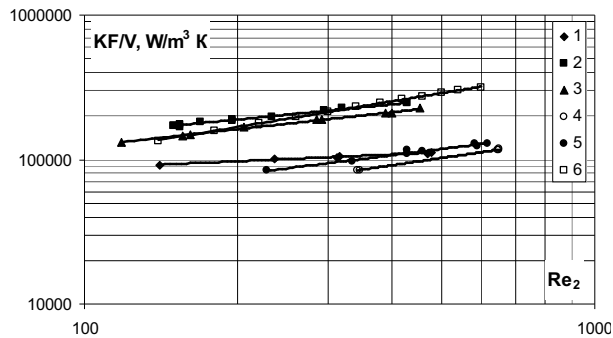


Fig. 2. Efficiency of use of fin tube bundles:

1 - the sheaf of smooth tubes, 2 - a dense beam of finned tubes, 3 - discharged beam fin indigenous tubes 4.5 - bundles small fin tube 6 - tube bundle with optimized the parameters of the fin (obtained by the authors)

Authors in the laboratory "Thermal energy vehicle systems" department "Cars" of the Volodymyr Dahl East-Ukrainian National University conducted research in order to get connected, the connections between the geometrical parameters describing the layout of the beams of small diameter tubes with rolling fin heatexchanger design apparatus (density layout of the tube bundle, the number of moves and the value of idle fuel leaks fuel in partitions) for thermal efficiency fuelepreheater. During the calculation of the energy system for heating fuel engine, namely during the thermal design of the fuelepreheater main difficulty is to determine the heat transfer coefficient k . This is mainly due to the complex structure of the surface heat transfer fuelepreheater and those with heat carrier. You also need to take into account the complex structure of the flow bathing the outer surface of the finned tube bundle [4, 13, 14, 19, 20].

Dependency is recommended On result of the studies for calculation of the factor heat exchanger:

$$k = \frac{1}{\left(\frac{\psi}{\alpha_1} + \frac{d_{cr}}{2 \cdot \lambda_w} \cdot \ln \frac{d_{cr}}{d_1} + \frac{1}{\alpha_2} \right)}. \quad (1)$$

The Methods of the calculation was elaborated by experimental studies, which results are submitted for fig. 3.

Equations were received On result of the processing experimental data for factor heatexchanger to parametric and criterion to form:

$$k = 973,84 \cdot v_2^{0,3632}; \quad k = 37,72 \cdot Re_2^{0,4262}. \quad (2)$$

The equations are valid for $v_2 = 0,4 \dots 1,0$ m/s and $Re_2 = 750 \dots 1000$.

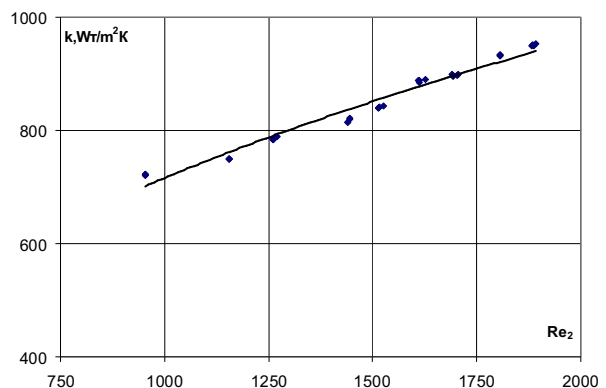


Fig. 3. The dependence of the heat transfer from the finned tube bundle Reynolds number of fuel

For revision result processing experimental data and methods of the calculation were organized special studies on determination physical characteristic winter diesel oil (refer to fig. 4, 5). The Results of these studies have confirmed the negative influence of the low temperature on characteristic fuel.

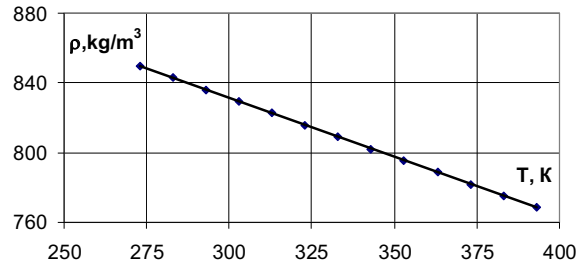


Fig. 4. The density of the winter diesel fuel, depending the temperature

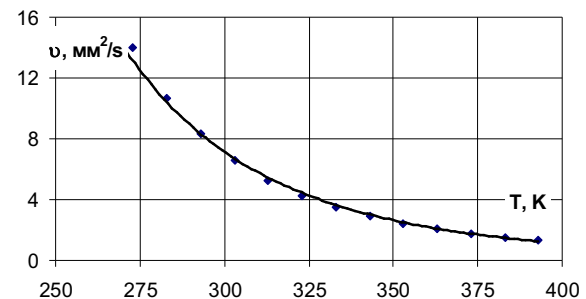


Fig. 5. Kinematic viscosity of diesel fuel Depending on the temperature

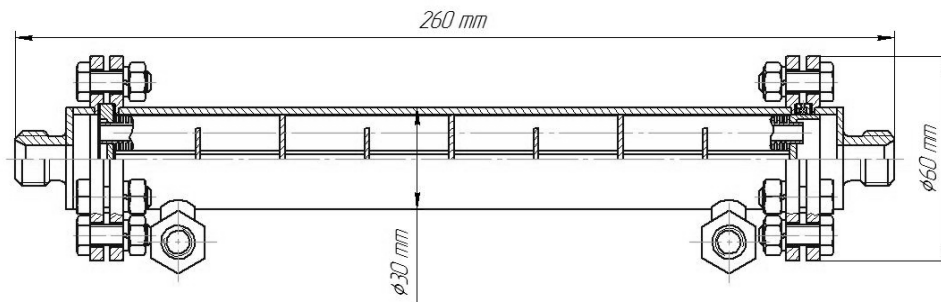


Fig. 6. Fuel heater for diesel engine

The Results of the studies have allowed to get the methods of the calculation heatexchanger device given type and systems with their use and design heatexchanger from finned tubes, made on technologies VNIIMETMASH, with optimized finned parameter (fig. 6) [15].

He is intended for cars with power of the engines from 240 before 320 h.p. and meets the demands usages of the engine at cool time of the year.

The Main element heatexchanger are a bunch of the tubes, trumpet lattices, body, lids, carbines. The End of the tubes bear up in trumpet lattice by expansion or soldering.

For increase the velocities of the motion heat carrier for the reason intensification of heat exchange are installed partitons in inter tubes space heatexchanger.

Fuelpreheaters has a triangular arrangement of the tubes with at a walk locations $S = 13$ mm (for the reason ensuring the optimum velocities of the motion fuel) and organization cross - opposite of the motion heat carrier (inwardly tubes - cooling liquid, in inter tubes - a fuel). Besides, appearing screw surface inwardly tubes at made fins promotes increasing to efficiency heat exchange. The Amount of the tubes in bunch is chosen from condition of the maximum filling the cross-section of the body fuelpreheater (3 tubes) [16].

The Comparative estimation experienced fuelpreheater with the best from the known analogue - PT 570 (SAINT PETERSBURG, RF) has shown [15]:

1. The Gabarit sizes less, than beside PT 570 in 1,5 times.

2. The General mass on 50% less, than beside PT 570.

3. Using the aluminum tubes will provide corrosive stability experienced fuelpreheater and

will allow to cut down expenses non-ferrous metals in 2,5 3 times.

CONCLUSIONS

As a result of performing the work is solved important research problem, concluding in improvement fuelpreheater for transport for the reason ensuring the reliable usage of the diesel transport vehicle in condition of the low temperature surrounding air and formulate the following recommendations:

- a most perspective method of increasing to efficiency of the system of the heating fuel - an use special heatexchanger device;

- as executive element heatexchanger device, use the bunch finned tubes made on technologies VNIIMETMASH with the following parameter fin diameter tubes on rib $d_r = 10,22$ mm; the diameter of the tube, carrying rib $d_{cr} = 5,8$ mm; the internal diameter of the tube $d_i = 4,4$ mm; the step rib $t_r = 1,59$ mm.

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МЕТОДЫ ПОВЫШЕНИЯ
ЭКСПЛУАТАЦИОННЫХ СВОЙСТВ
ТРАНСПОРТНЫХ СРЕДСТВ В УСЛОВИЯХ
НИЗКИХ ТЕМПЕРАТУР

*Юрий Куликов, Александр Азиппо,
Тарас Оробцов*

А н н о т а ц и я . Описаны методы повышения эксплуатационных свойств транспортных средств в условиях эксплуатации при низких температурах окружающего воздуха. Приведены результаты исследований процесса теплообмена и выбрана рациональная конструкция топливopодогpевателя.
К л ю ч е в ы е с л о в а . Температура, топливо, коэффициент теплопередачи, топливopодогpеватель.

CAD/CAE simulation of mechanical properties of tubular elements made from composite structures

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Summary. Simulation result of the wind turbine mast tubular element performed in software ANSYS Composite PrepPost and SolidWorks Simulation is given in the article. Also, there is a comparative analysis of simulation results and experimental samples. The material properties that are available in software systems are the initial data for simulation. The experimental data confirmed the results of the simulation models in CAD / CAE systems.

Key words: fiberglass, tubular element, software complex, SolidWorks, ANSYS, model.

INTRODUCTION

Materials based on composite structures find a great application in recent years. These ones include materials having with strength and stiffness with respect to the traditional structural materials and alloys [16-18]. Therefore, the need for simulation and experimental development of structures and their components made on the basis of these structures is arising [1].

Thus, the study of polymer composite structures based on simulation and calculation in CAD / CAE systems is an actual problem [5,19].

Main aims of this paper are the following: carrying out of experimental researches to determine the mechanical properties of the polymer composite material tubular elements (TE) and performing of a comparative analysis with the simulation in the CAD / CAE systems.

OBJECTS AND PROBLEMS

A fibrous fiberglass on the basis of glass strands EC-7x30-80 and epoxy binder EDT-10 is selected to be the object of research [15]. Making of full-scale TE samples and conducting of a series of experiments were the first step. Information on samples and the obtained strength are shown in table 1.

Getting known the layer thickness and internal diameter let us derive its area (formula 1):

$$S = \pi \cdot t \cdot (d_g + t), \quad (1)$$

Where t is the layer thickness.

Known compression force lets us to derive the stress in $[0^\circ]$ layer using the formula 2:

$$\sigma_3 = \frac{P}{S}, \quad (2)$$

where: P is the compression force.

Table 1. The strength characteristics of TE made of fiberglass

Sample No	S, mm^2	F, kN	σ, MPa	$\sigma_{\text{averaged}}, \text{MPa}$
1	18,72	15	801,28	908,12
2		19	1014,96	

The result of the destruction is shown in figure 1.



Fig. 1. TE sample in the testing adaptation and TE samples after the axial compressive loading

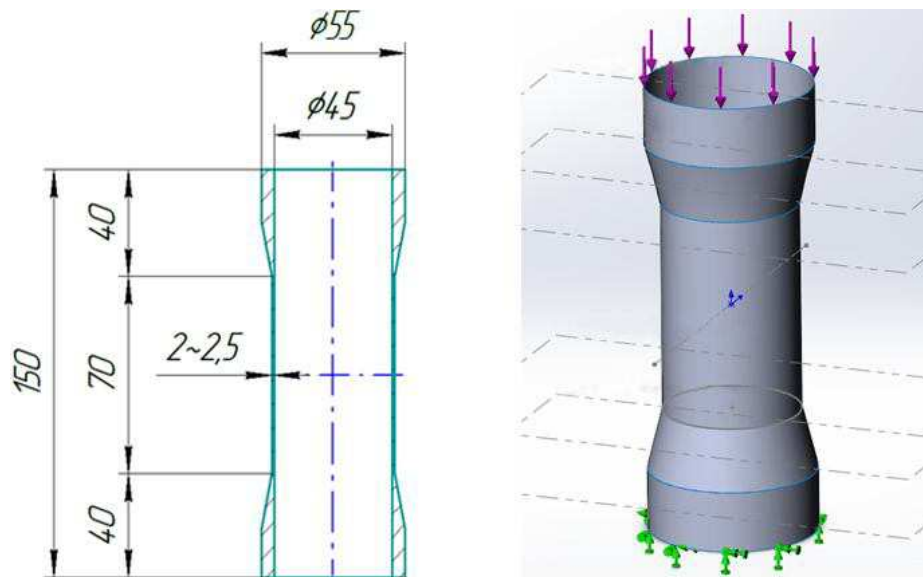


Fig. 2. The TE geometrical model and TE 3D-model

Solid Works 2012 and ANSYS 14.5 software complexes were selected for the wind turbine mast TE numerical experiments [1]. 3D-models of wind turbine mast elements made of polymer composite were constructed in software complexes according to specified parameters of a geometric model.

The next step was to simulate the process of compression loading mast element with forces up to 20 kN in a software module Simulation of the Solid Works 2012 software complex. Three-dimensional model was built according to geometrical parameters (fig. 2).

Finite element mesh is shown in figure 3. TE equivalent stresses are shown in figure 4. The maximum stress in TE are 819 MPa.

When compressed along its axis, the whole TE load is held just by the longitudinal layer (fiber lay angle is 0° relative to the axis). Transverse layer keeps circular and a minor part of the longitudinal load occurring under compression of the layer (90° relative to the axis). The simulation assumed that the whole applied axial load is applied only on the longitudinal layer.

The last step was to perform the calculation in ANSYS Workbench software.

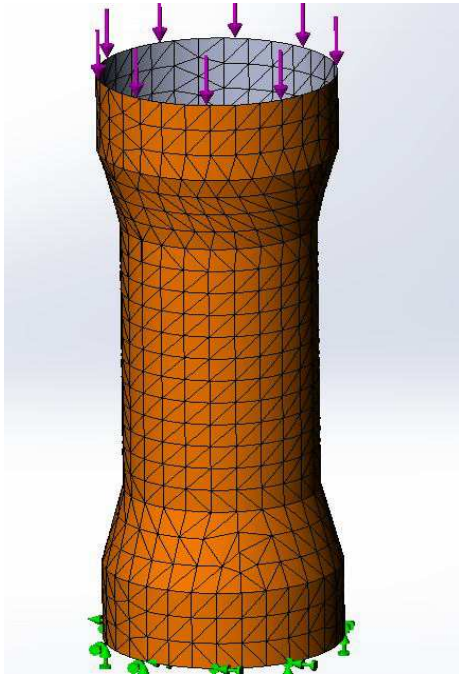


Fig. 3. Finite element model of the TE

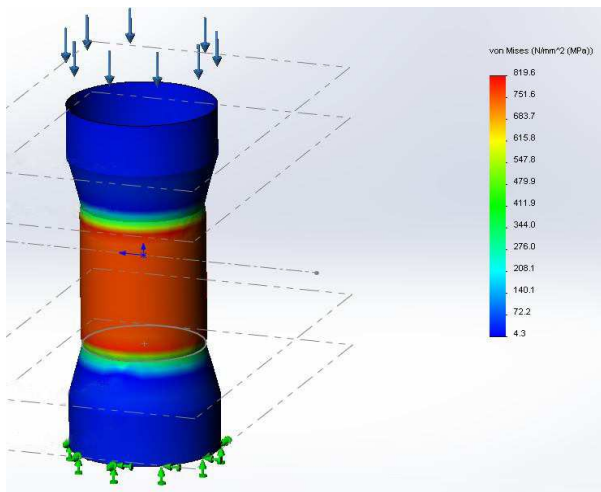


Fig. 4. Equivalent TE compressive stresses

Firstly, while calculation the elements strength in any CAD/CAE systems the material is to be selected. Epoxy EGlass material was selected in our case (E glass-based fiberglass). Table 2 represents the physical properties of material

After material application and geometry import into Workbench the ACP (Pre) (Ansys Composite PrepPost (pre-processing)) module is run. The layers thickness and packages structures are applied in it. As it was mentioned before, the tube consists of two layers $[0^\circ]$ and $[90^\circ]$ respectively of 0.3 mm thickness and has thickening at each end. There is no volume-of-the-layers displaying option in ACP, that is why we have used such function as kak Section Cuts for

schematic layers view. On Fig 6 the schematic layers view is represented. Scale in increased in four times for view clearness.

Table 2. Material pphysical properties

Physical quantity	Value
Elasticity modulus along fibres E_x , MPa	45000
Elasticity modulus along across E_y, E_z , MPa	10000
Poisson's ratio while loading along fibres μ_{xy}, μ_{xz}	0,3
Poisson's ratio while loading across fibres μ_{yz}	0,4
Shear modulus along fibres G_{xy}, G_{xz} , MPa	5000
Shear modulus across fibres G_{yz} , MPa	3846,2

While calculating in Composite PrepPost it is sufficient to consider that program deals with shells only without accepting the volume models. Taking this condition, the model for calculation was designed in SolidWorks and imported into Ansys. Calculation model is represented in Fig. 5.

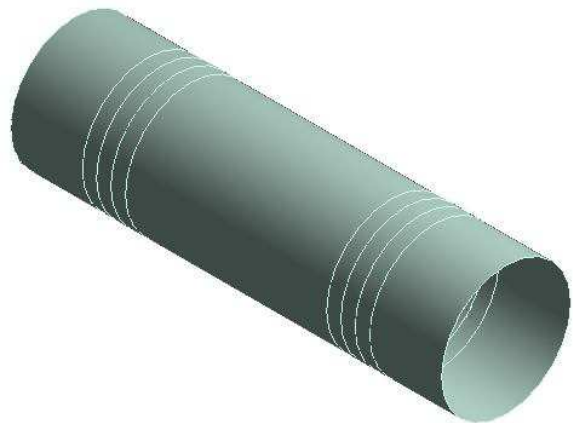


Fig. 5. Calculation tubular model

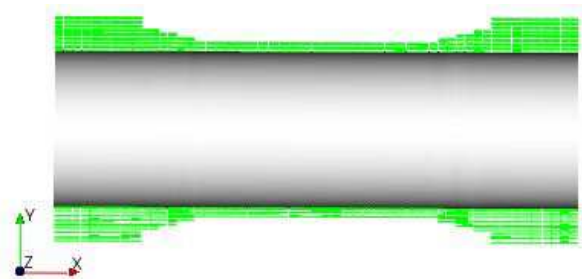


Fig. 6. Schematic layers view

The next module used in Workbench is Static Structural. We have defined the conditions of tube load in it: boundary conditions and force application. According to testing conditions the tube is to be resistance to load of 20 kN. Fig. 7 represents the design model of loading.

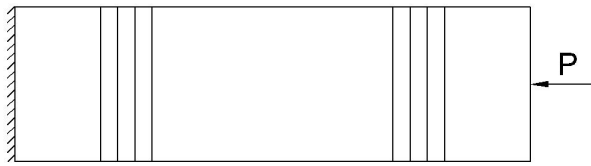


Fig. 7. Design model of loading

After loading we have reviewed the results in joined module ACP (Post) (Ansys Composite PrepPost (post-processing)). The stresses can be viewed clearly in this module. Figures 8, 9 and 10 represent the following: stresses in layers $[0^\circ]$ and $[90^\circ]$, deformation.

As you can see in fig. 6.7 stresses in TE when loading them in SolidWorks and ANSYS are arranged in the same areas.

A comparison computer simulations with experiments has shown that the method of calculating the composite TE in software ANSYS and SolidWorks gives adequate results (see table 3).

Table 3. Intensity of stresses in TE

experiment		var. coef.	simulation result	
			ANSYS	Solid-Works
σ , MPa	σ_{averaged} , MPa	%	σ , MPa	
801,28	908,12	11,76	1030	819,6
1014,96				

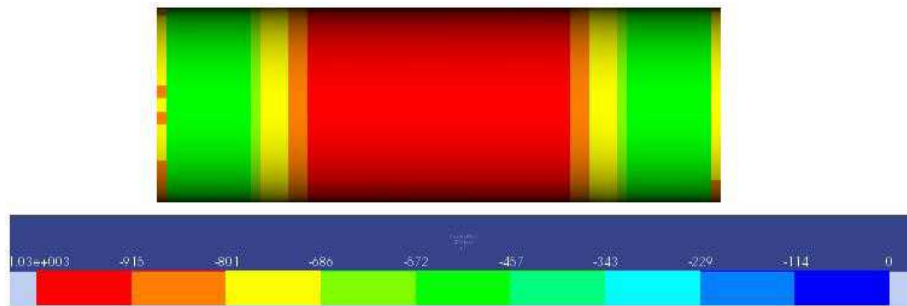


Fig. 8. Stress in layer $[0^\circ]$

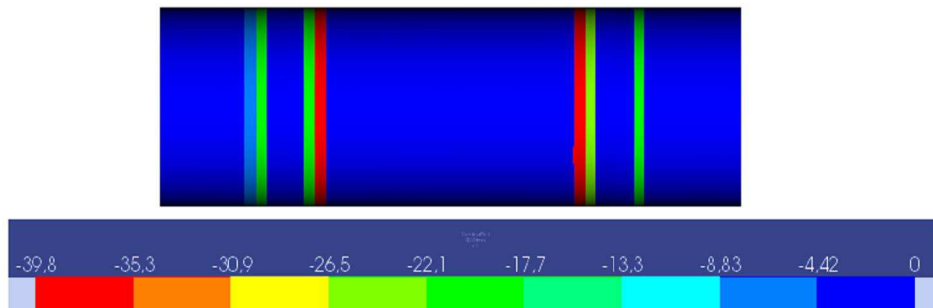


Fig. 9. Stress in layer $[90^\circ]$



Fig. 10. Deformation

Table 2 shows that the difference in the results of calculations in software complexes is 20%. Averaged experimental data differs from computer model up to 10%. Taking into account the stresses in TE obtained during the experiment (801 and 1014 MPa), it can be argued that the numerical experiment gives close to real results with an error of up to 5%. The obtained variation coefficient is 11.76%. This meets the permissible deviation.

CONCLUSIONS

1. The experimental research on testing the mechanical properties of the polymer composite TE was conducted. The values in the range from 801.28 to 1014.96 MPa were obtained. The variation coefficient was calculated. Its value does not exceed the maximum deviation that means the adequacy of the experimental results.

2. The numerical experiment was conducted in the module Simulation of software complex SolidWorks. The deviation of the obtained result from real experiment is up to 10%.

3. The numerical experiment was conducted in the software complex ANSYS Composite PrepPost. The deviation of the obtained result from real experiment is not more than 14%.

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МОДЕЛИРОВАНИЕ МЕХАНИЧЕСКИХ СВОЙСТВ
ТРУБЧАТЫХ ЭЛЕМЕНТОВ КОНСТРУКЦИЙ
ИЗ КОМПОЗИЦИОННЫХ МАТЕРИАЛОВ
В CAD/CAE СИСТЕМАХ

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Сергей Кашкаров, Игорь Непран*

А н н о т а ц и я . В статье приведен результат моделирования трубчатого элемента мачты ветроэнергетической установки, выполненного в среде ANSYS Composite PrepPost и SolidWorks Simulation, а также сравнительный анализ результатов моделирования с экспериментальными образцами. Исходными данными для моделирования являются свойства материалов, имеющиеся в программных комплексах. Полученные экспериментальные данные образцов подтверждают результаты моделирования в CAD/CAE системах.

К л ю ч е в ы е с л о в а : стеклопластик, трубчатый элемент, программный комплекс, SolidWorks, ANSYS, модель.

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The possibility of reducing kinematic slip with two-point contacting with rail wheel railway vehicle

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Summary. They were examined in comparison with the traditional design scheme features wheel kinematics of rolling wheels on the railway promising design concept, enabling the ridge in respect to wheel around their common axis. The possibility of a substantial reduction of the slippage of the wheel flange on the rail, and, according to the power of the friction forces in the raised bed of the contact wheel-rail compared to traditional.

Key words: wheel, flange, railway, independent rotation, loss of energy, slip

the railway vehicles [1, 2, 10, 18]. Without changing the traditional construction of the wheel (with monolith producing of the surface of the wheel) to avoid this kinematic slip, that causes run-out of the wheel and rail, is impossible. That's why we need to look through all opportunity of the principal changing of the constructive scheme, that lets flange to turn according to the wheel around their coaxis. [14, 15].

INTRODUCTION

Kinematic slip in the point of contact flange of the wheel with side edge of the head of the rail with two-point contacting is defined by various distance from the centers of the main and flange contacts to the wheel railway vehicle. Increasing wear of the contacting surface of the wheel and railways, and also extra resistance to the moving of the stock have a serious technical and economical problem for railway transport [5, 12, 17].

OBJECTS AND PROBLEMS

Lubrication of the zone of the contact of wheel with rail, improving of dynamic qualities of the railway vehicle, optimal chose of the ratio of the wheel and rail, and also selection of the conformal their profiles let decide pointed problem only particularly [3, 4, 6-9, 11, 13, 16, 20].

One of the way to decide pointed problem can be improvement of the wheels construction of

PURPOSE OF RESEARCH

The research purpose is to detection of the potential advantages of the constructive scheme of the wheel with moving flange.

RESULTS OF RESEARCH

Let's compare speed of slipping and friction force in the flange contact while moving on the railway for traditional and proposed constructive scheme of the wheels.

We'll look moving of the wheels according to the traditional system of decart coordinates:
1) Still, with a relation with railway –XYZ and
2) moving, with a relation to running wheel – xyz.

1. Let's define direction and module of the vector, speed of the slip of the flange of the wheel over the head.

Of the rail V_1^B in the flange contact for local accident of the moving wheel of the

traditional construction over the rail with the speed V_K with two-point contacting with the angle of the running wheel on the ψ . without slipping in the center of the main contact of the wheel with rail. Schemes are shown on the fig.1, 2.

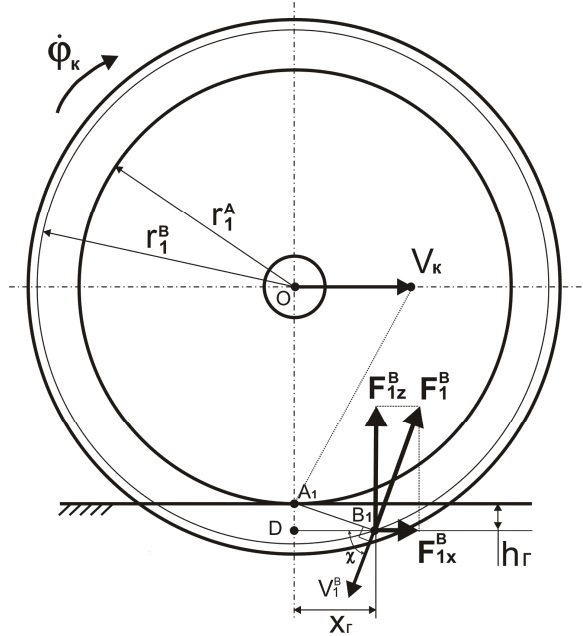


Fig. 1. Design scheme 1

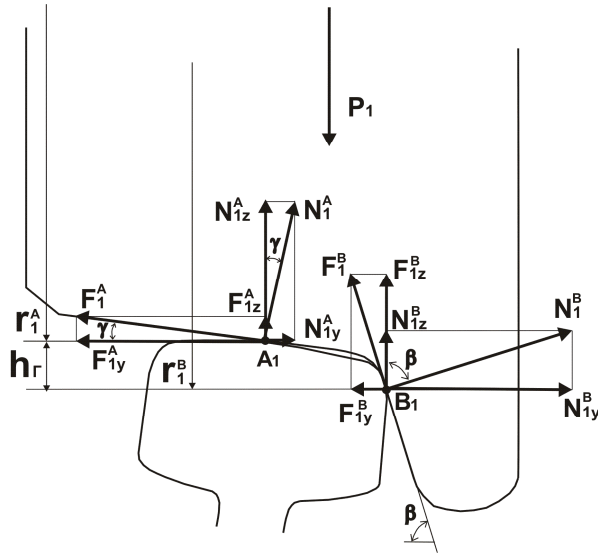


Fig. 2. Design scheme 2

The flange is contacting with side surface of the rail in the point B_1 , situated lower than the level of the main contact (point A_1) point on the point h_r ($h_r = 8...10$ mm) and in front of him in the way of running in the distance x_r . Heat of the flange can be defined from the expression:

$$x_r \approx (r_1^A + h_r) \cdot \operatorname{tg} \psi \cdot \operatorname{tg} \beta, \quad (1)$$

where: β - Is the angle to the horizontal, that forms a conical part of the flange of the wheel.

Angle speed $\dot{\phi}_k$ of the turning of the wheel to the axle wheelset $o-y$ will made up:

$$\dot{\phi}_k = \frac{V_K}{r_1^A}. \quad (2)$$

Immediate center of the running wheel will be at the point A_1 .

The angle χ between vector of the speed of the slip V_1^B in the flange contact and horizontal can be defined from the ratio (fig.1):

$$\chi = \operatorname{arctg}\left(\frac{x_r}{h_r}\right) = \operatorname{arctg}\left(\frac{(r_1^A + h_r) \cdot \operatorname{tg} \psi \cdot \operatorname{tg} \beta}{h_r}\right). \quad (3)$$

In this case the size of the angle χ is defined by the ratio x_r / h_r , that depend from the geometrical characteristics of the contacting of the wheel and rail and parameters of their profiles.

Module of the speed vector of the slip in the flange contact:

$$V_1^B = \dot{\phi}_k \cdot |A_1 B_1|,$$

where:

$$|A_1 B_1| = \sqrt{h_r^2 + x_r^2} = \sqrt{h_r^2 + ((r_1^A + h_r) \cdot \operatorname{tg} \psi \cdot \operatorname{tg} \beta)^2}.$$

$$V_1^B = \frac{V_K}{r_1^A} \cdot \sqrt{h_r^2 + ((r_1^A + h_r) \cdot \operatorname{tg} \psi \cdot \operatorname{tg} \beta)^2}. \quad (4)$$

Module's vector V_1^B is defined by the geometry of the contacting of the wheel and rail and angle speed of turning of the wheel (or speed of the running of the wheel – in case of absence slip in the main contact).

Vector's module of the friction force $F_1^B = \mu \cdot N_1^B$ in the flange contact B_1 will be directed to the side, contrast to the direction of the speed vector of the slip V_1^B .

From the fig. 1.2 we can see that projections of the speed vector F_1^B on the axe $O-X$ and $O-Z$ of the still coordinate system is defined in such way:

$$F_{1X}^B = F_1^B \cdot \cos \chi \cdot \sin \beta, \quad (5)$$

$$F_{1Y}^B = F_1^B \cdot \sin \chi \cdot \cos \beta,$$

$$F_{1Z}^B = F_1^B \cdot \sin \chi \cdot \sin \beta.$$

2. Let's look how the figure of relation of the wheel and rail in the flange contact while giving an opportunity of independent turning of the flange according to the wheel around their axis $o-y$. For this we'll also define the direction and module of the slip of the speed vector of the flange wheel on the rail V_1^B and friction force F_1^B in the flange contact with the same conditions of the moving as in the previous case.

The scheme for this case is provided on the fig 3. The location of the center contact flange with the side edge of the rail head in the point B_1 we see as at the first case.

During definition of the speed vector direction V_1^B it's necessary to consider that moving flange wheel participates in the difficult moving together with the wheel. The drive speed in the point of the flange contact B_1 will be $V_1^{BII} = V_K$.

At the same time point B_1 at the center of the wheel contact is in the relative movement with speed V_1^{BO} relating to the coaxis $o-y$ and moving flange, that goes through the point O to the plane scheme, that is shown on the fig. 3.

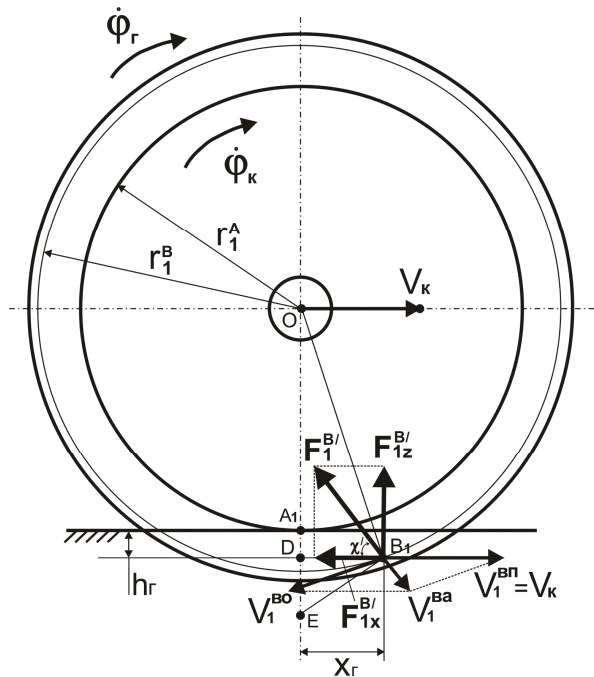


Fig. 3. Scheme

Let's find the absolute speed $\overrightarrow{V_1^{BA}}$ of the movement in the point flange B_1 in the still coordinate system (this speed is related to the speed of the slip on the still rail)

$$\overrightarrow{V_1^{BA}} = \overrightarrow{V_1^{BII}} + \overrightarrow{V_1^{BO}}. \quad (6)$$

From the condition that the conditional center of the movable crest is moving at a speed of V_K together with the geometrical center of the wheel, we find the position of the instantaneous center of rotation of the movable flange at the intersection of the normal to the velocity vector $\overrightarrow{V_K}$ and $\overrightarrow{V_1^{BA}}$, providing in the point of their adding.

Angle χ' between the vector of the absolute velocity of the slip in the raised bed $\overrightarrow{V_1^{BA}}$ and the horizontal contact can be determined from the expression:

$$\chi' = \arcsin\left(\frac{x_r}{|EB_1|}\right),$$

$$\text{where: } |EB_1| = \sqrt{|ED|^2 + x_r^2}$$

in this case according to:

$$|ED| = \frac{V_K}{\dot{\phi}_r} - r_1^A - h_r \text{ and } V_K = \dot{\phi}_k \cdot r_1^A,$$

$$\chi' = \arcsin\left(\frac{x_r}{\sqrt{\left(\left(\frac{\dot{\phi}_k}{\dot{\phi}_r} - 1\right) \cdot r_1^A - h_r\right)^2 + x_r^2}}\right).$$

Let's defined $\frac{\dot{\phi}_k}{\dot{\phi}_r} = K_w$, then:

$$\chi' = \arcsin\left(\frac{(r_1^A + h_r) \cdot \tan \psi \cdot \tan \beta}{\sqrt{((K_w - 1) \cdot r_1^A - h_r)^2 + ((r_1^A + h_r) \cdot \tan \psi \cdot \tan \beta)^2}}\right). \quad (7)$$

Speed module V_1^{BA} determined when considering the design scheme in fig. 3 for the following reasons:

- from the one side $\dot{\phi}_r = \frac{V_1^{BA}}{|EB_1|}$, where:

$$|EB_1| = \sqrt{|ED|^2 + x_r^2},$$

- from the other side $\dot{\phi}_\Gamma = \frac{V_K}{|EO|}$, where:

$$|EO| = r_1^A + h_\Gamma + |ED|. \text{ Then } \frac{V_{BF}^A}{|EB_1|} = \frac{V_K}{|EO|}.$$

After little conversion:

$$V_1^{BA} = V_K \cdot \frac{\sqrt{|ED|^2 + x_\Gamma^2}}{r_1^A + h_\Gamma + |ED|}, \quad (8)$$

considering: $|ED| = \left(\frac{\dot{\phi}_k}{\dot{\phi}_\Gamma} - 1\right) \cdot r_1^A - h_\Gamma$ and

$$x_\Gamma = (r_1^A + h_\Gamma) \cdot \operatorname{tg} \psi \cdot \operatorname{tg} \beta,$$

$$\begin{aligned} V_1^{BA} &= V_K \cdot \frac{\sqrt{((K_w - 1) \cdot r_1^A - h_\Gamma)^2 + x_\Gamma^2}}{K_w \cdot r_1^A} = \\ &= \dot{\phi}_k \cdot \frac{\sqrt{((K_w - 1) \cdot r_1^A - h_\Gamma)^2 + x_\Gamma^2}}{K_w} \end{aligned} \quad (9)$$

Obviously, in the case of constructive rotatably relative to the wheel flange, the angle of inclination to the horizontal vector slipping on the rail flange will depend on the ratio of the angular velocity of rotation of the wheel and the ridge (or the angular velocity comb at constant angular speed of the wheel).

Having known the meanings $\dot{\phi}_\Gamma$ with fixed meaning $\dot{\phi}_k$ we can found out the meaning χ' (fig.4) and vector module V_1^{BA} (fig.5).

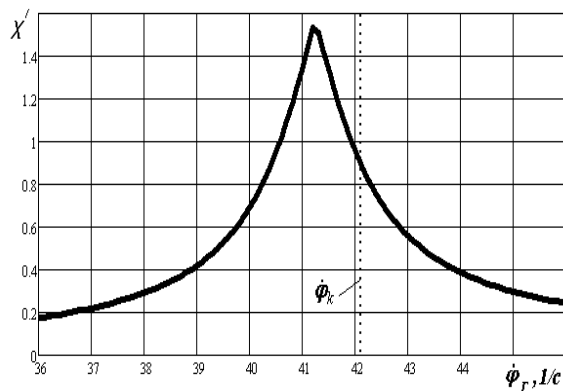


Fig. 4. Example of depending $\chi' = f(\dot{\phi}_\Gamma)$ with $V_K = 20$ m/s and $\psi = 0,015$

The modulus of the velocity vector in the raised bed slip contact on the speed of rotation of the ridge under the given conditions of motion is shown on the p.55.

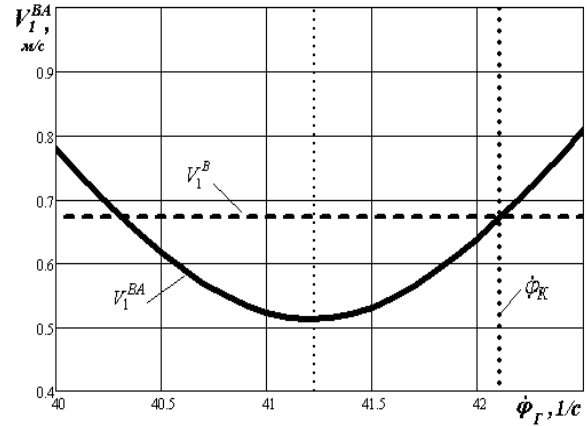


Fig. 5. example of modulus $V_{BF}^A = f(\dot{\phi}_\Gamma)$ if $V_K = 20$ m/s and $\psi = 0,015$

From the graph analysis on the fig.4 we can see that practically in all diapasons of meanings $\dot{\phi}_\Gamma$ dimension χ' is not big, but only in $\dot{\phi}_\Gamma \rightarrow \dot{\phi}_K \cdot \frac{r_1^A}{r_1^B}$ with line speed of running wheel angle $\chi' \rightarrow \pi/2$.

Speed vector V_1^{BA} of the flange flip on the edge side of the head of the rail is directed horizontal and perpendicular to the module of this vector has the minimum value.

So for the angle $\psi = 0,015$ and $r_1^A = 475$ mm, $\frac{r_1^A}{r_1^B} = 0,979$.

At the specified ratio of the angular velocities of the wheels and rolling ridge can be considered approximately equal to the linear velocity of the longitudinal center of the main ridge of contacts and rolling wheels at a constant speed V_K .

While from the fig.5 we see that with $\chi' = \pi/2$ for conditions of the movement in the slip flange V_1^{BA} is little, but don't is zero.

Analyzing the expression (8) we can define possible variants of move of the wheel, with some $V_1^{BA} = 0$. Obviously, for it conditions have to be done at the same time $x_\Gamma = 0$ and $|ED| = 0$.

Meaning $x_\Gamma = 0$ is reached with the angle zero ψ .

$$\text{As } |ED| = \left(\frac{\dot{\phi}_k}{\dot{\phi}_r} - 1 \right) \cdot r_1^A - h_r, \quad \text{so } |ED| = 0$$

with condition (in the fixed meaning $\dot{\phi}_K$):

$$\dot{\phi}_r = \frac{\dot{\phi}_k}{\frac{h_r}{r_1^A} + 1} = \frac{\dot{\phi}_k}{K_w^*}. \quad (10)$$

With meanings h_r and r_1^A size $K_w^* = 1,021$ and opportunity of it's changing is not so important. it means, that absence of the kinematic slip in the flange contact is $V_1^{BA} = 0$ can be realized with $\psi = 0$ and $\dot{\phi}_r = 0,979 \cdot \dot{\phi}_k$.

We use the well-known principle of minimum dissipation of energy, which states that if a is admissible not only state of the system, and a certain set of conditions that are consistent with the conservation laws and constraints imposed on the system, then realized that her condition, which corresponds to a minimal increase in entropy of the system or, the same, the minimum energy dissipation [12, 19].

With this in mind, we can assume kvazistatsiona-molecular weight (stable) state of the system (wheel movable comb interac-FIT-rail), it is a condition in which energy dissipation in the raised bed contact is minimal. To evaluate the effectiveness of the proposed scheme constructively wheel in terms of reduced wear the crest and to reduce the resistance to the motion of the vehicle, will determine how much power can be reduced friction in the raised-bed contact. We represent the instantaneous power of friction as a scalar product of the friction forces in the raised-bed contact B_1 and vector of the immediate speed of the slip B_1 flagen the rail:

$$N_1^B = \vec{F}_1^B \cdot \vec{V}_1^B = F_1^B \cdot V_1^B \cdot \cos \delta, \quad (11)$$

$$N_1^{B/} = \vec{F}_1^{B/} \cdot \vec{V}_1^{BA} = F_1^{B/} \cdot V_1^{BA} \cdot \cos \delta, \quad (12)$$

where: δ - angle between lines of vector

Given that the friction force vector is directed opposite to the corresponding instantaneous speed vector, $\delta = \pi$ but $\cos \pi = -1$, in our case:

$$N_1^B = -F_1^B \cdot V_1^B, \quad (13)$$

$$N_1^{B/} = -F_1^{B/} \cdot V_1^{BA}. \quad (14)$$

The sign "-" indicates that the work of friction is in the direction opposite to the crest of the slip contact and the targeted powertion is characterized by loss of energy by contacting the crest of the wheel on the rail.

Some results are on the fig. 6 where are shown graphs of the depending $N_1^B = f(\dot{\phi}_r)$ and $N_1^{B/} = f(\dot{\phi}_r)$ with $V_K = 20$ m/s, $F_1^B = 12500$ H and $\psi = 0,015$. A marked reduction in the raised-bed contact dissipated power in the range of circular speed crest $40,3 < \dot{\phi}_r < 42,1$ for moving conditions ($\dot{\phi}_K = 42,1$).

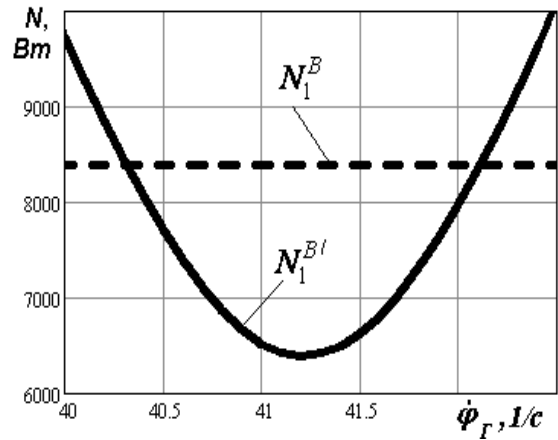


Fig. 6. Depending graph $N_1^B = f(\dot{\phi}_r)$ and $N_1^{B/} = f(\dot{\phi}_r)$ (with $V_K = 20$ m/s, $F_1^B = 12500$ N and $\psi = 0,015$)

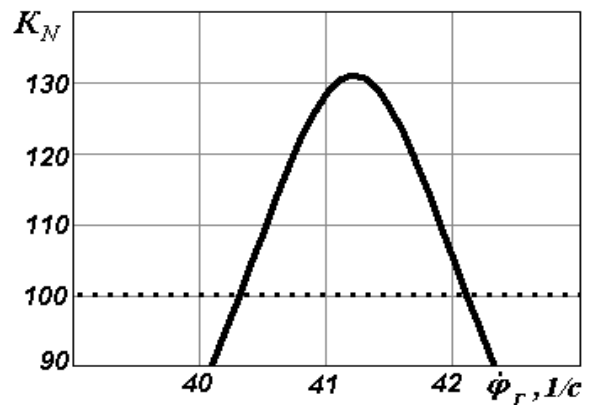


Fig. 7. Depending $K_N = f(\dot{\phi}_r)$ (if $V_K = 20$ m/s, $F_1^B = 12500$ N and $\psi = 0,015$)

We estimate the possible reduction in the capacity of the friction forces in the raised-bed contact for the proposed design of the wheel factor:

$K_N = \frac{N_1^B}{N_1^{B/I}} \cdot 100\%$. Depending scheme $K_N = f(\dot{\varphi}_r)$

(if $V_K = 20$ m/c, $F_1^B = 12500$ H and $\psi = 0,015$) I o the fig.7. Analysis of the graph shows that when the angular velocity of the ridge corresponding to

the relation: $\frac{\dot{\varphi}_K}{\dot{\varphi}_r} = \frac{r_1^B}{r_1^A}$ (with $K_w = \frac{\dot{\varphi}_k}{\dot{\varphi}_r} = 1,021$).

For given conditions of movement while using wheel construction is possible decreasing of the force to 32%

CONCLUSIONS

Analysis of the features of the kinematics of movement along the track wheel with movable crest showed a significant opportunity to reduce slippage of the wheel flange on the rail, and, consequently, the power of friction in the raised bed of the contact wheel-rail compared to traditional. This gives reason to expect a corresponding reduction in wear of wheel flanges and rails, as well as reducing the resistance to movement of rail vehicles.

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ВОЗМОЖНОСТИ СНИЖЕНИЯ
КИНЕМАТИЧЕСКОГО ПРОСКАЛЬЗЫВАНИЯ
ПРИ ДВУХТОЧЕЧНОМ КОНТАКТИРОВАНИИ С
РЕЛЬСОМ КОЛЕСА РЕЛЬСОВОГО ЭКИПАЖА

*Евгений Михайлов, Станислав Семенов,
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Аннотация. Рассмотрены в сравнении с традиционной конструктивной схемой колеса особенности кинематики качения по рельсу колеса перспективной конструктивной схемы, позволяющей гребню поворачиваться относительно колеса вокруг их общей оси. Показана возможность существенного снижения проскальзываний гребня колеса по рельсу, и, соответственно, мощности сил трения в гребневом контакте такого колеса с рельсом по сравнению с традиционным.

Ключевые слова: колесо, гребень, рельс, независимое вращение, проскальзывание, износ, потери энергии, мощность трения, сопротивление движению.

Computer modeling of destructive fire hazards dynamics

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Summary. Destructive fire hazards physical contents is considered, the basics of their dynamics prediction contemporary methods are set before in the article. The essence of zoned and field differential methods of fire mathematical simulation is revealed. The results of modeling allow to predict development of different fires and make recommendations regarding the type of fire-extinguishing means used and their disposition.

Key words. Fire, computer modeling, band models, CFD-models.

INTRODUCTION

The role of mathematical simulation in various research works is continuously increasing which arises from the necessity of a more profound insight in the essence of the objects being explored, on the one hand, and cost reduction as well as elaboration period decrease on the other [15]. Mathematical modeling is stimulated by the development of mathematical methods, enhancement of computational algorithms, software and computer engineering [21]. By turn, computational approaches, software and computer developments are initiated by the practical daily demands.

From the thermalphysic point of view a fire is a complicated nonsteady process of heat and mass exchange, since it is accompanied with burning, turbulent transfer, the presence of dispersed phase in the flow and intensive thermal radiation [9]. Thus, fire mathematical modeling is an interdisciplinary sphere, which implements the results of mechanics of continua, combustion theory, heat and mass exchange, quantitative analysis [2, 10, 14].

ANALYSIS OF LAST REASEACHES AND PUBLICATIONS

The first mathematical fire models were obtained in the 1950-s [4]. However those were only qualitative assessments of velocity fields and temperatures, since the computational base at that time couldn't allow to carry out full calculations adjusted to all types of heat exchange (convection, conduction, radiation) and alterations in composition and mass of indoor gaseous medium. From 1970-s the development of computer technologies took the modeling of heat and mass exchange processes, including fires, to a higher qualitative level [11]. In 1990 there were 36 actively supported models in the world. Among them, 20 ones simulate the environment properties changes at fire (mainly temperature), 19 models simulate smoke movement, 6 models can calculate the flame propagation velocity, 9 – the duration of fire, 4 – fire alarm and sprinklers response time, 2 – evacuation time. In 1997 the overall number of fire models exceeded 150, at that 100 of them are dedicated to different aspects of indoor fires simulation, the others – to vast spaces fires (city and forest fires) and underground structures fires [1, 3, 5, 6, 8, 12, 13, 16, 17, 19, 20, 22, 23].

MATERIALS AND RESULTS OF RESEARCHES

All fires differ in their characteristics. It is impossible to find even two fires absolutely identical in development characteristics. However,

all fires can be characterized by the presence of certain effects: combustion agent-oxygen or other oxidizing agent interaction in the flame layer; heat and combustion products emission in the burning area; heat transmission and combustion products spreading; when burning in closed spaces - thermal decomposition of combustible materials with emission of high-toxic substances which are the products of incomplete combustion.

Fires can cause people's deaths as a result of their smoke poisoning, as smoke contains high-toxic products of combustible materials and unburnt combustibles thermal decomposition, exposure to fire high temperatures and high level of flame thermal radiation.

The space where fire and its accompaniments take place can be divided into three zones: burning area, thermal action area and smoke formation area.

Burning area is a part of space where combustion materials prepare to burning (melt, evaporate, decompose) and burn. This zone includes the volume of steams and gases limited with a thin layer of flame and burning substances surface.

Thermal action area is a part of space surrounding the burning area. Thermal action leads to considerable changes in materials structure and condition and makes it impossible for people to be there without thermal protection means. If there are combustion materials or substances in this area, they undergo thermal preparation to burning and thus a real threat to the further spreading of fire is posed. At indoor fires, the thermal action is limited with elements of construction; the heat is transmitted mainly by means of convection and thermal conductivity. At outdoor fires, thermal action in the form of thermal radiation spreads to all directions of the hemisphere.

Smoke formation area is a part of space abutting to burning area and filled with combustion gases and thermal decomposition products in concentrations that pose a threat to human life and health, and hamper the actions of fire emergency brigades aimed at conducting the wrecking.

All mentioned above areas are different in sizes and forms, as well as in nature of processes at every fire. Fire parameters are unstable and vary with time. Their change from the occurrence of burning and till its cease is called fire elaboration. Fire elaboration conditions can be characterized with the following main parameters: linear rate of fire spreading on the combustion materials surfaces, fire specific heat, and combustion materials quantity in the burning area, their burn-

up rate, flame size, air space warm-up and smoke formation velocity at indoor fires.

In fire environment almost all gases, steams, liquids and solid materials burn in diffuse flame. This flame type structure considerably depends on combustible vapors and gases streamwise section and its velocity. According to the stream character, laminar and turbulent diffuse flame types can be distinguished. The first type of flame emerges at small section of combustible vapors and gases streams moving at low velocity. When burning of different materials in bigger fires turbulent diffusion type of flame emerges. Laminar and turbulent flame is a burning reaction zone surrounding the area of vapors and gases, the latter occupying almost the whole volume of burning area. Diffusion flame burning reaction zone is a very thin (only several micrometers) layer where heat and light emission takes place. Turbulent flame, unlike laminar, is characterized as the one that doesn't have distinct contours, uniform cross-sections and flame front disposition.

The temperature in vapor zone is much lower than in reaction zone. As vapor steams move to the reaction zone their temperature rises first at the expense of flame thermal radiation, then – at the expense of diffusion from the heated combustion products reaction zone. As a result of heating thermal decomposition (dissociation) of vaporous substances takes place, and generated free atoms and radicals along with combustion products come directly to the reaction zone. Carbon atoms, coming to burning reaction zone, get warm and start glowing thus creating so-called luminous flame. Temperature in burning reaction zone changes according to flame height. In the lower part of flame it decreases due to discharge of considerable amount of heat to warm cold air masses that come to burning area; this temperature is minimal for every type of burning. The highest temperature is usually recorded in the middle part of flame, since in the upper part reaction rate decreases at the expense of reaction agents' concentration drop which leads to heat emission level fall and temperature decreases.

Air oxygen partial pressure at standard conditions equals 228,72 kPa, whereas in burning reaction area it equals 0, therefore oxygen from the air diffuses through combustion products layer to the reaction area due to differences in partial pressure. Burning reaction rate at the height of process generally depends only on the amount of oxygen coming into the reaction area, i.e. on its diffusion rate.

Substances interaction in gas and vapor phases progress much quicker than in liquid or solid state. Solid materials- and -oxidant interaction velocity changes dramatically depending on their granulation ratio.

When indoor fires, volumic average temperature of the premises where fire takes place, is taken as their fire temperatures. That is why these fires, compared to outdoor ones, are sometimes called subambient. Maximal temperature at these fires is located in the burning area and above it. Minimal temperature is recorded in the remotest point from the burning area and on the room floor. The following factors affect the indoor fire temperature: fire propagation rate, surrounding equipment and frame filling warm-up, gaseous exchange rate, etc.

Sharp temperature rises by room height is a feature of indoor fires temperature distribution. Temperature rise is the most visible in premises with small stud. When fire burns in closed air parcel, gas exchange occurs at the expense of convective streams of air-gas blend and oxygen diffusion into the burning area. In this case it is the amount of air, filling the volume of premises where the fire occurs, that affects fire propagation.

Combustion products composition depends on the chemical composition of combustible materials and burning conditions. When excess coefficient is close to one combustible materials burn incompletely, as a result, various suboxidized substances, generally being high-toxic substances, like cyanhydric acid, carbon monoxide, acrylonitrile, acrolein, phosgene, hydrogen chloride and anhydrous hydrogen fluoride, etc. can come into the air of premises or into smoke formation area. Solid substances in the form of slags and small dispersed particles containing soot and solid oxides can be generated along with gaseous and vaporous products of combustion. These dispersed particles due to their small volume are usually in suspension state and carried away from burning area with convection flows which leads to smoke formation. Smoke particles diameter is quite insignificant and can be from 0,01 to 1,00 micrometer. Larger particles with relatively bigger mass fall out of convection flow.

Nowadays researchers use various computer codes to simulate fire hazards dynamics. Implementation of these codes requires high-performance computers, especially in the sphere of three-dimensional modeling. The results of modeling allow to predict development of different fires and make recommendations regarding the

type of fire-extinguishing means used and their disposition.

From the huge variety of models and program packages band models are the most widely spread nowadays [7]. They are based on energy and mass conservation laws for gas-air environment of premises. Environment condition during fire is at the moment calculated by zones. Zone is a space in the room volume where temperature and physical characteristics are assumed identical. Thus, as a result of modeling scientists receive zone temperature and other characteristics time variation dynamics. As a rule, the main stress in band model is made on calculation of gaseous medium thermal condition and combustion products concentration in premises. Different band models divide the room into different number of checking volumes, depending on the desired level of detailing.

In real fire environment when modern polymeric materials start burning, premises become filled with smoke very quickly (in several minutes). Therefore, physical properties of gaseous medium can be considered equal all over the premise volume (one-band model).

When breaking the window opening temperature jump occurs. At that strong interaction of substances from the two zones takes place, consequently, temperature in the lower zone rises, whereas in the upper zone it drops. This process cannot be reflected in one-band model. The indoor pressure falls which corresponds to the process of hot combustion products weathering right after the window is opened. At that the zones' temperatures somewhat decrease, while the boundary between two zones rises. The inflow of oxygen facilitates further spreading of fire and zones' temperatures continue to rise.

Two-band combustion model is more widespread. According to this model, upper and lower zones are distinguished in the room. The first one is hotter and more smoke-filled, while the second one is cooler and doesn't contain smoke. Accessory control volumes for convection column over fire source and hot ceiling steam jets are sometimes introduced into premises.

Such an approach is justified through observation of similar exfoliation in real fires and full-scale fire experiments. Hot gases accumulate under the ceiling and fill the room from the above. Although certain nonuniformity of properties by every layer is observed in experiments, it is insignificant compared to layers difference. Hereby, the two-band model quite accurate in most cases.

The model of fire elaboration dynamics in a room with one window and equally distributed fire load allows for the possibility of window break in the process of fire (i.e. when temperature of window surface reaches approx. 500 °C window glass bursts and a more intense heat and mass exchange with environment occurs). This model also describes the spread of flame over the load surface and its further attenuation. Gaseous mixture main components mass change dynamics in the room volume is taken into account (oxygen, inert gases, and combustion products).

As fire progresses the two-band fire model doesn't enable such indoor gaseous medium temperature rise, as one-band model. It is caused by the following reasons: upper zone constantly loses heat through radiation-convective heat exchange with relatively cooler lower zone; upper zone energy is partly spent on change of its own volume; the mentioned above two-band model doesn't provide for the opportunity of specifying different materials for different walls of premises, thus thermophysical properties of window, and consequently, radiation heat exchange are not taken into account before the window is opened.

In the large, band models accuracy falls as the premises fire load unevenness distribution and volume rise.

The most informative and perspective method of fire simulation is field method that uses computational solutions for mass conservation equations and transport equations for different physical parameters. It enables to get time and space distribution of such values as velocity, temperature, heat currents, etc.

The software implementing field models (including those of fires) is rapidly developing and describes more and more complicated physical processes. On one hand, new parameters are being introduced; changing them can affect the results of numerical experiment. On the other hand, calculation results to an even greater degree depend not merely on the quality of software, but on its implemented mathematical models being used correctly. Computer programs using this model are generally called CFD-pack (Computational Fluid Dynamics). The main disadvantage of CFD-pack is computational

difficulties when modeling premises thermal condition.

When using CFD-models to simulate fires the number of control volumes can reach hundreds thousands. The number of differential equations being solved, as well as calculation time, increases accordingly. Moreover specialists who work with CFD programs are required a more profound mathematical training. These factors limit spreading of fire models based on CFD technology.

The work [18] shows that it is reasonable to use full three-dimensional set of equations in curvilinear or polar cylindrical coordinates in cases of close disposition of local fire source to room centre when simulating three-dimensional processes in order to save computer time.

Figure 1 illustrates rated temperature fields at combustion of ethanol on the floor of a 7×10×4m-sized room in a 0,43×0,43m-sized pan for time frames of 30 and 60 seconds. Rated temperature fields denote completion of combustion gases movement along the ceiling and their further subsiding along the walls. At that it is obvious that subsiding of gases occurs predominantly along the corners of room. It is caused by the large surface of heat exchange namely in these locations. Greater chilling of gases occurs at the expense of this phenomenon.

A set of equations in three-dimensional cylindrical polar coordinates is used for simulation. The set consists of one medium continuity equation, three conservation of linear momentum equations along radial, tangential and vertical directions, fuel vapors concentration conservation equations, energy conservation equations and two equations for turbulent kinetic energy and energy dissipation velocity.

For numerical implementation this set of equations was formatted as a generalized transport equation in three-dimensional cylindrical polar coordinates. This set of equations was supplemented with state equation and turbulent viscosity ratio.

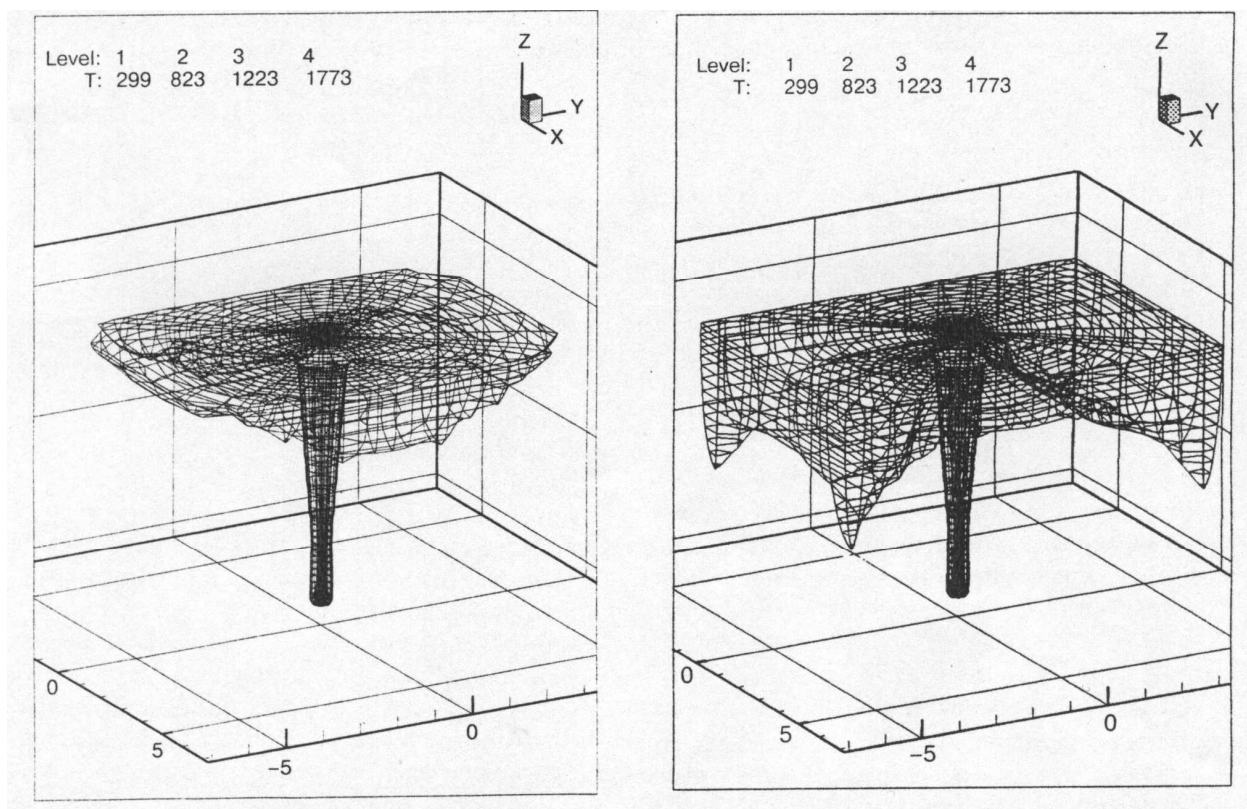


Fig. 1. Temperature fields at ethanol combustion in the 0,43×0,43m-sized pan in the centre of a 7×10×4m-sized room in timeframes of 30 and 60 seconds

CONCLUSIONS

Combustion models analysis, based on mass, momentum and energy conservation laws or using experimental data to obtain the sought relationships between certain parameters, enables us to draw a conclusion that, on one hand, in both cases some errors occur when doing mathematical reduction or simplification. On the other hand, when considering convective column in premises with open aperture the models don't take into account the fact that in real fire the column has deflecting geometry due to air currents affecting the flame and due to heated gases movement. The air currents come into burning area from window aperture. Thus it is necessary to conduct additional studies of the mentioned factors influence on the model.

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КОМПЬЮТЕРНОЕ МОДЕЛИРОВАНИЕ ДИНАМИКИ ОПАСНЫХ ФАКТОРОВ ПОЖАРА

Дмитрий Михайлов

Аннотация. Рассмотрено физическое содержание опасных факторов пожара, изложены основы современных методов прогнозирования их динамики, показана сущность зонного и полевого дифференциального методов математического моделирования пожара. Результаты моделирования позволяют прогнозировать развитие различных пожаров и вырабатывать рекомендации по типу применяемых средств пожаротушения и их размещению.

Ключевые слова. Пожар, компьютерное моделирование, зонные модели, полевые модели.

Analysis and evaluation of the life cycle cost of technical rail systems (for example, a wheel pair)

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Summary. In terms of sustainable thinking, life cycle costing attracts major notice among railway industries all over the world. Railway companies reconsider several reasons for the special need of life cycle costing investigations within the railway infrastructure. Ultimately, the railway companies address the question "how life cycle costs of a transport system can be measured, considering the special circumstances in the railway industry". Due to the reason that railway industries are bound to various regulatory rules and because of the high complexity of transport systems, life cycle costs cannot be evaluated by simple cost measurement approaches. To analyze life cycle costs among railway industries and to gain cost reductions by deriving consolidated findings from a cost comparison among industries of different countries, the special methodology to analyze life cycle costs has been applied within a research project.

Companies have to make important decisions about future investment projects and options all the time. Especially in the manufacturing and plant engineering industry a major part of the total costs is caused by investment and equipment costs.

Investment decisions are mainly based on quality-, reliability- and especially on (investment) cost- aspects. In many cases more than 50% of the total costs are not regarded due to the fact, that only purchasing costs are considered. In order to avoid this deficient calculation of investment options the Life Cycle Cost measurement approach can be applied.

The LCC approach provides a complete overview about the total cost structure of a product in each phase of its individual lifetime. Thus, the original investment decision will be optimized due to the fact that all follow-up costs are considered.

In a long term perspective the holistic investment proposal is more sustainable and eventually also more favorable than the initial investment decision.

This article describes the methodology of the complex railway technical systems life cost calculation.

Key words: life cycle, life cycle cost (LCC), wheel pair.

INTRODUCTION

The primary purpose of the structural railway reform is to update, upgrade and modernization of its rolling stock to improve the utilization of resources, strengthening financial and economic conditions and increasing competitiveness in the domestic and foreign markets. This focus transportation companies on the preservation of existing and development of new competitive advantages, creating innovation, achieving an optimal combination of price and quality of transport services through the development, promotion and implementation of product and process innovations in the industry.

With a comprehensive evaluation of the effectiveness of innovation must take into account the effect generated by all phases and components of the life cycle of the object implementation. Scientific and technological progress has reduced the life cycle of a variety of products. At the same time, the high technical complexity of the system leads to the fact that the majority (90%) is determined by projected cost of production parameters at the design stage. In connection with this assessment of the life cycle cost of the technical system is a tool for cost management at its various stages.

Developers, suppliers, and manufacturers should be held responsible for non-economic parameters required life-cycle engineering of rail

transport systems. It will form a more perfect management mechanism of the transport costs of the operational phase of technical systems in the process of their creation. Theoretical and methodological foundations of a comprehensive assessment of the life cycle cost of technical rail systems in order to control costs and results of the implementation of innovation has not yet been worked out, which makes the urgency of the problem. [17-19]

The concept of the product life cycle was first published in 1965 by Theodore Levitt. Currently, there is no single standard methodology for assessing the value of the product life cycle. For example Ragusa and Pyro believe that a single methodology cannot exist and each manager independently determines the method of calculating LCC.

The creation of a unified methodology for calculating LCC engaged scientist such as J. Kawauchi and M. Rausandu. They developed a method based on six main stages and the theory has become fundamental to most modern techniques.

In world practice, rail LCC analysis of industrial products began to be applied in the 90-ies of the last century [2].

A product's life cycle consists of six major phases according to IEC 60300-3-3:

- Concept and definition.
- Design and development.
- Manufacturing.
- Installation.
- Operation and maintenance.
- Disposal.

LCC model is based on the summation of several mathematical models used to estimate the value of various items (fig. 1), which together cover the total cost of the product life cycle [1].

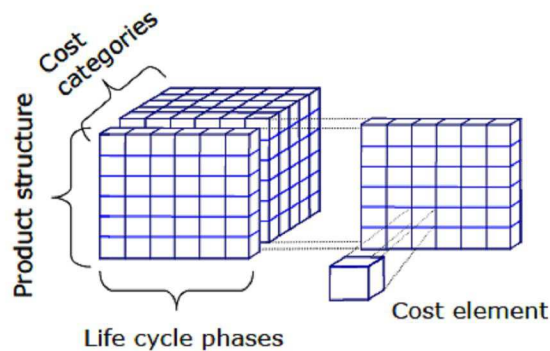


Fig. 1. The concept of cost elements

An LCC model usually includes:

- Ground rules and Assumptions.
- Cost breakdown structure (CBS).
- Product/Work breakdown structure (PBS/WBS).
- Selection of cost categories.
- Selection of cost elements.
- Estimation of costs.
- Presentation of results.

LCC is an appropriate method to identify cost drivers, allow the comparison of different systems and deliver the necessary information for technical and economic decisions to be made.

Both the CBS and PBS are hierarchical tree structures necessary for describing an LCC model. If necessary, a work breakdown structure (WBS) is used to describe which activities the product needs to be produced or used.

Different cost calculation methods can be used to estimate cost elements. According to IEC the most common methods are (IEC, 2005) [11, 12]:

- Analogous cost method; A method that draws conclusions based on historical data from components of similar products
- Parametric cost methods; For this method mathematical cost equations are developed between parameters and variables and general characteristics of the product or process are defined. This method is especially important when actual or historical detailed product component data is limited to few parameters
- Engineering cost method; The method involves the direct estimation of a particular cost element by examining the product component-by-component and uses standard established cost factors to develop the cost of each element. This method is used when there is detailed and accurate capital and operational cost data

THE RESEARCH METHODOLOGY

Evaluation of consumer properties of products is the basis for the development of necessary management decisions in the quality management system. In general, the assessment of the level of consumer properties consists of the following steps [8]:

- choice of nomenclature indicators of the consumer properties,
- selection or development of methods for determining the values of the indicators,

- choice of baseline values of indicators and benchmarks for determining actual values estimated production,
- determination of actual values and their comparison with the base (regulatory),
- comparative analysis of the options of possible solutions,
- obtain data to assess the value of the life cycle.

The content of each of these steps and the amount of work each one essentially depends on the purpose of evaluation of the properties of consumer products.

Life cycle cost wheel pair is all the costs the consumer associated with its acquisition and possession.

The life cycle of any product is a set of processes (steps) of establish the requirements for consumer characteristics and technical parameters, creation, use and disposal of products [20].

Assessment of the value of the life cycle wheel pair can be made on any and / or all stages of the life cycle. Calculation LCC railway wheel is carried out on the basis of the monitoring of consumer properties and excluding repair and maintenance costs. Depending on the category of failures that occur during the life cycle, add up the cost of repairing the wheel pair [13, 16].

Life cycle cost wheel pair is given by:

$$LCC = P_t + \sum_{t=1}^T (C_t \pm L_t) \cdot \alpha_t, \quad (1)$$

where: P_t - purchase price of the wheel pair, UAH.

C_t - the annual running costs of operation, UAH.

t - current year life cycle (billing period), $t = 1, 2, \dots T$.

L_t - the liquidation value of the wheel pair.

α_t - the discount rate

As the duration of the life cycle of taking the life of the wheel pair.

When comparing different LCC wheel pair is compulsory observance of the principle of comparability, including the duration of the life cycle. In this case, the duration of the life cycle may not coincide with the term of the wheel or the resource (or one of the options being compared), and must be arranged [10].

The residual value is determined by the formula:

$$L_t = P_{pt}(1 - \gamma) - C_{pt} \quad (2)$$

where: C_{pt} - the cost of the breakup wheel pair for wheel removal, performance has reached the allowable value of the thickness of rim;

P_{pt} - income (profit) on disposal of scrap wheel, . Determined from the expression:

$$P_{pt} = M_p \cdot m, \quad (3)$$

where: M_p - the market price of 1 ton of scrap metal at the time of writing off the wheel, UAH.

m - mass of the excluded railway wheel kg.

The calculations can be taken as the mass of the wheel, that are excluded from the operation of the rim on a thin (~ 270 kg);

γ - tax rate on profits of a unit.

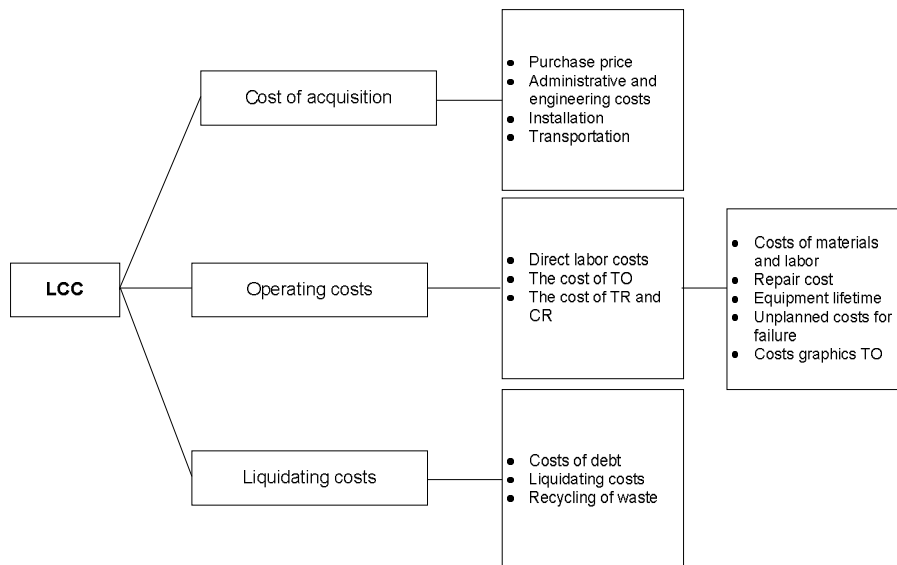


Fig. 2. Model life-cycle cost

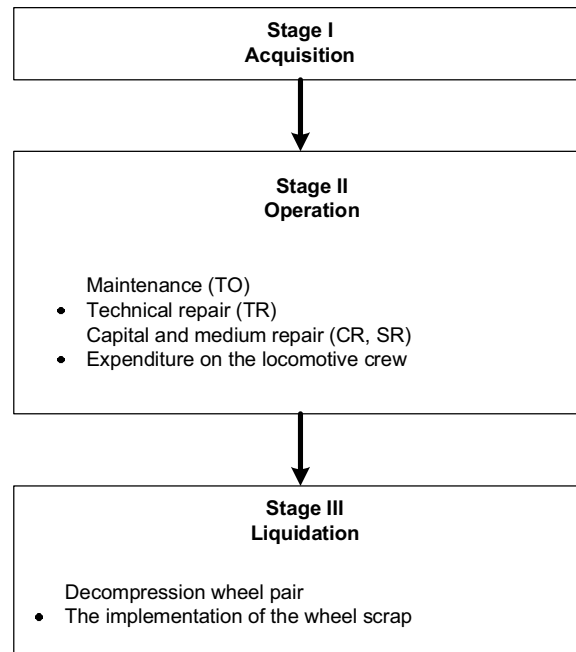


Fig. 3. The stages of the life cycle wheel pair

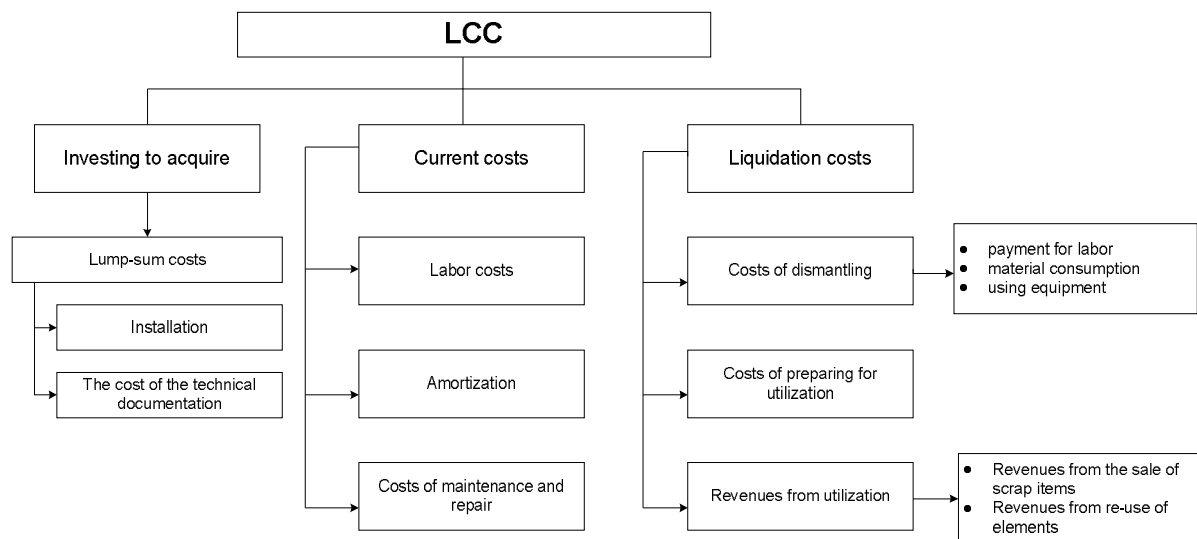


Fig. 4. Schematic of the formation of life cycle cost

Life cycle cost wheel pair can be defined as including and excluding the time factor (discount). Discounting is applied in order to bring the cash flows occurring at different times of the value of the initial period of time by the introduction of the discount rate in the calculation.

Life-cycle costs, calculated without taking into account the discount to evaluate the cost structure of the life cycle, especially for a small period of the life cycle, to identify the most costly items of expenditure with a view to taking action to reduce them possible.

To evaluate the efficiency of the wheel pair to the cost of its life cycle calculation LCC spends with discounting [3].

Since LCC calculated for a specific time period the various aspects of the time factor are taken into account:

- Lack of comparability over time of the same costs,
- Inflation,
- The uncertainty and risk.

Time factor is produced by bringing the cost parameters for the value of the initial period - discount.

Discounting is carried out by introducing into the calculation of the discount rate α_t .

The discount factor for the constant discount rate is determined by the formula:

$$\alpha_t = (1 + E)^{-t} = \frac{1}{(1 + E)^t} \quad (4)$$

where: t - step calculation period ($t = 0, 1, 2, \dots T$);

T - horizon calculation (lifespan),

E - the discount rate (the discount rate).

The changing data of discount rate, the discount factor is given by:

$$\alpha_t = \frac{1}{\prod_{k=1}^t (1 + E_k)} \cdot \alpha_0 = 1 \quad (5)$$

Since the definition of a railway wheel LCC maintained throughout its service life, it is necessary to take into account the time variation of the price of consumed during operation of the facility resources due to inflation. Accordingly, the change, and life-cycle costs, determined on the basis of the quantity of consumed during operation of resources (material, labor, financial), and the unit price of the resource. With the passage of time even at constant volume (quantity) the total amount of resources consumed of cost is influenced by inflation. Prices depending on the method reflect the inflation divided into fixed, variable and deflated [4, 5].

Constant prices - fixed prices at a point in time (at the beginning of the accounting period) that are considered valid for the whole billing period.

The variables (forward) price - time-varying rates, which are expected to apply to the respective steps of the calculation period.

The dynamics of variable prices projected either directly (for example, by extrapolating current trends or based on the level of world prices), or calculated on the base of projected inflation rate of Economic Development.

Deflated prices are variables (expected) prices given to the reference value by dividing by the total (base) rate of inflation (index-deflator of gross domestic product).

The change rate (increase) of the cost of the life cycle, expressed in varying prices, called nominal, if the costs are expressed in constant or deflated prices, the rate is called real.

In assessing the impacts of inflation distinguish real and nominal discount rate is

calculated according to the formulas for constant data rate of inflation accounting period i :

$$E_p = \frac{1 + E_x}{1 + i} - 1, \text{ or } E_p = \frac{E_x - i}{1 + i} \quad (6)$$

where: E_p - the real discount rate, the proportion of units;

E_x - The nominal discount rate that takes into account inflation, of a unit;

i - The rate of inflation, of a unit;

E_p - a real discount rate adjusted for inflation. At low values of the index (the rate) Inflation rate (< 0.05), this component cannot be ignored. It uses a simple formula for determining the nominal and real discount rate.

$$E_p = E_H - i \text{ or } E_H = E_p + i \quad (7)$$

By changing data rate of inflation used by the adjustment of cash flow by a factor of k , taking into account the rate of inflation in a given year of calculation period and the nominal discount rate:

$$k = \prod_{t=0}^T (1 + i_t) \quad (8)$$

If it is impossible to predict the dynamics of prices (inflation) over the expected period (life cycle), the definition of LCC provides on constant (unchanging, basic) prices.

Access and analyze LCC wheel pair involves uncertainties and risks that need to be taken into account in the calculations.

By uncertainty refers to incomplete or inaccurate information on the cost of the life cycle at different steps of the calculation. The uncertainty associated with the occurrence of adverse events and additional costs, is characterized by the concept of "risk".

Risk - the probability of losing of resources, revenue or additional costs.

With regard to the assessment of LCC wheel pair estimated the probability of the following risks:

- commercial risk associated with changes in the economic situation in the industry, country or region, tax laws, etc.;
- occupational hazards associated with the occurrence of abnormal situations, changes in operating conditions, the failure of hardware and equipment, etc.;
- force majeure - natural disasters, accidents, fires, etc.

Risk and uncertainty in the determination of LCC wheel pair taken into account by adjusting the

cash flow (cost) or by amendment to the risk discount rate. Furthermore, the stability can be analyzed. Analysis of the sustainability of the project is carried out in full, usually after paying the expected value LCC wheel set on the basis of the initial parameters of the project in one way or another. For example, it may be considered a situation of change (increase) the original value of annual or annual operating costs by 10, 20, 30%. The stability analysis is provided when evaluating several options of LCC and determining the performance of application of new types of products (net present value, payback period, etc.).

The method of adjusting the cash flow would increase the cost by the amount of the damage caused by the occurrence of abnormal situations in the respective steps of the calculation period.

Adjustment of the components of cash flow is also carried out on the basis of estimates of growth of operating costs associated with the wear of wheel pair.

The method of risk adjustment provides the discount rate used in the calculation of the discount rate, calculated on the basis of the discount rate, which includes the level of risk. In this case, the discount rate is determined by the formula:

$$E_r = E - z/100, \quad (9)$$

where: E_r - The discount rate, taking into account the risk factor,

z - the percentage of risk adjustment.

Since the calculation is carried out on LCC expensive items purchase and operation of the wheel pair and does not account for the revenue component, lower discount rate increases the possible risk of costly cash flow (LCC). When comparing the applications in use wheel pair with different levels of risk of cost value of cash flow with a high level of risk will be higher due to the reduction of the discount rate.

In order to identify the factors that have the greatest impact on the LCC value, the cost structure of the life cycle is estimated. This is usually no discounting.

In identifying the cost elements that do not have a significant impact on the overall LCC, these components can be excluded from consideration.

METHODS OF DETERMINING THE LIMIT PRICE

Limit price of a new wheel pair is calculated with the net effect of a consumer as defined for the life cycle, and must be lower than the price of indifference.

The price of indifference new wheel pair is that price at which it is LCC replacement unit or equivalent, and the application of innovations do not provide to the consumer of any effect, that is, the consumer equally beneficial use of new and existing wheel pair [14].

Price limit is determined by the customer and the developer provided the terms of reference, along with other input data and requirements.

To determine the maximum level of prices calculated value of the net economic benefit that can be obtained by the consumer for the life of the new wheel pair is calculated [9].

Saving the life cycle cost, which is determined based on the useful effect is a reduction in operating costs by using a wheel pair for life and includes:

- Reducing the cost of reducing uncoupling of the top of defects w / d of wheels;
- Lower costs for scheduled repair;

Reducing the costs of the use of a wheel pair for life ($\Delta LCC'$), is a change in current expenditure, defined by the formula:

$$\Delta LCC' = \Delta I_o + \Delta I_{tr} + \Delta I_{pf}, \quad (10)$$

where: $\Delta LCC'$ – reducing operating costs for the use of a wheel pair for life (life cycle), UAH.

ΔI_o - reducing the cost of turning wheels for a lifetime, UAH.

ΔI_{tr} - reducing the cost of the current uncoupling repair (TOR) for the life cycle of the car wheel pair UAH.

ΔI_{pf} - reducing the cost of reconfiguring the wheel pair life cycle, UAH.

Calculation of reducing the cost of turning wheel over the life performed by the formula:

$$\Delta I_o = (N_{ob} - N_{on}) \cdot C, \quad (11)$$

where: N_{ob} - average (life-cycle) of facing base wheel facing (defined by indicator of consumer properties of the "frequency of turning");

N_{on} - average (life-cycle) of facing new wheel facing (defined by indicator of consumer properties of the "frequency of turning");

C - the cost of turning one wheel, c.

Calculation of reducing the cost of repair of the car over the life of the wheel pair is performed using the formula:

$$\Delta I_{tr} = (Q_d - Q_n) \cdot C, \quad (12)$$

where: ΔI_{tr} - reducing the cost of repair of the car over the life wheel UAH.

Q_n - average (life-cycle) the number of cars in the top of uncoupling of the defects of the new wheel pair uncoupling (defined by indicator of consumer properties of the "Mean time between failures");

Q_d - average (life-cycle) the number of cars in the top of uncoupling of the defects base wheel pair uncoupling (defined by indicator of consumer properties of the "Mean time between failures");

C - the cost of one of the top cutaway car, c.

Calculation of cost savings to re-form wheel sets for defects wheels for a lifetime is performed using the formula:

$$\Delta I_{pf} = (P_b - M_o) \cdot P_r, \quad (13)$$

where: ΔI_{pf} reducing the cost of re-formation of wheel pairs for life, UAH.

P_b - the average (for the life of) the number of re-formation of wheel sets on defects base w / a wheel (defined by indicator of consumer properties of the "Resource");

M_o - average (life-cycle) number of re-formation of wheel sets on defects of the new wheels (defined by indicator of consumer properties of the "Resource");

P_r - cost per reshaping wheel pair Rs.

Limit price of a new wheel set is determined at the design stage in order to assess the economic and social feasibility of developing new products with specified technical and economic parameters, to limit the growth of production costs and provide a relative reduction in price per unit of final beneficial result (effect).

Price limit expresses the legal limit price of a new wheel set, that is determined base of the valuation improve the product's functionality, which is provided at relatively cheaper performed wheel pair features.

Price limit is determined by the user (customer) based on the predictive value of the useful effect and determines the limit value of the new wheel set, in which the consumer is provided a minimal beneficial effect compared with replaceable pair of wheels or equivalent.

Limit (limit) price is determined by the formula:

$$P_l = P_b + E_u \cdot K_u, \quad (14)$$

where: P_l - the limit price of a new wheel set;
 P_b - base price wheel pair for the changes in performance,

E_u - a useful effect of the new wheel set,

K_u - the coefficient of useful effect of accounting in the price of a new wheel pair.

K_u coefficient varies depending on originality, significance and characteristics of the production and application of a new wheel pair.

The coefficient K_u should consider a commercial interest as the consumer, as the manufacturer. Therefore, in each case, its value may be adjusted by agreement of the parties. In the absence of the required data rate K_u , according to the established practice, it may be assumed to be 0.7.

The upper limit of the price (the price of indifference) of the new (upgraded) technology is the price calculated at a value of $K_u = 1$, i.e., all useful effect is included in the price and is for the manufacturer. The application of this wheel set in operation is economically impractical.

In calculating the life-cycle cost as an expense during the period of operation wheel pair count only those expenses that are different for the two comparable models [6, 15].

Total expenses for each period is calculated by the formula:

$$P_t = \sum_{i=1}^l p_i, \quad (15)$$

where: p_1 - the cost of depot repair, taking into account the frequency ratios of the meeting (on run, but at least once in n years),

p_2 - the cost of major repairs in view of his conduct at the time specified by the manufacturer,

p_3 - the cost of turning the wheels on normative mileage,

p_4 - the cost of unplanned types of repairs (if available) based on the likelihood of their occurrence,

p_5 - the cost of parts and components to be replaced in accordance with their regulatory and claimed the resource and the cost of work to replace them (in the calculation of the limit price of components for wagons), determined on the basis of cost and expense ratios parts and components during planned and unplanned types of repairs,

p_6 - the cost of a PPO / PPP (if not the same frequency or cost of the work),

p_7 - the cost of empty run with the empty run ratio (based revenues in the second embodiment in the case that for comparable models of freight cars used different tariff schemes to pay for empty runs),

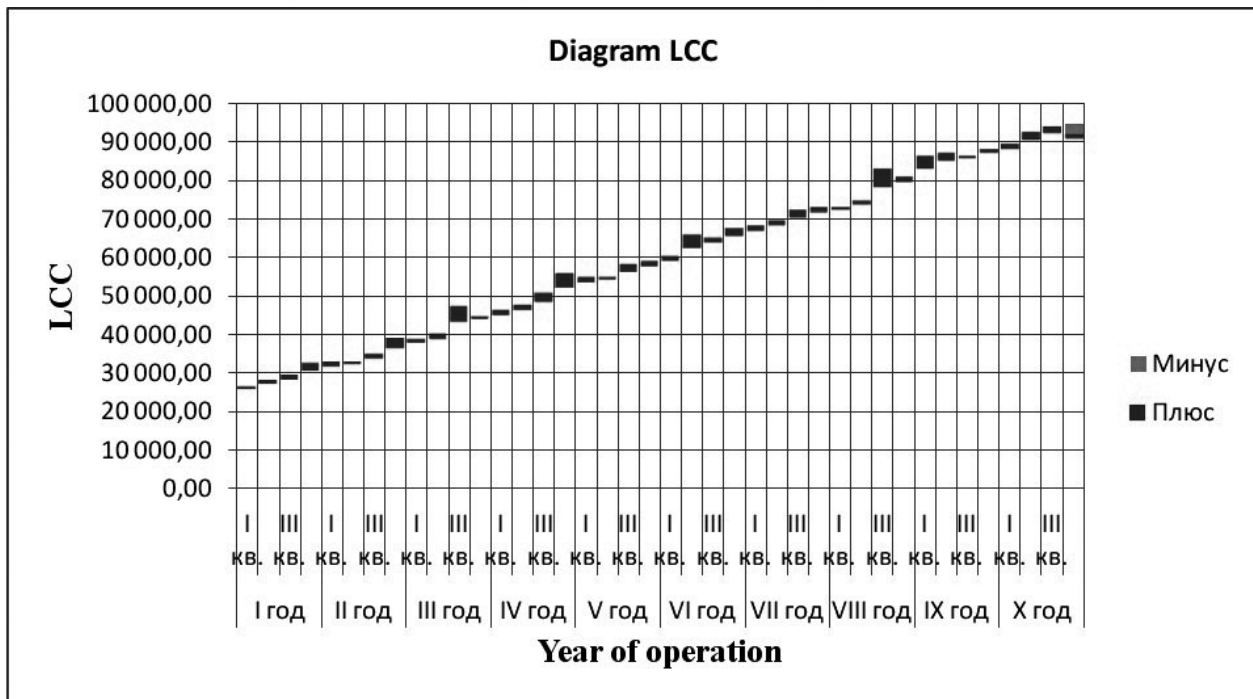


Fig. 5. Example of calculation of LCC. Cash-flow

p_8 – depreciation,
 p_9 – property tax,
 p_{10} – tax profit margin from the operation of the car,

p_{11} – infrastructure-locomotive component of the tariff (when the difference between revenue by the second method),

p_i – other expenses that are not the same for comparable models of freight cars, that is, the value or the frequency of which varies (the costs of preparing the car for transport, cleaning, cargo fasteners, etc.), regardless of who bears the costs – the operator, the consignor or consignee.

Wheel pairs must comply with instructions for checking, inspection, repair and formation of wheel pairs ИБ/3429 [7].

Wheel sets are examined under the cars by viewer, and during routine maintenance uncoupling cars – masters and foremen.

When viewed under a wagon wheel pairs are checked:

- the status of the various elements of the wheel sets,
- compliance with the standards and wears size of the elements of wheel sets,
- compliance with the type of wheel sets the type and size of the car and its carrying capacity (only during the current uncoupling repair of cars in terms of rolling out a wheel set).

On the basis of the proposed method was carried out the calculation of life cycle cost for the wheel pair ПУИИ-950. The results of the calculation are shown by the diagram Cash-flow (fig. 4). During operation the initial cost of the wheel pair due to maintenance costs increased by 4 times. The main costs for the period of the life cycle were technical and overhaul.

CONCLUSIONS

The results of calculation of LCC is directly dependent on the input data. In this regard, special attention should be paid to their credibility. To determine the actual cost of the life cycle need to organize regular collection of data on the state of the railway element, as well as annually updated forecast values, by monitoring for evidence of exploitation.

The proposed method of calculation of life-cycle is universal and can be applied to different rail elements. LCC analysis can be applied not only to obtain a clear picture of the life cycle cost, and for the comparison of alternatives and decision making.

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АНАЛИЗ И ОЦЕНКА СТОИМОСТИ ЖИЗНЕННОГО ЦИКЛА ТЕХНИЧЕСКИХ СИСТЕМ ЖЕЛЕЗНОДОРОЖНОГО ТРАНСПОРТА (НА ПРИМЕРЕ КОЛЕСНОЙ ПАРЫ)

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Аннотация. В настоящее время на рынке технических систем железнодорожного транспорта наблюдается высокая конкуренция. При выборе поставщика таких систем железнодорожные компании рассматривают не только стоимость приобретения, но и затраты, возникающие в течение всего срока службы изделий. С точки зрения стратегического планирования предприятий железнодорожной отрасли, подходы, основанные на оценке жизненного цикла железнодорожных систем на сегодня представляются наиболее перспективными. Железнодорожные компании рассматривают несколько методик расчета стоимости жизненного цикла для различных объектов железнодорожной инфраструктуры. В конечном счете для потребителя важен ответ на вопрос: «каким образом можно объективно измерить стоимость жизненного цикла транспортной системы, учитывая специфику железнодорожной отрасли?» В связи с тем, что одним из главнейших аспектов деятельности железнодорожных предприятий является обеспечение безопасности перевозок, учитывая большую сложность технических систем железнодорожного транспорта, не представляется возможным использовать стандартные подходы к оценке стоимости жизненного цикла. Для анализа расходов на протяжении всего срока службы систем железнодорожного транспорта, поиска путей сокращения издержек, получения консолидированной информации для сравнения стоимостей жизненного цикла конкурирующих изделий, в рамках научно-исследовательского проекта была разработана специализированная методика. Железнодорожные

компании принимают важные решения относительно будущих инвестиций, базирующиеся, в основном, на качестве, надежности, а также на экономических аспектах. Во многих случаях более 50% от общей стоимости владения системами железнодорожного транспорта не рассматриваются в связи с тем, что при анализе проектов учитываются только затраты на приобретение. Анализ стоимости жизненного цикла обеспечивает полное представление о структуре стоимости продукта. Таким образом, исходное инвестиционное решение может быть оптимизировано за счет полного учета затрат, связанных с владением техническими системами железнодорожного транспорта.

В данной статье описывается методология оценки стоимости жизненного цикла технических систем железнодорожного транспорта, а также предложены рекомендации по расчету лимитной цены на подобные изделия.

Ключевые слова: жизненный цикл, стоимость жизненного цикла, колесная пара.

Construction analysis of mechanical parts of locomotives

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Summary. To determine the dynamic properties of the mainline freight locomotives, characterizing the safe movement on straight and curved sections of track in the whole range of operating speeds, you need a set of studies including selection of design scheme, the development of an appropriate mathematical model of spatial fluctuations of the locomotive, making a computer calculation program, conducting the theoretical, and then experimental investigations of new designs. In this case, one should compare the results with existing constructions. One of the necessary conditions for improving the quality of traction rolling stock is to define the parameters of its running gears. Among the questions related to this problem, an important place occupies the problem of determining dynamic qualities of the locomotives at the stages of design, taking into account with the chosen technical solutions in the running gear design. The work focuses on key tendencies of some types of main locomotives embodiment, focusing on improving the running gears design. As a result of investigations one can see that the creation of a modern locomotive requires from designers and scientists realization of scientific and technical solutions providing the design speed increase with simultaneous improvement of the traction, braking and dynamic qualities to provide the simple and reliable construction, especially construction of the running gear, reducing the operating costs, low original cost and operating costs for the total service life, high traction force during take-off, work capability in the multiple traction mode, maximally approximated to the limited clutch and sufficient design speed. Research of mathematical modeling is conducted by the method of numerical integration of the dynamic loading of the main-line locomotive using the software system «Dynamics of Rail Vehicles» («DYNRAIL»). Design features of the running gear elements of some types of the main-line locomotives, which have inclined rods between bogie and the body, transmitting the traction forces between them and providing essential dynamic performance of the carriage motion are studied.

Key words. Locomotive, running gears, bogie, communication, inclined rods.

INTRODUCTION

To determine the dynamic properties of the mainline freight locomotives, characterizing the safe movement on straight and curved sections of track in the whole range of operating speeds, you need a set of studies including selection of design scheme, the development of an appropriate mathematical model of spatial fluctuations of the locomotive, making a computer calculation program, conducting the theoretical, and then experimental investigations of new designs. [1, 2, 3]. In this case, one should compare the results with existing constructions.

One of the necessary conditions for improving the quality of traction rolling stock is to define the parameters of its running gears. Among the questions related to this problem, an important place occupies the problem of determining dynamic qualities of the locomotives at the stages of design, taking into account with the chosen technical solutions in the running gear design.

The creation of a modern locomotive requires from designers and scientists the realization of scientific and technical solutions providing the design speed increase with simultaneous improvement of the traction, braking and dynamic properties [5, 6, 10, 11]. One should mark the following requirements:

- A simple and reliable design, especially the running gears, which allows reducing maintenance and repair costs,
- Low initial cost and operating cost for the total service-life,

- High traction when taking off maximally approximated to the limited clutch,
- Ability to work in multiple traction mode,
- Sufficient design speed,
- Easy control cabin with modern management and monitoring means,
- Unification of design and hardware components within a small number of runs in order to simplify and reduce the cost of maintenance and repair, as well as to ensure the interoperability of locomotives belonging to different networks and companies.

Now let's in more detail study the main tendencies of locomotive embodiment, focusing on improving the running parts design.

When improving the rolling stock design, generalization of theoretical, scientific, methodological and experimental studies aimed at further running parts improvement of some types of main-line locomotives promising designs is an urgent task. [4, 7]. It is known that the dynamic properties of the locomotive are determined by the size and distribution of the static deflections of the spring suspension and its damping capacity. It is believed that the use of a more flexible suspension reduces the amplitude of the additional loads in the carriages; for bogie locomotives a two-stage spring suspension is provided. On the basis of this requirement during the dynamic properties of locomotives research one should more thoroughly take into account the following characteristics:

- A body suspension on bogies;
- Connection of body and bogie elements.

THE MAIN PART

In the end of the last century on Ukrainian railways were operated mostly physically and morally outdated locomotives. First of all it refers to electric locomotives VL8, produced since 1953, VL80 electric locomotives, which were launch in production in 1961, and some other locomotives. To provide the railway transport of Ukraine with more advanced electric locomotives the development of new designs is necessary. Therefore, the rational parameters definition of the freight electric locomotive underframe is an urgent task.

To develop a mathematical model of electric locomotive spatial oscillations and conduction of the following theoretical studies it is necessary to choose a design scheme.

To do this, we considered two schemes [8, 17]. The first is made on the basis of the electric locomotive VL85 design. This is one of the most

powerful mainline freight locomotives AC of that time (the design speed is 110 km/h) with a support and axial suspension of the traction motors, two-section twelve-axial electric locomotive with devices, providing operation according to a system of many units.

Each section is based on three-axle boll-joint bogies that are different from each other by the construction: the extreme bogies have the body support in the form of cradle suspension, the middle ones have the body support in the form of elastic oscillating rods (fig. 1). Central suspension – of the cradle type or with springs, with the so-called "negative stiffness" is for central bogies. The bogies are all-welded; the spring suspension is performed using the springs. Parallel to the springs of central suspension the dampers of viscous friction are located; the axle box is of the flanged type; each bogie has two wheel-motor units [21].

Communication of the body with bogies is intended to transmit all kinds of efforts from the body frame to the bogies of vertical and horizontal, longitudinal and transverse types. In construction, the connection of the body with the extreme and center bogies is different. Body communication with the extreme bogies (fig. 2) consists of a cradle suspension, stops, traction device, the inclined rod and the oscillation dampers. The vertical stop is used to limit the vertical oscillations of the body relative to the bogie and to prevent the closing of spring coils of cradle suspension.

The second scheme is made on the design basis developed by the Ukrainian Research Design and Technological Institute of Electric Locomotive Construction (URDTIELC) in Dnepropetrovsk, which was a member of the Scientific and Production Association of Electric Locomotive Construction (SPAELC). The first Ukrainian freight locomotive was built with the assistance of a number of scientific and industrial organizations, including the Dnipropetrovsk National University of Railway Transport named after Academician V. Lazaryan (DIIT).

Biaxial electric locomotive bogie (fig. 3) is boll-joint, non-articulated, with individual drive for axle and axle support suspension of the traction electric engines [2, 3, 16].

Axle box is an agnathous; individual spring suspension is used admortization of the blows, transmitted to bolster structure from the track irregularity.

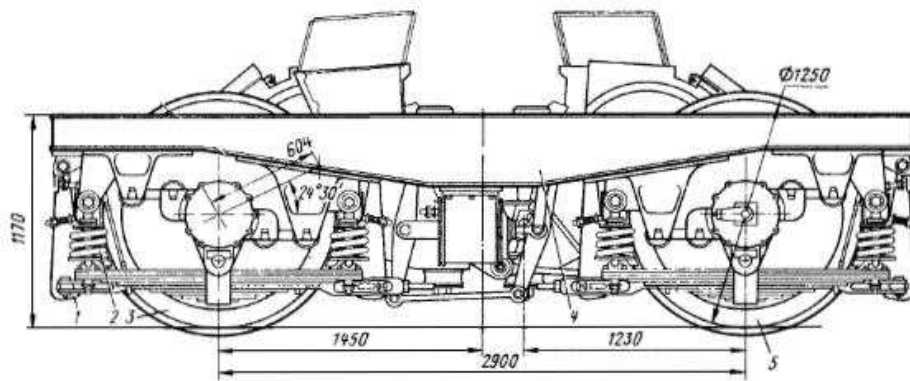


Fig. 1. Scheme the electric locomotive bogie: 1 – braking system 2 – spring suspension, 3, 5 – wheel set with electric motor, 4 – bogie frame

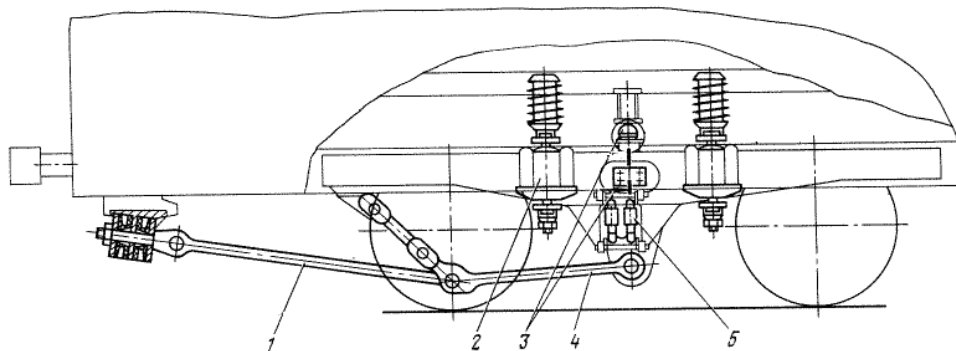


Fig. 2. Connections of the body with the extreme bogies: 1 – inclined rod, 2 – cradle suspension, 3 – stops, 4 – the traction device, 5 – oscillation damper

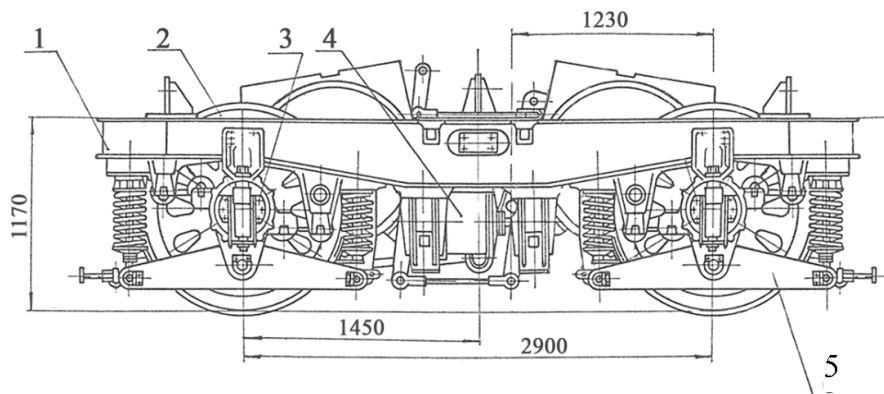


Fig. 3. The scheme of electric locomotive bogie: 1 – frame, 2 – wheel set, 3 – bush, 4 – braking system, 5 – spring suspension

To improve the dynamic qualities of the carriages on the locomotive is the construction cradle suspension of the body with a static deflection of 120 mm. On each side of the bogie the body is connected by two inclined cradle suspensions with the cross-bearer. Each cross-bearer in the transverse direction through a spherical joint is connected to the center beam of a bogie frame and in the longitudinal direction it is connected pivotally with two rods, which are

connected to the sidewalls of the bogie frame by means of rubber washers.

Traction and braking forces are transmitted from the bogies to the body by means of inclined rods, which are connected on one side with the body using equal-arm beam, metal rods and brackets with rubber washers, reinforced at the bottom to the bogie frame, and on the other side – with traction devices on the bogie frame (fig. 4). In the system of the body bearing on the bogies there

are intermediate beams, with which is the body connected by means of cradle suspension.

The first stage of suspension consists of the springs, hydraulic shock absorbers and elastic leashes; suspension of the second stage is the cradle one with hydraulic shock absorbers. In this construction to improve the reliability of cradle suspension work, the springs of the body vertical connection with the bogies are installed not on the suspensions themselves, but between the bogie frame and the intermediate beams, pivotally connected to the bogie frame. Intermediate beam in this case is a lever one end of which through the cradle suspension bears a part of the body weight. At the pass point the load is transferred to the springs of the body spring suspension, based on the bogie frame. Springs for vertical loads, are located separately between two intermediate beams and the bogie frame. Body through the cradle suspension is suspended to the intermediate beams, attached to the bogie frame in the horizontal longitudinal and transverse directions using the hinged-rod connections with elastic-dissipative elements of the unilateral action, which are working for the compression only.

The advantage of the construction is in that the elements, in which the restoring forces appear in the vertical (spring) and horizontal (suspension cradle) planes, are spaced apart.

When the carriage negotiates the curves, there occurs a fairly significant turning point that takes intermediate beam through elastic

connections. Two cradle suspensions are located diagonally on the bogie, when turning the bogie should lengthen, the other two – shorten. The resulting skew-symmetric load forces the intermediate beams work as a "propeller", that is to oscillate galloping in the opposite direction. This facilitates the space joint with which the two beams are connected with the bogie frame. Thus, when negotiating the curve, besides the restoring torque, which appears in the cradle suspensions, it also appears in the springs (one extreme spring of the three in the set, located on one side of an electric locomotive is compressed, another is stretched and the center one thus performs the function of supporting).

Among the other locomotives (built recently), where the traction and braking forces are also transmitted from the bogie to the body by means of inclined rods, can be identified as follows:

- Bogies of the main-line six-axle passenger electric locomotive EP10 are biaxial, agnathous, the spring suspension is two staged. The bogie consists of a wheel pair with axle boxes and pulling gear, axle box spring suspension system equipped with hydraulic dampers, bogie frame, traction engine and the brake system. Among the features of an electric locomotive undercarriage design, as compared to other ones, you should point out that it has a traction drive of the 2-class

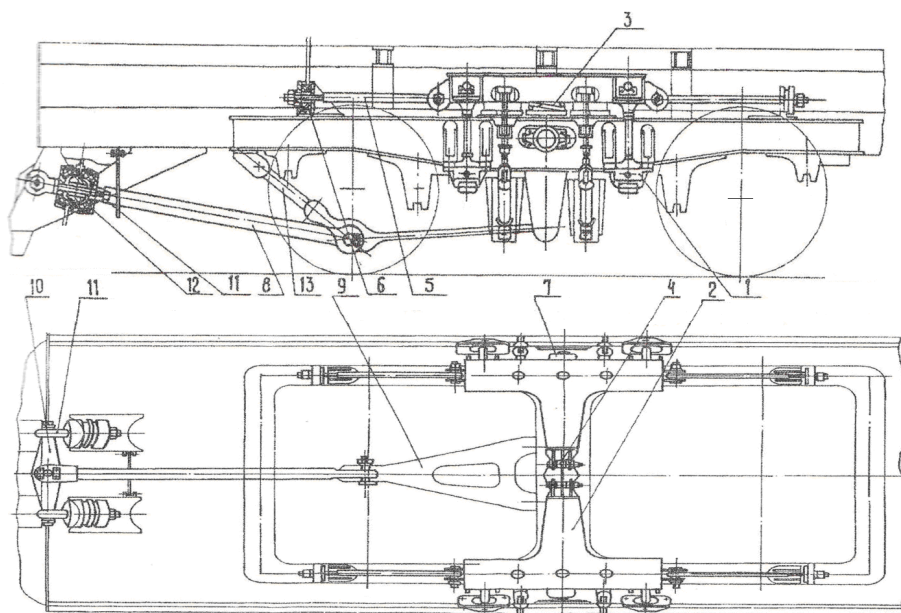


Fig. 4. Connection of bogie with the body: 1 – cradle suspension, 2 – intermediate beam, 3 – a set of springs, 4 – spherical joint, 5, 9, 13 – rods, 6 – washer, 7 – side stop, 8 – inclined rod, 10 – beam, 11 – rod, 12 – washer

with the support suspension of the traction motors, communications systems of the bogies with the body, the first and third bogies have a better system of the second-stage spring suspension, in which the coil springs of the Flexi coil type were used. Bearing of the body on extreme bogies (fig. 5) is radically new, using the springs working for compression and shear. The spring through the bearing rib rests on the rubber-metal washers, which deform under load, providing its equilibrium distribution on the length of inactive coil. [14].

When passing through the curve and straight sections, when any relative displacement of the ends of the springs to each other in a horizontal plane occur, they spring and reduce the deformation of the coils, and hence, they reduce the stress in the turns of the spring coils and the stiffness of suspension system of the bogies angular rotation relative to the body. It is also provided during offset of the body relative to the horizontal plane of the bogie.

A significant reduction in the stiffness of the body bearing on the bogies, the transverse shear of the body relative to the bogies when moving in straight lines and angles of rotation, curves

negotiating, and motion in circular curves significantly improves the dynamic performance of the carriage and eliminate its impact on the way.

Characteristic of the body cross-link with the bogies is formed by the support springs of the body and a special spring anti offset device. Rigidity of the cross-link of the body with the bogie is not higher than the stiffness of the pendulum gear with the length 500 mm. Installation of horizontal hydraulic dampers at the level of the bottom bearing belt of the body and the selection of their characteristics provided a good horizontal dynamics of the new carriage. It is also promoted by the installation of horizontal and anti wobble hydraulic dampers that prevent the development of bogie whipping at high speeds.

In the longitudinal direction the bogie with body are connected by whole low-lying rod. Exception of the intermediate parts of the longitudinal brace system and the installation of single communication became possible after the application of brushless traction motors, which have significantly smaller diameter with higher power.

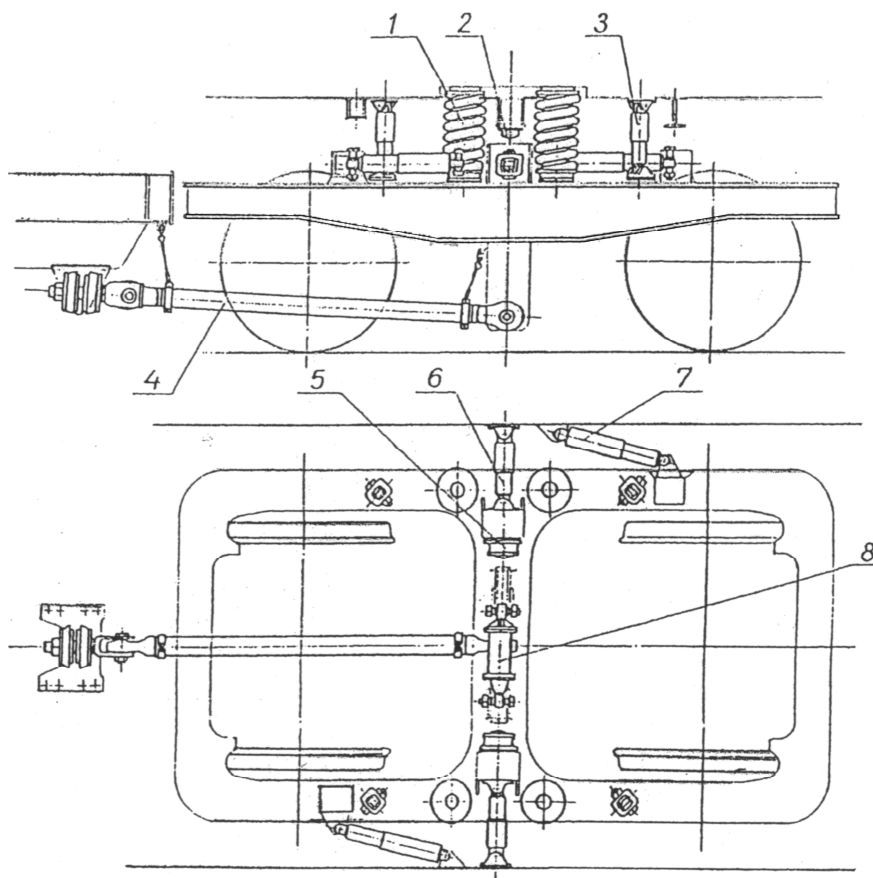


Fig. 5. The system of the body links with extreme bogie: 1 – body support, 2, 5 – vertical and horizontal supports, 3, 6, 7 – hydraulic dampers, 4 – longitudinal brace rod of the bogie with body, 8 – anti offset device

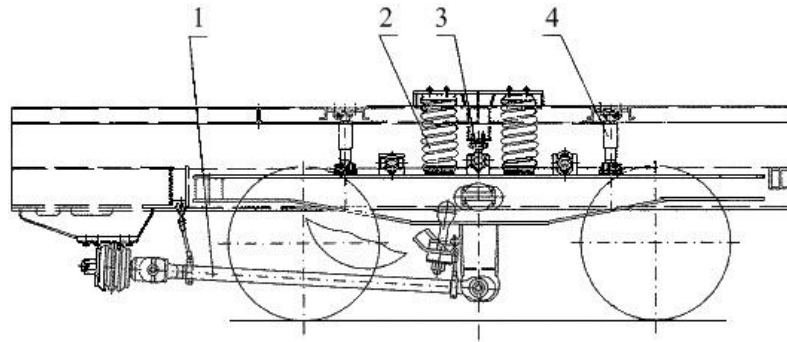
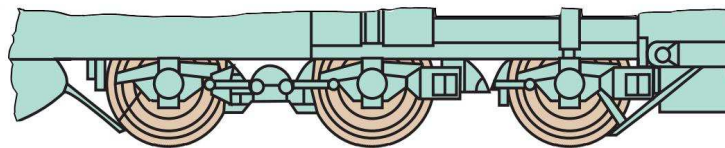


Fig. 6. The scheme of body connection with the bogie of the electric locomotive 2ES6 series "Sinara": 1 – inclined rod, 2 – body support of the type "flexi coil", 3 – vertical stop, 4 – vertical hydraulic damper



a



b

Fig. 7. Running gear: a – electric locomotive 2ES10 "Granite", b – diesel locomotive Maxima 40CC

- Body of each section of electric locomotive 2ES6 "Sinara" is based on two-axle boll-joint bogies (fig. 6).

The body and the bogies are interconnected in the vertical and lateral directions by means of elastic and damping elements – by means of the spring-type "Flexi coil" through the special limit stops and the one piece inclined rods; for body oscillations and the bogie spring parts damping the vertical and horizontal hydraulic dampers of the body were applied [9].

- The body and the bogie of electric locomotive 2ES10 "Granite" are connected in the vertical and transverse directions using the elastic and damping elements.

The maximum reciprocal movements of the bogies and electric locomotive 2ES10 body are limited in the vertical and lateral directions by special stops. The power and braking forces transmission from the bogies to body is performed by one piece inclined rods (fig. 7, a) [15].

- In the design of the locomotive bogie Maxima 40SS (fig. 7, b) in the second stage of the spring suspension the coil springs of Flexi coil type were used, providing a reduced impact of the locomotive on track. The transfer of longitudinal forces between the body and bogies performed by low-lying rods [18]. Bogies are also equipped with independent systems of antiskid protection.

- In the design of the running parts of the Prima locomotives one can see that the relationship between the body and bogies (fig. 8) is carried out by means of two inclined bars, working for stretching/compression. Rods transmit the traction and braking forces at the level of the rail heads. This solution minimizes the discharge of wheels and optimizes the use of available adhesion weight [19].

Traction motors have the support-axle suspension and rely on the axes of the wheel set of the locomotive through the bearing bushing.



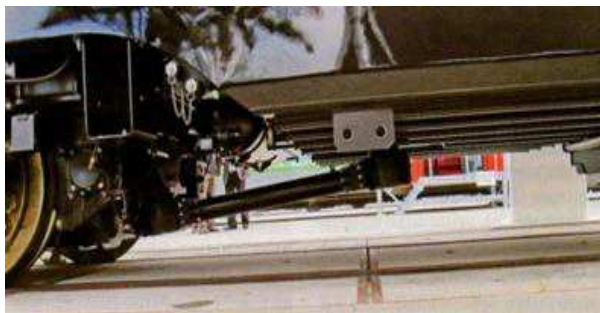
Fig. 8. Running part of the Prima locomotives

The spring of central (second) stage of the bogie suspension rests on the top of the longitudinal beams. The longitudinal beams are in turn supported by an axle-box (first) stage of the bogie spring suspension.

- Locomotive of the type ALP-45DP is located on the bogies of the FLEX Power 250 type (fig. 9, a). In the first stage of spring suspension the steel coil springs are used; in the second stage of suspension used the dual spiral steel coil springs of the type Flexi coil [20].



a



b

Fig. 9. A general view of the running part: a – bogie of the type LEX Power 250, b – The rod for the transmission of longitudinal forces between the bogie and the body

The transfer of longitudinal traction and braking forces between the body and bogies is performed through two longitudinal inclined rods, connected with the body in the area of the fuel tanks (fig. 9, b).

CONCLUSIONS

Thus, it was considered the design features of the running gear elements of some main-line types of locomotives, which have between the bogie and the body the inclined rods transmitting the traction forces between them and provide the essential dynamic performance of carriage motion.

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АНАЛИЗ КОНСТРУКЦИЙ МЕХАНИЧЕСКОЙ ЧАСТИ ЛОКОМОТИВОВ

Сергей Мямлин, Николай Луханин, Лариса Недужая

А н н о т а ц и я . Для определения динамических качеств магистральных грузовых локомотивов, которые характеризуют безопасное движение по прямолинейным и криволинейным участкам пути во всем диапазоне эксплуатационных скоростей, необходим целый комплекс исследований, который включает в себя выбор расчетной схемы, разработку соответствующей математической модели пространственных колебаний локомотива, составление компьютерной программы вычислений, проведение теоретических, а потом и экспериментальных исследований новых конструкций. При этом сопоставление результатов необходимо выполнить с существующими конструкциями. Одним из необходимых условий качественного улучшения тягового подвижного состава железных дорог является определение параметров его ходовых частей. Среди вопросов, связанных с этой проблемой, важное место занимает задача определения динамических качеств локомотивов на стадии проектирования с учетом выбранных технических решений в конструкции ходовых частей. В работе рассмотрены основные тенденции конструктивного исполнения некоторых типов магистральных локомотивов, уделив основное внимание совершенствованию конструкции ходовых частей. В результате исследований видно, что создание современного локомотива требует от конструкторов и ученых реализации научных и технических решений, обеспечивающих повышение конструкционной скорости с одновременным улучшением тяговых, тормозных и динамических качеств для обеспечения простой и надежной конструкции, особенно ходовой части, позволяющей снизить расходы на обслуживание и ремонт, низкую первоначальную стоимость и эксплуатационные расходы в расчете на весь жизненный цикл, высокую силу тяги при трогании, максимально приближенную к предельной по сцеплению, возможность работы в режиме кратной тяги, достаточную конструкционную скорость. Исследования математического моделирования проводятся методом численного интегрирования динамической нагруженности магистрального локомотива с использованием программного комплекса «Dynamics of Rail Vehicles» («DYNRAIL»). Рассмотрены конструктивные особенности элементов ходовых частей некоторых типов магистральных локомотивов, имеющих между тележкой и кузовом наклонные тяги, которые передают тяговые усилия между ними и обеспечивают необходимые динамические показатели движения экипажа.

К л ю ч е в ы е с л о в а . Локомотив, ходовая часть, тележка, связи, наклонные тяги.

Expert system, as component of diagnostics system of man's sight

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Summary. The analysis of existing methods and information systems of spatial contrasting sensitivity diagnostics is carried out. New computer diagnostics based on more exact valuation method of spatial man's sight, and also the module of expert system of the primary diagnosis setting are offered.

Key words. Computer diagnostics of sight, expert system.

INTRODUCTION

The large rate of life of people requires more rapid analysis of the state of health of man: nobody already wishes to expend the enormous amount of time in search of the best doctor and expectation in turns to him, it results in that more frequent than all patients begin self-treatment is can only aggravate a situation. Actual are creations of such informative systems (IS) and technologies which will give possibility to conduct primary examination without a doctor or consulted with him staying in a house or office.

Development IS medical setting gives possibility to work out these problems [14]. Today in a medical informatics large attention is taken to development of the intellectual systems of support of acceptance of medical decisions and formalization of his knowledge's as consulting models. Such systems have a few considerable features: allow to conduct diagnostics without a doctor, to do raising of diagnosis automated and expressly to outline the new symptoms of diseases, select them from plenty of indefinite factors.

ANALYSIS OF PUBLICATIONS, MATERIALS, METHODS

The computer methods of measuring of the state of the visual system of man are widespread in medical practice [6, 7]. They are realized in such hardware and software complexes, as VCKuser [19], ILDK "Academician" [1] and as on-line-testing of sight with the use of tables of Sivtseva-Golovina or Rings of Landolta on the official sites of many known ophthalmology clinics of the world. Such methods give a certain result, but does not allow quickly and without intervention from a doctor to get information, in relation to a spatial contrasting sensitiveness which gives possibility to warn development of many pathologies on the early stages.

PURPOSE AND RAISING OF RESEARCH TASK

Improvement of process of diagnostics of diseases in ophthalmology due to development of the module of consulting model for the system of computer diagnostics of eye diseases of "SOTA".

MATERIALS AND RESULTS OF RESEARCHES

For simplification of inspections and accumulation of necessary information computer

realization of reverse of hexagonal method of measuring of spatial contrasting sensitiveness (SCS) of "SOTA" [8, 10, 13] was developed. In times of the use of this program some conformities to law, which allowed to show out a few normative curves, were got (Fig.2-9). Value of curves were confronted with the generally accepted indexes [4] and supposition was pulled out, about possibility of their further using for the leadthrough of diagnostics as standards. However found out it was, that each time to examine the chart of SCS, coming running to the analysis each of curves in all ranges of frequencies not comfortably. A decision to improve the comfort of the use of the diagnostic program and enter in the complement of the system the module of consulting model [18] which will be able right after diagnostics to pull out supposition was accepted, in relation to development of one of possible pathologies or its absence.

As reliable expert estimations, also there were the used materials of the leading Russian ophthalmologists of Shamshinova A.m., Volkova V.V. and mathematics of Belozeroва A.E. [3, 4, 17].

A base of knowledges of consulting model is edited [2, 20], it enables at the protracted use of the program, on the basis of the accumulated statistics, to save the exposed conformities to law, as new diagnosis.

A consulting model supposes the presence of list of questions, which have direct attitude toward facts [12] which result in a certain decision and choice of diagnosis. As "questions" the graphic image of hexagonal nets, shown out on the screen of computer, is used in a consulting model (fig.1).

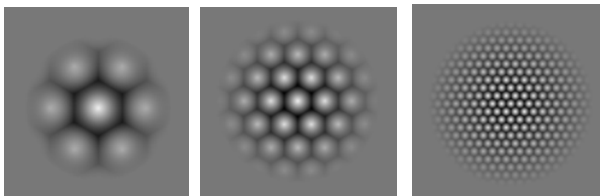


Fig. 1. "Questions" of consulting model

A dialog with an user is carried out by the answers of type "See - does not see" at producing to him grates of different frequency and contrasty [9]. With the purpose of increase of authenticity of answers (exception of possibility to answer "at random") a certain mechanism is foreseen in the program: stimuli are produced by turns for left, for

a right side or after the center of screen of monitor, thus, probability of guessing of next position of stimulus is eliminated [11]. This mechanism also allows practically fully to remove the effect of "remaining perception" - when eye of man long time fixed in one point of the produced object (especially in the case of bright object), then yet some time after translation of look aside we see the afterimage of this object.

A consulting model uses information got on the stage of diagnostics, that information about a spatial contrasting sensitiveness for different spatial frequencies (table 1).

Table 1. Example of entrance information for ES

№ measu rings	Spatial frequency, cycle/grad											Sensitivity, dollar
	0,5	0,8	1	1,5	2	3	4	6	8	12	16	
1	42	45	49	53	56	57	59	52	48	41	37	
2	40	41	51	53	52	56	58	51	50	45	40	
3	38	38	50	55	60	50	51	45	39	35	33	

According to the diagnosis offered by the system it is possible to do the followings conclusions about the state of health of the visual system of patient:

- Healthy (fig.2);

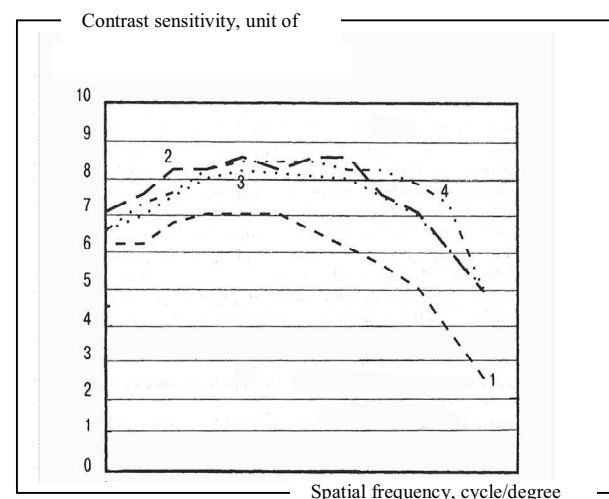


Fig. 2. Normative curves of contrasting sensitiveness on a black background.

1 - dark blue; 2 - green; 3 - red; 4 - white

- Rods disfunction (nightly blindness) takes place - SCS higher than norm in all range, especially on high-frequencies (fig.3);

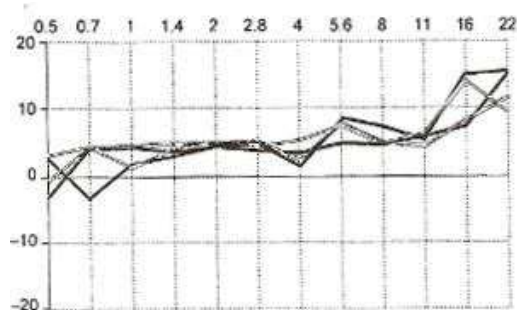


Fig. 3. Rods disfunction

- Cones disfunction takes place - SCS mionectic a greater measure on midfrequencies (fig.4);

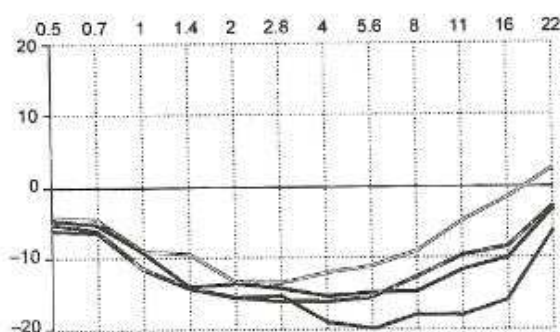


Fig. 4. Cones disfunction

- Central dystrophy of retina (illness of Shtargardt) takes place - a sensitiveness is fully absent on high-frequencies (fig.5);

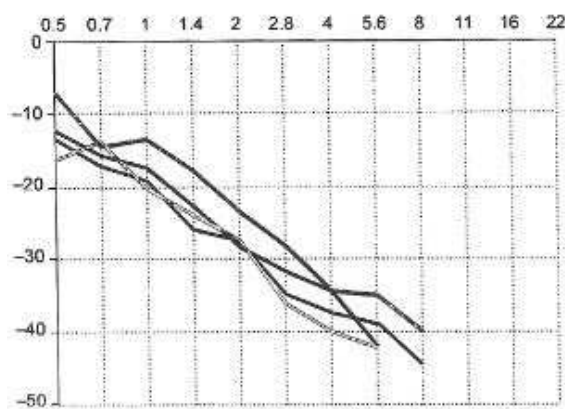


Fig. 5. Dystrophy of retina

- Optic neuritis - SCS goes down evenly in all range (fig.6);

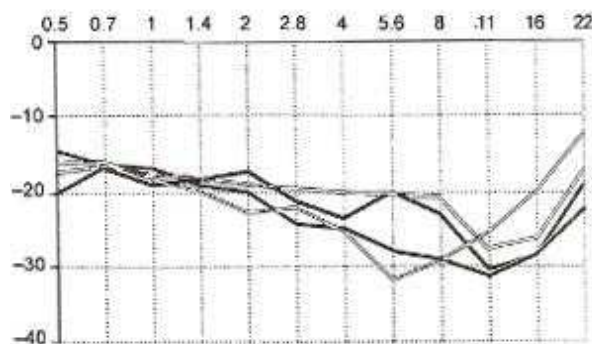


Fig. 6. Optic neuritis

- The defeat of visual bark (craniocerebral trauma) takes place is a characteristic not-even brokenness of curve of SCS on all frequencies, thus breaking does not meet for the different colors of researches (fig.7);

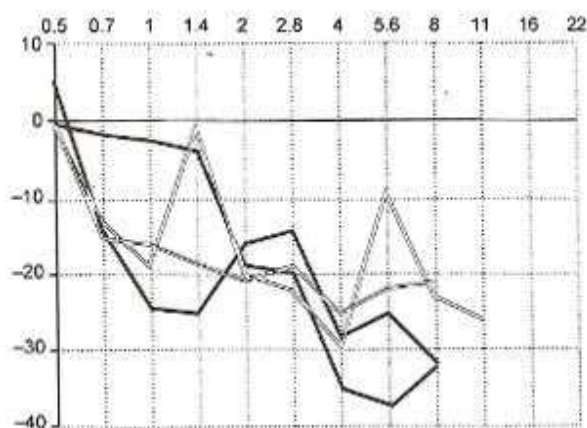


Fig. 7. Defeat of visual bark

- Different forms and stages of amblyopia:
1) Optic amblyopia of weak degree is a smooth decline and in the following подъем curves on middle and high frequencies (fig.8);

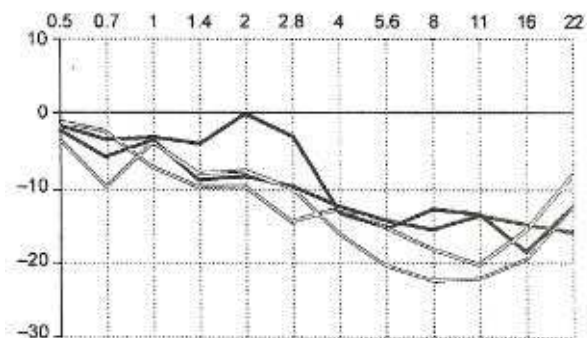


Fig. 8. Disbinokulyar amblyopia

2) Refraction and anisometric amblyopia is a decline of SCS on high and middle spatial frequencies (fig.9).

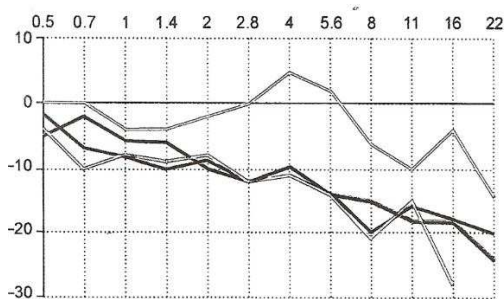


Fig. 9. Refraction and anisometric amblyopia

A job of ES performance is a preliminary diagnosis and to recommendation on the further chart of treatment of this patient which hatches for every measuring in the alphanumeric field. In addition, a job of consulting model performance is plugged in a printing report in a column "Diagnosis ES".

On this design time ES allows to define seven types of rejections in the visual system of man, which can in future result in difficult consequences и/или become reason of serious eye diseases up to the loss of eyesight.

CONCLUSIONS

There are no doubts, that not looking on progress which did not go round a side medicine, major in the end for a patient there is knowledge and ability of doctor. Therefore, destiny of this ES consists in a help to the doctor-ophthalmologist to accept a faithful decision in relation to the further method of treatment: on the got results an ophthalmologist draws conclusion about the necessity of setting of additional inspection of patient, with the purpose of confirmation or refutation of diagnosis.

The use of similar consulting models is special topically in those cases, when in medical establishment skilled enough specialists absent or not possibility or technical base, to expose a rejection physically, also the similar systems come for help to the young doctors without experience of diagnosticating and treatment of rare, difficult diseases [5].

Introduction of this system (or similar systems) in everyday practice of doctor of ophthalmologist can considerably reduce the risk of eye diseases, shorten time expended on

prophylactic examinations, to simplify the estimation of level of diseases in the separately taken district, city, areas et cetera Today there are some limitations from the side of legislative base for introduction of the similar systems (additional certification, limit on the use of the personal information and electronic card indexes), however, similar problems can be worked out due to effective activity of government [16].

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**ЭКСПЕРТНАЯ СИСТЕМА,
КАК СОСТАВЛЯЮЩАЯ СИСТЕМЫ
ДИАГНОСТИКИ ЗРЕНИЯ ЧЕЛОВЕКА**

*Григорий Пантелеев, Султан Рамазанов,
Константин Кривошеев*

А н н о т а ц и я . Проведен анализ существующих методов и информационных систем диагностики пространственной контрастной чувствительности. Предложено новую компьютерную диагностику на основании более точного метода оценки пространственного зрения человека, а также модуль экспертной системы постановки первичного диагноза.
К л ю ч е в ы е с л о в а . Компьютерная диагностика зрения, экспертная система.

Mathematical model-building of relax processes taking place in concrete mix at vibro impact compact deformation

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Summary. In the article is examined the modified cementing system at vibro impact compact method of compression. It is solving the task of system's movement taking into consideration relax processes. It has been considered the physical sense of relax processes taking place at vibro impact compact deformation and it is defined the character of the internal parameters. It has been received complete system of equations describing the course of modified cementing system of concrete mix in the process of vibro impact compact compression.

Key words. Modified concrete mix, vibro impact compact method of compression, relax processes, phenomenological formulas of movement

ACTUALITY OF RESEARCH AND PROBLEM DEFINITION.

The course of modified concrete mix at vibro impact compact deformation in comparison with the course of Newtonian liquids has definite peculiarities [11, 14, 16]. Particularly at a simple move there are normal stresses in a modified concrete mix, which is not observed in Newtonian liquids. At a simple move the viscosity of modified cementing systems, as a rule, is decreasing and a simple extension it is increased and it depends both on applied stresses (or gradients of velocity) and the type of the flow [2, 18]. It is also observed the range of "non classical" effects while considering the non-stationary movement of the system [4, 7, 15, 21, 22, 23].

PURPOSE AND OBJECT, MATERIALS AND RESULTS OF INVESTIGATIONS.

If known internal parameters characterizing the system, the constitutive equation can be defined with a necessary precision. But in general case we cannot define the universal connection between the tensor of stresses and tensor of the gradients of velocity neglecting the internal parameters.

It should be marked the evident properties of a liquid phase of cementing system of zero range which constitutive equation in the first order has the view [15]

$$\sigma_{ik}(\xi, t) = -p\delta_{ik} + \varepsilon_0\xi\delta_{ik} + 2(\varepsilon_1 + \varepsilon_2\xi)v_{(ik)}. \quad (1)$$

As the liquid phase of cementing system has only scalar internal parameters which change with the change of the system density [15] the viscosity is not changing at a shift deformation

$$\frac{d\xi}{dt} = -\frac{1}{\tau}(\xi - \xi_0) + (\alpha_1 + \alpha_2\xi)v_{ii}. \quad (2)$$

Non-Newtonian behavior can be discovered at the other types of deformations [9-11, 15]. Shift viscosity of a liquid phase of cementing system of zero rank of the second order depends on the gradient of the velocity as the shift in the second order leads to the appearance of diagonal components of tensor of stresses and at the same time to the change of the volume; this in its turn

leads to the change of indexes of internal parameters defining the measurable value of the viscosity [8, 12, 19-21]. The peculiarity of a liquid phase of a zero rank is its isotropy in the process of the flow.

The peculiarities of a liquid phase of a zero rank do not answer the peculiarities of a modified cementing system because in the process of the flow the cementing system becomes anisotropic and it's necessary to appeal to the systems of higher rank for its description.

Without the analysis of the obtained system of equations for the system of the second rank in the general aspect [15], let's clarify the physical sense of relax process on the ground of the views of building of cementing system taking place at vibro impact compact deformation and define the character of internal variables [5, 6, 13, 14, 16].

While building the theory of the behavior of cementing system of compressed modified concrete mix was used that circumstance that hydrated cement grain is the macrosystem which can be described with the help of phenomenological concerns: free energy, index of friction [1-3, 17, 18].

Let considered system consist of hydrated grains of the cement with the equal density. In the cementing system of a modified concrete mix in the balanced state the hydrated grains of the cement together with the chemical modifier form floccules the sizes of which let's take as the equal to mean squared radius of inertia $\bar{R}^2$. It can be also taken the effective radius of floccules r^* , having defined it as the distance from the center of the floccules on which the density in comparison with its index is decreasing twice in the center. The effective radius is connected with the mean squared radius by the ratio:

$$r^* = 0,64 (\bar{R}^2)^{1/2}. \quad (3)$$

The sizes of the floccules in the cementing system depend on the character of intermolecular interaction and differ from the sizes of floccules which are in the cement-water paste of a usual concrete mix. But as intermolecular interactions in a modified cementing and general cement-water paste do not differ fundamentally, it can be supposed that in the equilibrium the indicated sizes do not differ considerably i.e. coincide according to the order of an index.

There are forces of different nature between the hydrated grains as it leads to the appearance of labile floccules having final life cycle and connecting all the grains into uniform system in

which can be the floccules of different type (which differ by the time of life) connected by a definite type of interaction.

Thus, the cementing system in the process of physical modification can be introduced by effective system with labile floccules the number of which depends on the temperature, pressure and applied stress. Let's consider the law of the change of the number of floccules of one of the types in detail. Let it set K – a maximum possible number of floccules. Let it set the possibility of destruction and possibility of the formation of floccules for the unit of time p^- and p^+ . Then the change of the number of floccules in the unit of time can be found as the difference between the number of the formed and destructed nodes:

$$\frac{dz}{dt} = -p^-z + (K - z)p^+. \quad (4)$$

For the stationary case we found:

$$z_0 = \frac{p^+}{p^+ + p^-} K \approx \frac{p^+}{p^-} K. \quad (5)$$

The equation (4) can be written as:

$$\frac{dz}{dt} = -\frac{1}{\tau}(z - z_0), \quad (6)$$

where: $\tau = \frac{1}{p^+ + p^-}$ – time of relax

depending on the applied gradients of velocity (or stresses).

At small gradients of the velocity the time of relaxation can be decomposed according to the gradients of velocity. Then from the formula (6) with the accuracy to the members of the first order according to the gradients of the velocity we got the equation (2).

Thus, one of the relaxing processes in a physically modified cementing system introduces itself the destruction and formation of floccules. The definition of the possibility of the formation of floccule is connected with the consideration of its nature.

Thus, at the first approach the building of a cementing system is described by the following indexes: mean squared index of radius of inertia $\langle R^2 \rangle_0$ of hydrated cementing grain; by the type of floccules differed by their mean life cycle; number of floccules taken as a unit of volume. Let's suppose that the considered system consists of cementing grains of an equal diameter and all the floccules have the same nature and, thus, the equal life cycle.

Let's consider the change of sizes and the form of the floccules in the stream at vibro impact compact way of compression of concrete mix.

Let's enumerate all cementing grains from 0 to z . Let set s_i^α – the distance between the neighbor grains with the numbers $\alpha-1$ and α ; r_i^α – the coordinate of α -floccule, thus, $s_i^\alpha = r_i^\alpha - r_i^{\alpha-1}$.

Let's formulate, first of all, the kinetic equation for the function of the possibility of finding coordinates $z+1$ of a floccules in the space at the given index of tensor of the gradients of velocity v_{ik} . The spring force acts on each of floccules:

$$2 \text{Tk} (s_i^{\alpha+1} - s_i^\alpha) = -2 \text{Tk} A_{\alpha\gamma} r_i^\gamma. \quad (7)$$

And the force of hydrodynamic resistance:

$$X = \zeta (v_i^\alpha - w_i^\alpha), \quad (8)$$

where: $v_i^\alpha = v_{ik} r_k^\alpha$ – the velocity of the system in the place where is α -floccule on condition that as it would not be there,

w_i^α – medium velocity of the movement of α -floccule,

κ – elastic ratio of the phase between the floccules,

$\zeta = 6\pi\eta_{(s)}\alpha$ – frictional coefficient of the floccules of the radius (α) in the medium with the viscosity $\eta_{(s)}$.

The matrix $A_{\alpha\gamma}$ is given by:

$$\begin{pmatrix} 1 & -1 & 0 & . & . & . & 0 \\ -1 & 2 & -1 & . & . & . & 0 \\ 0 & -1 & 2 & . & . & . & 0 \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ 0 & 0 & 0 & . & . & . & 1 \end{pmatrix}. \quad (9)$$

The velocity of movement of hydrated grains of cement is defined on condition of the equilibrium of forces acting on a grain moreover, to real forces it should be added the effective force:

$$F_{\Phi} = -T \frac{\partial \ln W}{\partial r_i^\alpha}. \quad (10)$$

Then continuity equation:

$$\frac{\partial W}{\partial t} + \sum_{\alpha,i} \frac{\partial (w_i^\alpha W)}{\partial r_i^\alpha} = 0, \quad (11)$$

for the case of many particles leads to the desired equation.

Considering the viscosity of a cementing system a considerable, we drop the force of inertia and, setting equal to zero the sum of forces (7), (8) and (10), we find the expression for the medium velocity of movement of α -floccule:

$$w_i^\alpha = v_i^\alpha - \frac{2\text{Tk}}{\zeta} A_{\alpha\gamma} r_i^\gamma - \frac{T}{\zeta} \frac{\partial \ln W}{\partial r_i^\alpha}. \quad (12)$$

From the continuity equation (11) with the usage of (12) we find the kinetic equation for the plastic modified cementing system:

$$\frac{\partial W}{\partial t} = \sum_{\alpha} \left[\frac{T}{\zeta} \frac{\partial^2 W}{(\partial r_i^\alpha)^2} - \left(v_{ik} r_k^\alpha - \frac{2\text{Tk}}{\zeta} A_{\alpha\gamma} r_i^\gamma \right) \frac{\partial W}{\partial r_i^\alpha} \right] + \frac{12\text{Tk}z}{\zeta} W. \quad (13)$$

By the orthogonal transformation of coordinates $r_i^\alpha = R_{\alpha\gamma} \rho_i^\gamma$ и $\rho_i^\gamma = R_{\beta\gamma} r_i^\beta$ the matrix (9) can be taken to the diagonality with approximate chief indexes $\lambda_\alpha = \frac{\pi^2 \alpha^2}{z^2}$. In view of properties of transformation it is true the ratio:

$$\sum_{\alpha} \langle \rho_i^\alpha \rho_k^\alpha \rangle = \sum_{\alpha} \langle r_i^\alpha r_k^\alpha \rangle. \quad (14)$$

Let's copy out the sums of different degrees of characteristic numbers:

$$\sum_{\alpha} \lambda_\alpha = 2z; \quad \sum_{\alpha} \lambda_\alpha^{-1} = \frac{z^2}{6}; \quad \sum_{\alpha} \lambda_\alpha^{-2} = \frac{z^4}{90}.$$

The equation (13) has the following view in the new coordinates:

$$\frac{\partial W}{\partial t} = \sum_{\alpha} \left[\frac{T}{\zeta} \frac{\partial^2 W}{(\partial \rho_i^\alpha)^2} - \left(v_{ik} \rho_k^\alpha - \frac{2\text{Tk} \lambda_\alpha}{\zeta} \rho_i^\alpha \right) \frac{\partial W}{\partial \rho_i^\alpha} \right] + \frac{6\text{Tk} \lambda_\alpha}{\zeta} W. \quad (15)$$

PURPOSE AND OBJECT, MATERIALS AND RESULTS OF INVESTIGATIONS

Multiplying the equation (15) by $\rho_i^\gamma \rho_k^\gamma$ and integrating to all variables, we find the following system of equations for the moments of distribution function of the second order $\langle \rho_i^\alpha \rho_k^\alpha \rangle = \int W \rho_i^\alpha \rho_k^\alpha d\rho$:

$$\frac{d\langle\rho_i^\alpha\rho_k^\alpha\rangle}{dt} = -\frac{1}{\tau_\alpha}\left(\langle\rho_i^\alpha\rho_k^\alpha\rangle - \langle\rho_i^\alpha\rho_k^\alpha\rangle_0\right) + v_{ij}\langle\rho_k^\alpha\rho_j^\alpha\rangle + v_{kj}\langle\rho_i^\alpha\rho_j^\alpha\rangle, \quad (16)$$

where: $\tau_\alpha = \frac{\zeta}{4T\kappa\lambda_\alpha}$ – time of relaxation,

$\langle\rho_i^\alpha\rho_k^\alpha\rangle_0 = \frac{1}{2\kappa\lambda_\alpha}\delta_{ik}$ – equilibrium index for

the moments of distribution function.

If the gradients of velocity disappear suddenly, the moments relax according to the law $\langle\rho_i^\alpha\rho_k^\alpha\rangle - \langle\rho_i^\alpha\rho_k^\alpha\rangle_0 \approx e^{-t/\tau_\alpha}$.

Thus, here the internal variables are tensor moments $\langle\rho_i^\alpha\rho_k^\alpha\rangle$, the law of change of which is defined by the system (16). The system (16) has the same structure as a phenomenological equation [15]:

$$\begin{aligned} \frac{d\xi_{ik}}{dt} = & -\frac{1}{\tau}(\xi_{ik} - \xi_{ik}^0) + \beta_1\delta_{ik}v_{ss} + \beta_2v_{(ik)} + \\ & + \beta_3\xi_{ss}v_{(ik)} + \beta_4\delta_{ik}\xi_{js}v_{js} + \beta_5\xi_{jj}\delta_{ik}v_{ss} + \beta_6\xi_{ik}v_{ss} + \\ & + \beta_7(\xi_{is}v_{sk} + \xi_{ks}v_{si}) + \beta_8(\xi_{is}v_{ks} + \xi_{ks}v_{is}). \end{aligned} \quad (17)$$

However, some members of equation (17) disappear in this case.

Let's find the solution of the system (16) for simple shear flow ($v_{12} = 0$). At this the system (16) is given by (index of a grain for the simplicity of writing is dropped):

$$\begin{cases} \frac{d\langle\rho_1^2\rangle}{dt} = -\frac{1}{\tau}(\langle\rho_1^2\rangle - \langle\rho_1^2\rangle_0) + 2v_{12}\langle\rho_1\rho_2\rangle; \\ \frac{d\langle\rho_2^2\rangle}{dt} = -\frac{1}{\tau}(\langle\rho_2^2\rangle - \langle\rho_2^2\rangle_0); \\ \frac{d\langle\rho_3^2\rangle}{dt} = -\frac{1}{\tau}(\langle\rho_3^2\rangle - \langle\rho_3^2\rangle_0); \\ \frac{d\langle\rho_1\rho_2\rangle}{dt} = -\frac{1}{\tau}\langle\rho_1\rho_2\rangle + v_{12}\langle\rho_2^2\rangle; \\ \frac{d\langle\rho_1\rho_3\rangle}{dt} = -\frac{1}{\tau}\langle\rho_1\rho_3\rangle + v_{12}\langle\rho_2\rho_3\rangle; \\ \frac{d\langle\rho_2\rho_3\rangle}{dt} = -\frac{1}{\tau}\langle\rho_2\rho_3\rangle. \end{cases} \quad (18)$$

The solution of introduced system (18) is given by:

$$\langle\rho_1^2\rangle = \langle\rho_1^2\rangle_0 \left[1 + 2\tau^2 v_{12}^2 \left(1 - e^{-t/\tau} - \frac{t}{\tau} e^{-t/\tau} \right) \right],$$

$$\langle\rho_1\rho_2\rangle = \langle\rho_1^2\rangle_0 \tau v_{12} (1 - e^{-t/\tau}), \quad (19)$$

$$\langle\rho_2^2\rangle = \langle\rho_2^2\rangle_0 = \langle\rho_2^2\rangle_0 = \langle\rho_3^2\rangle_0; \quad \langle\rho_1\rho_3\rangle = \langle\rho_2\rho_3\rangle = 0.$$

The expression for $\langle\rho_i^\alpha\rho_k^\alpha\rangle$ can be calculated directly after the definition of distribution function. The final result for the stationary case accurate to the members of the second order in accordance with the gradients of velocity:

$$\begin{aligned} \langle\rho_i^\alpha\rho_k^\alpha\rangle = & \frac{1}{2\kappa\lambda_\alpha} [\delta_{ik} + 2\tau_\alpha v_{(ik)} + \\ & + 2\tau_\alpha^2 (2v_{(si)}v_{(sk)} - v_{(si)}v_{[sk]} - v_{(sk)}v_{[si]} + \dots)] \end{aligned} \quad (20)$$

The characteristic of a floccule of deformed cementing system as the whole can be served diad:

$$\langle R_i R_k \rangle = \frac{1}{Z} \sum_\alpha \langle r_i^\alpha r_k^\alpha \rangle, \quad (21)$$

which is after (14) and (20), is written by the gradients of velocity in the stationary case by the following way:

$$\begin{aligned} \langle R_i R_k \rangle = & \frac{Z}{12\kappa} \left[\delta_{ik} + \frac{\zeta Z^2}{30\kappa T} v_{(ik)} + \right. \\ & \left. + \frac{\zeta^2 Z^4}{1260 T^2 \kappa^2} (2v_{(si)}v_{(sk)} - v_{(si)}v_{[sk]} - v_{(sk)}v_{[si]} + \dots) \right] \end{aligned} \quad (22)$$

The distribution function of density of cementing system, obviously, answers the conditions $\int \rho(r) dr = m \int \rho(r) r_i r_k dr = m \langle R_i R_k \rangle$, where m – the weight of hydrated cementing particle. Approximating $\rho(r)$ as Gaussian function, from the formulas (22) in the system of coordinates where diad $\langle R_i R_k \rangle$ is diagonal, we get:

$$\rho(r) = \left(\frac{1}{2\pi} \right)^{3/2} \frac{m}{\left(\langle R_1^2 \rangle \langle R_2^2 \rangle \langle R_3^2 \rangle \right)^{1/2}} e^{-\frac{1}{2} \sum_{i=1}^3 \frac{r_i^2}{\langle R_i^2 \rangle}}. \quad (23)$$

It is obvious that the distribution function of density can be approximated by triaxial ellipsoid. Defining the effective sizes of ellipsoid as per the decrease of density in two times, we find the semi-axes $a_{(i)} = 1, 10 \langle R_i^2 \rangle^{1/2}$ and effective volume of hydrated cementing grain $\Omega = 5, 6 \left(\langle R_1^2 \rangle \langle R_2^2 \rangle \langle R_3^2 \rangle \right)^{1/2}$, which depends on the gradients of velocity. The decomposition of effective volume in the gradients of velocity do not contain the members of the first order as $v_{ik} = 0$. It follows that at the smallest

gradients of velocity the floccule is deformed in the flow without any change in the volume, and then the volume of a floccules is increasing with the increase of the gradient of the velocity.

If the gradients of velocity are absent, all non-diagonal components $\langle R_i R_k \rangle$ are equal to zero and the diagonal ones become equal one to each other. At this the distribution function of density transforms into spherically symmetric function:

$$\rho(r) = m \left(\frac{3}{2\pi \langle R^2 \rangle_0} \right)^{3/2} e^{-\frac{3}{2} \frac{r^2}{\langle R^2 \rangle_0}}. \quad (24)$$

The additional dissipation of energy in deformed cementing system takes place because of the connection of punctiform centers of friction into unified whole. This means the presence of additional punctiform forces in the liquid phase distributed in volume.

The averaged tensor of stresses of a system σ_{ik} can be calculated by the average index of a tensor of the flow of impulse [4] $\sigma_{ik} = \rho v_i v_k - \Pi_{ik}$. All the indexes are average here. We define non-averaged ones by the stroke.

In the linear as per the velocity (stokes) approximation:

$$\sigma_{ik} = \frac{1}{V} \int \sigma'_{ik} dV. \quad (25)$$

Let the density of volumetric forces acting on deformed cementing system $\sigma_i(x)$, then the law of conservation of momentum is given by:

$$\frac{\partial(\rho v'_i)}{\partial t} + \frac{\partial \Pi'_{il}}{\partial x_l} = \sigma_i(x). \quad (26)$$

The substitution of the expression for the tensor of flow of impulse leads to the formula:

$$\frac{\partial(\rho v'_i)}{\partial t} + \frac{\partial(\rho v'_i v'_l)}{\partial x_l} = \frac{\partial \sigma'_{ij}}{\partial x_j} + \sigma_i(x). \quad (27)$$

Neglecting in the equation (27) inertial members, we obtain:

$$\frac{\partial \sigma'_{il}}{\partial x_l} = -\sigma_i(x). \quad (28)$$

To find the averaged value of tensor of stresses, we multiply both parts of the equation (28) by x_k , integrate over the volume $\int \frac{\partial \sigma'_{il}}{\partial x_l} x_k dV = -\int \sigma_i x_k dV$ and describe the left part of the last ratio

$$\int \frac{\partial(\sigma'_{il} x_k)}{\partial x_l} dV - \int \sigma'_{ik} dV = -\int \sigma_i x_k dV. \quad (29)$$

The first integral in the left part of the equation (29) we convert into the integral over the surface of the frame and obtain $\oint \sigma'_{il} x_k df_l - \int \sigma'_{ik} dV = -\int \sigma_i x_k dV$.

Thus, we find the average value of tensor of stresses:

$$\sigma_{ik} = \frac{1}{V} \int \sigma'_{ik} dV = \frac{1}{V} \oint P_i x_k df + \frac{1}{V} \int \sigma_i x_k dV. \quad (30)$$

where: P – the force acting on the unit surface area of volume.

The first integral which is to the right in the equation (30) and which is the tensor of stresses connected only with the surface forces and, thus, the expression (30) can be rewritten as:

$$\sigma_{ik} = \sigma_{(ik)}^0 + \frac{1}{V} \int \sigma_i x_k dV, \quad (31)$$

where: $\sigma_{ik}^{(0)}$ – tensor of stresses at the absence of volumetric forces and the last member in the expression (31) describes additional stresses appearing while adding volumetric forces with the density σ_i .

The forces acting on a liquid phase in the considering case of a cementing system can be defined as punctiform. Thus, the density of forces:

$$\sigma_i(x) = \sum_{a_\alpha} \psi_i^{a_\alpha} \delta(q_k^a + r_k^{a_\alpha} - x_k), \quad (32)$$

where: q_k^a – coordinate of center of masses of a-floccule of a cementing system,

$r_k^{a_\alpha}$ – coordinate of a_α -floccule,

$\psi_i^{a_\alpha}$ – a force acting on α -hydrated grain of a cement of a_α -floccule.

Calculating with the help of (32) the integral in the expression (31), we obtain:

$$\int \sigma_i x_k dV = \sum_a q_k^a \sum_\alpha \psi_i^{a_\alpha} + \sum_{a_\alpha} \psi_i^{a_\alpha} r_k^{a_\alpha}. \quad (33)$$

In the frames of one floccule $\sum_\alpha \psi_i^{a_\alpha} = 0$.

Further, as all the floccules we consider the equal ones and in the last summand the summation by the floccules can be substituted by the multiplication by the number of floccules and, thus:

$$\frac{1}{V} \int \sigma_i x_k dV = n \sum_\alpha \psi_i^{a_\alpha} r_k^{a_\alpha}, \quad (34)$$

where: n – the number of floccules in the unit of volume.

The obtained expression describes the additional stresses caused by the presence of connected centers of friction at their momentary location.

For the connected floccules with the total volume ϕ the volumetric forces disappear when the velocities of floccules and the velocity of the flow in the point where is the floccule coincide. This will happen only then when the connections between the floccules disappear, the system thixotropic thins down, and the tensor of stresses of which can be defined and, thus, for such cementing system:

$$\sigma_{ik}^{(0)} = -p\delta_{ik} + 2\eta_{(s)}(1 + 1,5\phi)v_{(ik)}. \quad (35)$$

The force acting on a liquid phase is equal in value and reciprocal in sign of force with which the liquid phase acts on the grain of the cement:

$$\psi_i^\alpha = -\zeta(v_i^\alpha - w_i^\alpha) \quad (36)$$

And, thus, the extra term after averaging-out is given by:

$$-n\zeta\sum_{\alpha}\left\langle\left(v_i^\alpha - w_i^\alpha\right)_k^\alpha\right\rangle, \quad (37)$$

where: the brackets as previously define averaging-out in coordinates of all floccules with the help of the distribution function. Using the expressions (12) and (15), we calculate the value (35) and write the tensor of stresses for deformed cementing system as:

$$\sigma_{ik} = -p\delta_{ik} + 2(1 + 1,5\phi)\eta_{(s)}v_{(ik)} + \frac{1}{2}n\zeta\sum_{\alpha}\frac{1}{\tau_{\alpha}}\left(\left\langle\rho_i^\alpha\rho_k^\alpha\right\rangle - \left\langle\rho_i^\alpha\rho_k^\alpha\right\rangle_0\right). \quad (38)$$

The obtained constitutive equation is a private case of general expression (1) with tensor internal parameter.

$$\begin{aligned} \sigma_{ik}(\xi_{js}, t) = & -p\delta_{ik} + q\xi_{jj}\delta_{ik} + \mu(\xi_{ik} - \xi_{ik}^0) + \\ & + \zeta_1\delta_{ik}v_{ss} + \zeta_2v_{(ik)} + \zeta_3\xi_{ss}v_{(ik)} + \\ & + \zeta_4\delta_{ik}\xi_{js}v_{js} + \zeta_5\xi_{jj}\delta_{ik}v_{ss} + \zeta_6\xi_{ik}v_{ss} + \\ & + \zeta_7(\xi_{is}v_{sk} + \xi_{ks}v_{si}) + \zeta_8(\xi_{is}v_{ks} + \xi_{ks}v_{is}) + \\ & + \zeta_9(\xi_{is}v_{sk} - \xi_{ks}v_{si}) + \zeta_{10}(\xi_{is}v_{ks} - \xi_{ks}v_{is}) - \\ & - \frac{2}{3}(\zeta_9 + \zeta_{10})\xi_{ss}v_{[ik]}. \end{aligned} \quad (39)$$

The ratio (16) and (36) together with the equations of movement and continuity form complete system of equations describing the flow

of modified cementing system of concrete mix in the process of vibro impact compact compression.

CONCLUSIONS

On the ground of the results of the experimental theoretical investigations:

1. It has been defined the physical sense of relaxing processes and the character of internal variables in the process of vibro impact compact deformation.

2. It is built the theory of the behavior of cementing system of compressed modified concrete mix where the hydrated cementing grain is the macrosystem which can be described with the help of phenomenological terms: free energy and index of friction. The cementing system of concrete mix in the process of physical modification is introduced as the effective system with labile floccules, the number of which depend on the temperature, pressure and applied stress.

3. It has been obtained the constitutive equation which is a private case of a general expression with tensor internal parameter. The obtained equations together with the equations of movement and continuity form complete system of equations describing the flow of modified cementing system of concrete mix in the process of vibro impact compact compression.

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МАТЕМАТИЧЕСКОЕ МОДЕЛИРОВАНИЕ
РЕЛАКСАЦИОННЫХ ПРОЦЕССОВ,
ПРОИСХОДЯЩИХ В БЕТОННОЙ СМЕСИ
ПРИ ВИБРО-УДАРНОИМПУЛЬСНОЙ
ДЕФОРМАЦИИ

Владимир Пилипенко

Аннотация. В статье рассматривается модифицированная цементная система при вибро-ударноимпульсном способе её уплотнения. Решается задача движения системы с учётом релаксационных процессов. Рассмотрен физический смысл релаксационных процессов, происходящих при вибро-ударноимпульсной деформации, и определён характер внутренних переменных. Получена полная система уравнений, описывающая течение модифицируемой цементной системы бетонной смеси в процессе вибро-ударноимпульсного уплотнения.

Ключевые слова. Модифицированная бетонная смесь, вибро-ударноимпульсный способ уплотнения, релаксационные процессы, феноменологические уравнения движения.

The determination of the characteristics of iron ore slurry under the conditions of ultrasonic control

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Summary. The paper presents the results of theoretical investigations of the characteristics of the iron ore slurry necessary for controlling the processes of the iron ore beneficiation. It is shown that such physical characteristics as magnetic permeability can be calculated with the distribution of firm particles of suspension by size and density being taken into account. The calculation algorithm is given.

Key words: ore crushing, iron ore slurry, magnetic permeability.

INTRODUCTION

At the modern mining and processing factories the iron ore beneficiation is usually carried out in several stages. Herewith ore crushing-classification at the first stage is one of the primary operations defining the overall performance of the production line. This results from the fact that, on the one hand, this operation implies the maximum losses of iron in the waste. On the other hand, the process of ore crushing is the most power expensive, and its efficiency considerably defines the general economic effect of the beneficiation process. The necessary extent of the mineral disclosure, which defines the beneficiation results, is determined exactly by the crushing processes. Therefore the continuous control of the technological parameters, which characterize the quality of processed ore materials, is an essential condition for the effective use of automatic control systems in the technological processes of beneficiation.

ANALYSIS OF PUBLICATIONS, MATERIALS, METHODS

The ultrasonic control appeared to be the most applicable for the definition of the main characteristics of a slurry – the density and the granulometric structure [2, 7, 8, 11, 13, 15]. For these purposes the volume [3, 6] and the superficial [14, 19, 20, 24, 25] ultrasonic waves are used.

The research reported in the work [17] showed that the quality of a crushed product is characterized by the content W of a firm phase in a slurry and by the granulometric structure of a firm phase. Also the quality is defined by the quality indicators of initial raw materials (the content of useful components, the mineral structure etc.), which do not depend on a technological operating mode of a crushing cycle [27, 28]. Within the work [10] it was concluded that there exists an essential interrelation between the density and the granulometric structure of a firm phase in the qualifier discharge, i. e. in the final product of a crushing cycle. The higher the discharge density, the greater the size of a firm material particles in a product. Within the work [12] the analysis of the granulometric characteristics at the stages of crushing and at the first stage of magnetic beneficiation was conducted. There was made a conclusion that the full disclosure of a useful component for each type of ore during its crushing-classification is reached in the terms of a certain

granulometric structure, which has to be supported constant at this technological stage.

Within the works [9, 10] it was also mentioned that one of the major technological indicators – the extent of a useful component disclosure – is defined by the density of fixed-size particles. Therefore, measuring the size and the density of the crushed material particles in a slurry allows to define the extent of useful component disclosure. Such measurements can be carried out on the basis of ultrasonic methods.

The fundamental analysis of control methods based on volume ultrasound was conducted within the work [10]. It was shown that most of the abovementioned methods have common disadvantages. For example, the methods basing on the work [7] are based on the following. The signal being defined by the intensity ratio of volume ultrasonic waves in the pure water I_0 and the slurry I_v depends on the concentration $\frac{N}{V}$ of solid particles $F(r)$ and on their size distribution r :

$$A = \frac{1}{Z} \ln(I_0/I_v) = \frac{N}{V} F(r) \sigma(v, r),$$

where: $\sigma(v, r)$ the section of the attenuation of ultrasound with frequency v on a solid spherical particle of radius r [1].

The disadvantages of this method, as well as of many other methods considering the volume ultrasound only, are associated with the need of the slurry degasation, which is especially necessary when using the low frequencies [12]. Furthermore, it is necessary to use a large number of ultrasonic measuring channels to provide the sufficient frequency range.

Similar methods were proposed within the works [5, 8] with variations in the number of channels, in the frequency range of ultrasound and in certain design features. In the terms of analyzing the abovementioned methods, apart from the disadvantage associated with the need for degasation, the low accuracy of the controlled parameters measurement [7, 26] and the need to configure devices at the monitoring place [5, 8] can be mentioned.

The use of ultrasonic superficial waves, such as Lamb's waves [16, 18, 23], in the terms of the same tasks allowed to avoid many problems inherent in the methods based on the use of volume ultrasound. Figure 1 shows an example of the spread of the Lamb's wave.

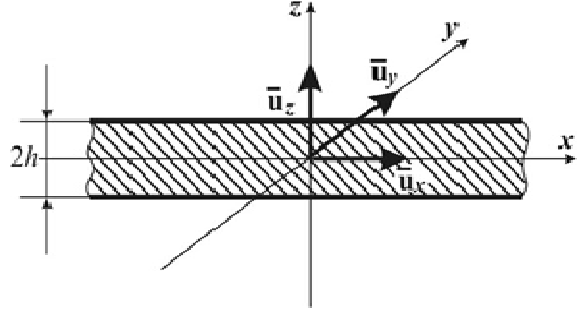


Fig. 1. Displacements caused by the spread of an ultrasonic Lamb's wave in a slab

The energy of the superficial wave is mainly concentrated in a narrow layer of material near its surface. In the terms of a contact of such a surface with various environments, the emission of the wave in the environment takes place; such emission causes a decrease of the energy and the intensity of the wave. The intensity change is dependent on the properties of the environment the wave is emitted in. These dependencies are the fundamental basis for the methods of controlling the technological environment properties using superficial ultrasound.

In the terms of using various methods to determine the characteristics of the slurry there arises a need for experimental determination of the constants inherent for each method. For example, within the work [21, 22] the controlled values were determined on the basis solving the system of equations:

$$\begin{cases} (1 - \eta) \left(\frac{\sigma_s}{\sigma_{nm}} \right)^{1/3} = \frac{\sigma_m - \sigma_s}{\sigma_m - \sigma_{nm}}, \\ \mu(W, \eta) = W\eta \cdot \mu_m + 1, \\ \rho_{hp}(W, \eta) = (1 - W)\rho_w + W[(1 - \eta) \cdot \rho_{nm} + \eta \cdot \rho_m] \\ S(W, \eta) = \frac{\sigma(W, \eta) \cdot \mu^2(W, \eta) H^2 \beta^2(W, \eta)}{2 \cdot \rho_{hp}(W, \eta) \cdot c_o c^2 (1 + \beta^2(W, \eta))} l, \end{cases}$$

where: ρ, μ, σ — the density, the magnetic permeability and the electrical conductivity of various system components respectively. Thus there arises a need to determine the physical characteristics (ρ, μ, σ) of the slurry as of the complex heterophase system.

Within the work [20], the following expression for finding the magnetic component fraction in the slurry was obtained as a result of the analysis of ultrasound and magnetic influences on the slurry:

$$\eta = A \frac{(\mu-1)H}{\ln\left(\frac{I_{ov}}{I_v}\right)} = A_1 \frac{(qC_1-1)}{\ln\left(\frac{I_{ov}}{I_v}\right)},$$

where: H — the magnetic field strength; q — the charge. Thus it is proposed to determine the value of C_1 experimentally.

In order to improve the accuracy and efficiency of ultrasonic methods of controlling the characteristics of the slurry, there should be the possibility to operatively determine the auxiliary values used in the control algorithm.

OBJECT AND TASKS OF RESEARCH

The purpose of the research presented in this paper is to determine the average physical characteristics of the iron ore slurry, which are required for the effective application of ultrasonic control methods.

The studied environment is considered as a two-component heterophase system: the heterogeneous solid phase particles are placed in a homogeneous liquid. The size and the composition of the solid particles may vary within certain limits. It is considered that the solid particles have a two-component structure. They include: a ferromagnetic component with density ρ_m and magnetic permeability μ_m , a nonmagnetic component with density ρ_n , and μ_n magnetic permeability (e. g., magnetite and quartz).

The magnetic permeability of the considered environment is calculated as follows. At first the simple case is considered: all the solid particles are similar in size and composition. The task is solved in two steps: 1) the magnetic permeability of the two-component solid particle is determined; 2) the magnetic permeability of the "liquid — solid particles" system is determined. Herewith is possible to use the approach proposed by A. K. Weinberg [4] at the first step.

MAIN PART WITH RESULTS AND ANALYSIS

Let the magnetic permeability of the non-magnetic solid phase component be μ_n , of the magnetic component — be μ_m , and of the entire particle — be μ_p . The volume fraction of the magnetic component — v — is interrelated with the mass fraction $x = \frac{m_m}{m_p}$ as follows:

$$v = \frac{x\rho_n}{x\rho_n + \rho_m(1-x)}. \quad (1)$$

For the systems with a small fraction of magnetic of spherical inclusions, the Maxwell's expression can be used:

$$\mu_p = \mu_n \frac{\mu_m + 2\mu_n + 2(\mu_m - \mu_n)v}{\mu_m + 2\mu_n - (\mu_m - \mu_n)v} \quad (2)$$

If it is expanded into a power series with respect to v , then one will get the following expression with the accuracy up to the first two terms of the expansion:

$$\mu_p = \mu_n + \frac{3\mu_n(\mu_m - \mu_n)}{\mu_m + 2\mu_n}v \quad (3)$$

Let's consider the expression (3) as a basis for further transformations. Since it is applicable only for small values of v , let's determine μ for particles in the terms of incremental filling a non-magnetic environment with small portions of the magnetic component. Having determined the magnetic permeability μ at some stage, let's determine the increment $d\mu$ of the magnetic component at the next step, taking into account the expression (3):

$$d\mu = \frac{3\mu(\mu_m - \mu)}{\mu_m + 2\mu}dn \quad (4)$$

where: dn is a small amount of the contributed magnetic component. Since in the terms of such contribution the correspondent part of the non-magnetic component is being replaced, the increment of the volume fraction dv will be equal to:

$$dv = (1-v)dn \quad (5)$$

After integrating (4) with respect to (5) one will get the following expression:

$$(1-v) \left(\frac{\mu_p}{\mu_n} \right)^{\frac{1}{3}} = \frac{\mu_m - \mu_p}{\mu_m - \mu_n} \quad (6)$$

or, after applying certain transformations:

$$\mu_p^3 + \mu_p^2(-3\mu_m) + \mu_p(A + 3\mu_m^2) - \mu_m^3 = 0 \quad (7)$$

$$\text{where: } A = \frac{(\mu_m - \mu_n)^3(1-v)^3}{\mu_n} \quad (8)$$

Considering the abovementioned, on gets the following expression for the magnetic permeability of the solid particles:

$$\mu_p = \mu_m + \left(\sqrt{\left(\frac{A}{3}\right)^3 + \left(\frac{A \cdot \mu_m}{2}\right)^2} - \frac{A \mu_m}{2} \right)^{1/3} + \left(-\sqrt{\left(\frac{A}{3}\right)^3 + \left(\frac{A \cdot \mu_m}{2}\right)^2} - \frac{A \mu_m}{2} \right)^{1/3} \quad (9)$$

After that, a similar procedure needs to be done to determine the magnetic permeability of the "liquid — solid particles" system (second stage). The liquid is now considered as the nonmagnetic component, and the solid phase particles — as the contributed magnetic inclusions. Analogously to the expression for the particle, a formula for the magnetic permeability of the system is obtained:

$$\mu_s = \mu_p + \left(\sqrt{\left(\frac{B}{3}\right)^3 + \left(\frac{B \mu_p}{2}\right)^2} - \frac{B \mu_p}{2} \right)^{1/3} + \left(-\sqrt{\left(\frac{B}{3}\right)^3 + \left(\frac{B \mu_p}{2}\right)^2} - \frac{B \mu_p}{2} \right)^{1/3}, \quad (10)$$

$$\text{where: } B = \frac{(\mu_p - \mu_l)^3 (1 - v_s)^3}{\mu_l}.$$

The volume fraction of the solid component v_s is interrelated with the mass fraction of fluid in the system $y = \frac{m_l}{m_s}$ (m_l — the mass of the liquid, m_s — the mass of the system) as follows:

$$v_s = \frac{\rho_l (1 - y)}{\rho_l (1 - y) + \rho_p y} \quad (11)$$

or, with respect to the expression for the particle density:

$$\rho_p = \frac{\rho_n \cdot \rho_m}{\rho_m + x(\rho_n - \rho_m)},$$

the expression (11) takes the following form:

$$v_s = \frac{\rho_l (1 - y)}{\rho_l (1 - y) + \frac{\rho_n \cdot \rho_m \cdot y}{\rho_m + x(\rho_n - \rho_m)}}. \quad (12)$$

As follows from the expressions (10)-(12), the magnetic permeability of the environment depends on the magnetic component fraction in solid particles, x , which may vary within the range $0 \leq x \leq 1$, as was mentioned at the first step. In order to consider the classification of the particles according to composition, the following method

for determining the magnetic permeability is proposed. Firstly, the respect is paid to the fact that the expression (9) allows to calculate the magnetic permeability μ_{pj} for each j -th class of particles:

$$\mu_{pj} = \mu_m + \left(\sqrt{\left(\frac{A_j}{3}\right)^3 + \left(\frac{A_j \cdot \mu_m}{2}\right)^2} - \frac{A_j \mu_m}{2} \right)^{1/3} + \left(-\sqrt{\left(\frac{A_j}{3}\right)^3 + \left(\frac{A_j \cdot \mu_m}{2}\right)^2} - \frac{A_j \mu_m}{2} \right)^{1/3}, \quad (13)$$

$$\text{where: } A_j = \frac{(\mu_m - \mu_n)^3 \left(1 - \frac{\rho_n \cdot x_j}{\rho_n \cdot x_j + \rho_m (1 - x_j)} \right)}{\mu_n}.$$

Secondly, it is considered that the solid particles have different composition. Let the fraction of particles with a certain composition x_j be v_j . Thirdly, the "filling" of the liquid phase with solid particles is produced not only step by step, but also considering the composition of the particles. That is, the solid particles with a minimum of magnetic component are "contributed" first, and then the particles with greater values of x_j are "contributed". If necessary, each class is fractioned to the desired number of portions for the reasons of small increments. After "contributing" the particles of the j -th class, the magnetic permeability of the system is assumed to be equal to μ_j , and in the terms of integrating the expression (4) the limits of integration will have corresponding indices:

$$\int_{\mu_{j-1}}^{\mu_j} \left(\frac{1}{3\mu} + \frac{1}{\mu_{pj} - \mu} \right) d\mu = \int_0^{v_j} \frac{dv}{1 - v}. \quad (14)$$

Here the respect is paid to the fact that before "contributing" the particles of the j -th class the magnetic permeability is equal to μ_{j-1} ; in the terms of filling the environment with particles of the j -th class, their volume fraction in the system will increase from 0 to v_j ; μ_{pj} is determined from the expression (13). The integration of the expression (14) allows to get a formula, which relates the magnetic permeabilities of the two sequential iterations:

$$(1 - v_j) \left(\frac{\mu_j}{\mu_{j-1}} \right)^{\frac{1}{3}} = \frac{\mu_{pj} - \mu_j}{\mu_{pj} - \mu_{j-1}}, \quad j = \overline{1, N_B}, \quad \mu_0 = \mu_l.$$

It can be represented as the cubic equation and solved analogously to the equation (6). The

number of iterations is determined by the number of classes N_B .

CONCLUSIONS

Thus, the expressions allowing to theoretically calculate the required physical properties of the slurry without conducting experimental electromagnetic research were obtained. The algorithm for the calculation of the magnetic permeability is presented within the paper. The proposed technique can also be used to determine the electrical conductivity and other characteristics of the system.

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ОПРЕДЕЛЕНИЕ ХАРАКТЕРИСТИК ЖЕЛЕЗОРУДНОЙ ПУЛЬПЫ В УСЛОВИЯХ УЛЬТРАЗВУКОВОГО КОНТРОЛЯ

Ольга Поркуян, Татьяна Сотникова

Аннотация. В статье представлены результаты теоретических исследований характеристик железорудной пульпы, необходимых для контроля технологических процессов обогащения железной руды. Показано, что физические характеристики, такие как магнитная проницаемость, могут быть рассчитаны с учетом распределения твердых частиц суспензии по размерам и плотности. Приведена методика расчета.
Ключевые слова: измельчение, железорудная пульпа, магнитная проницаемость.

Neural network simulation in running of acetic acid synthesis unit while start-up

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Summary. The present article focuses on the researches' results of artificial neural networks architecturing using in automated control systems for acetic acid synthesis unit by means of GUI, i.e. Neutral Network Toolbox interface of the software simulator Matlab. The structural schemes of such systems are attached.

Key words: neural network with feed-forward back propagation; radial-basic neural network; activation function.

INTRODUCTION

To run complex systems, it is necessary to build a model adequately reflecting the properties of the object to be controlled. In the majority of cases such model parameters are determined directly within the process of object is in operation, i.e. the identification is performed on the basis of occasional input and output signals. Nowadays the way of automated control systems architecturing on the basis of artificial intelligence technologies usage (e.g. neural networks, fuzzy logic, genetic algorithms) [6, 8, 11-14, 17, 29, 30] is being rapidly developed. Those factors which are badly formalized using common mathematical methods may be subjected to generalization (e.g. one's professional experience or intuition, etc.). Only few attempts are known to use artificial intelligence technologies in chemical industry. They are used to interpret sensors' readings, to run temperature mode of the technological processes, to monitor chemical and technological processes [1-5, 7, 9, 10, 15, 16, 18-28].

Architecturing and researching of artificial neural networks performance can be carried out via software-based simulators. The most commonly used packages to model neural networks characteristics are as follows: Neural Works Pro Plus, Neuro Solution, Matlab (Neural Network Toolbox), Neuro Wisard, ANsim, Neural Ware and others. The software is differed by its complexity, quantity of neurons types and algorithms of studying maintained at the system.

MATERIALS AND METHODS

The purpose of the present work was the building up and researching of the neural network properties which might be used in running of acetic acid synthesis unit at start-up at PJSC "SEVERODONETSK AZOT ASSOCIATION". For this purpose the statistical data of the acetic acid synthesis unit while the plant starting up process were used. Block diagram of the column acetic acid synthesis is shown in figure 1.

Analysis of the acetic acid synthesis unit as a control object shows that concentration Q of acetic acid, process temperature T , pressure P in the synthesis column and the reaction mass level L in the reactor may be used as the output coordinates.

To control the synthesis column as control (input) coordinates can be used the flow rate of methanol F_1 and carbon monoxide F_2 fed to the reactor.

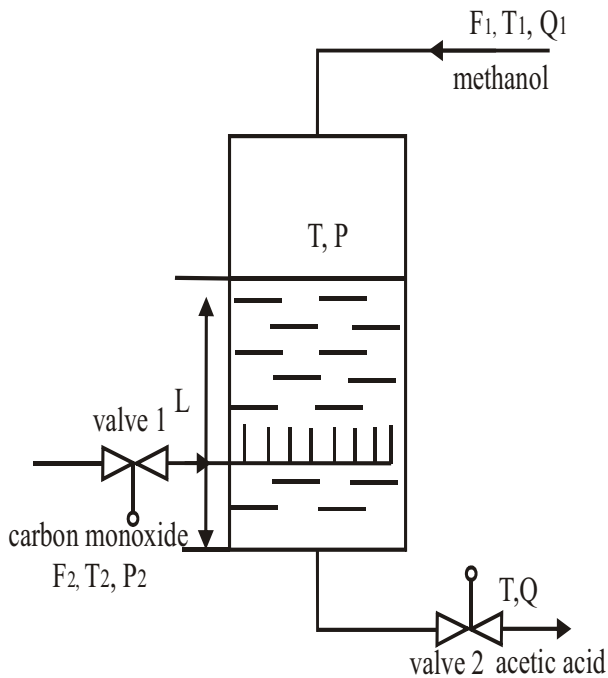


Fig. 1. Block diagram of the column for synthesizing acetic acid

All other parameters of the process: the temperature of the methanol feed T_1 , supply pressure of carbon monoxide P_2 , the temperature of the feed carbon monoxide T_2 , should be attributed to the perturbing parameters.

Information and logic synthesis column acetic acid is shown in figure 2.

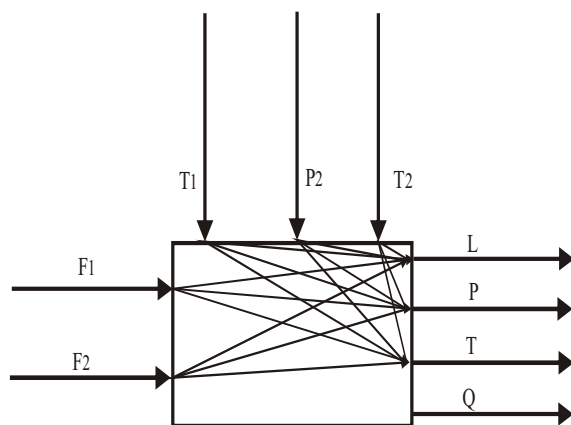


Fig. 2. Information and logic diagram synthesis column acetic acid

The environment of software-based simulator MATLAB 7.1.0 (GUI - Neural Network Toolbox interface) was used for building up process. This pack is recommended for neural network with different type of activation function architecturing.

The following parameters were used as the input data:

1. Inlet methanol consumption.
2. Inlet carbon oxide consumption.
3. Inlet methanol temperature.
4. Inlet carbon oxide pressure.
5. Inlet carbon oxide temperature.

The following parameters were used as the output data:

1. Reaction mass level at the unit.
2. Reaction mass pressure at the unit.
3. Reaction mass temperature at the unit.

50% of the main observations were involved in the process of the neural network learning (the other half was used for verification purposes).

RESULTS

The structure and parameters of the neural network with feed-forward back propagation shown at Fig.3 were determined as a result of GUI - Neural Network Toolbox interface MATLAB 7.1.0.

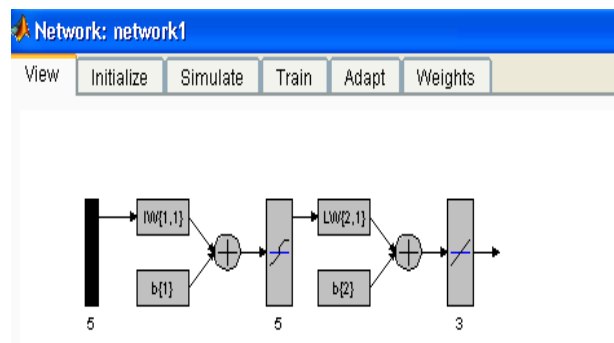


Fig. 3. Neural network with feed-forward back propagation structure

The network was built up on the basis of five neurons at the network input, five sigmoid (TANSIG) neurons of a buried layer and three linear (PURELIN) neurons of an output layer. The functions implementing learning algorithm as well as training and error functions ensuring minimum relative accuracy of data approximation were determined to build up the network. The respective parameters of three networks for the acetic acid synthesis units are given in tab. 1.

While making a comparison of the networks respective parameters, the following observations were found: the minimum relative accuracy is insured by the network based on gradient descent method with disturbance as a learning function, function of the gradient descent with account of the moments as a training function, mean-square error as an error function.

Table 1. Neural networks parameters with feed-forward back propagation

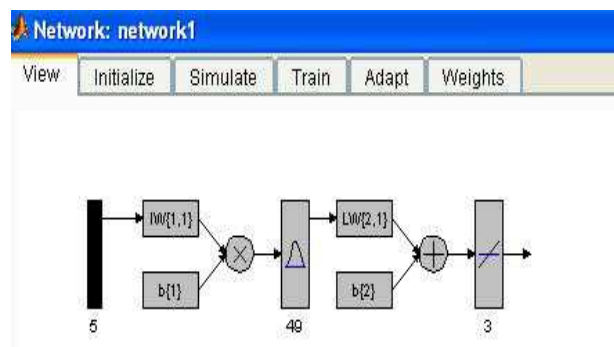
Net-work Number	Learning algorithm implementing function	Training function	Error function	Output parameter	Relative accuracy	Average relative accuracy
1	2	3	4	5	6	7
1	Gradient descent method	Learning function of gradient descent with account of the moments	Mean-square error	1	0,078	0,075
				2	0,060	
				3	0,086	
1	2	3	4	5	6	7
2	Gradient descent method with account of the moments	Learning function of gradient descent	Mean-square error	1	0,790	0,312
				2	0,061	
				3	0,086	
3	Levenberg-Marquardt method	Learning function of gradient descent	Mean-square error	1	0,801	0,316
				2	0,062	
				3	0,086	

In addition, a radial-basic neural network which structure is shown at fig.4 was built up as a result of the research.

The parameters of the input $\bar{P}$ and target values $\bar{T}$ arrays, as well as GOAL (network tolerated mean-square error) and SPREAD parameters (the parameter of interference) were used as the input data for the radial-basic networks, while radial-basic network parameters were used as output data. SPREAD parameter of interference was taken to be bigger than a partition step of the learning sequence interval, but smaller than the interval itself, that is equal to 0.1. GOAL parameter was chosen to be equal to 0. While architecturing of the radial-basic network with a zero error, the number of neurons of a radial-basic layer is equal to the number of input values. Weight and bias of the radial-basic network are set in such a way that its outputs are accurately equal to the targets. Relative accuracies of the data fitting were determined as a result of networks forecasting by means of a testing data selection. The respective parameters of the network with a minimum relative accuracy for acetic acid synthesis unit are given in tab. 2.

If we compare the relative accuracies of feed-forward neural networks to those of a radial-basic network, we can see that the minimum relative accuracy is insured by the radial-basic neural network, that is one of the networks has an

advantage before another in solution of the management problem. There're much more neurons in the radial-basic networks than a compared network with feed forward signal and sigmoid activation functions at a buried layer has.

**Fig. 4.** Radial-basic network structure**Table 2.** Radial-basic neural network parameters

Interference parameter	Mean-square error	Output parameter	Relative accuracy	Average relative accuracy
1,0	0	1	0,025	0,016
		2	0,002	
		3	0,020	

CONCLUSIONS

To create control system with the usage of the neuron networks at the acetic acid synthesis unit start-up process it's necessary to determine neuron network structure, to hold a learning on the basis of technological specifications and to do the approbation of network performance with an application of acetic acid plant equipment. Neural network architecturing with a usage of GUI - Neural Network Toolbox interface MATLAB 7.1.0 has proved the success of the neuron network building up and learning process and its satisfactory quality. That will let use neural networks to manage the technological processes of the acetic acid synthesis and proves the urgency of the further researches of this area.

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НЕЙРОСЕТЕВОЕ МОДЕЛИРОВАНИЕ
ДЛЯ УПРАВЛЕНИЯ КОЛОННОЙ СИНТЕЗА
УКСУСНОЙ КИСЛОТЫ В ПЕРИОД ПУСКА

Ольга Поркуян, Жанна Самойлова

Аннотация. В данной статье приведены результаты исследований построения искусственных нейронных сетей, используемых в автоматизированных системах управления колонной синтеза уксусной кислоты с помощью GUI –интерфейса Neural Network Toolbox программного симулятора Matlab. Приведены структурные схемы подобных сетей.
Ключевые слова: нейронная сеть с обратным распространением ошибки, радиально-базисная нейронная сеть, функция активации.

Anvilless hydraulic hammer with double-sided drive and increased lower ram mass

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S u m m a r y . The presented work determines dependencies for calculating values of ram motion when square of hydraulic unit plungers are proportional to masses of the rams. It is demonstrated that when equal forces are applied to the rams by the drive during direct idle stroke, the rams have equal momentum at any given time, which ensures minimum level of vibrations for the hammer.

Key words: hydraulic hammer, pressure, force, speed, acceleration.

INTRODUCTION

Anvilless hammers constitute a part of the most powerful equipment used in die forging production. The main disadvantage of hammers with hydraulic connection of ram drive is the harmonic component present in the equations describing ram motion.

ANALYSIS OF PUBLICATIONS

Reference books on press-forging equipment [1, 6, 19, 20] consider anvilless vertical hammers with pneumatic drive and hydraulic connection between equal mass rams in terms of their functional action and impact energy; motion equations are not cited. Recently technical literature has started to include information on technical solutions for hammers with underhead [6] and overhead [7] drive, motion equations for overhead and underhead rams are presented in the works [13, 14]. According to researchers and specialists of forging workshops opinion no-anvil hammers are better than anvil hammers because of

low vibration activity. This information can be found in [7, 10, 12], but the estimate of vibratory activity no-anvil vertical hammers was not made by experts until recently. Technical solutions for vertical no-anvil hydraulic hammers with one-way drive appeared recently, [2, 4, 5, 11, 18]. Kinematic analysis of the hammer head of this hammers is made in references [2, 9, 15, 17] it shows that in hydraulic anvilless hammers with single-side drive parabolic equations for motions of rams include harmonic components with cosine function. This results in fluctuating increase of the hydraulic pressure in the hydraulic reservoir in overdrive hammers and decrease of hydraulic pressure in underdrive hammers. These harmonic components of velocities which are out of phase lead to uncertainty of cooperative ram motion in the final stage of the load phase. Pressure ripple of aqua in hydraulic tank, as it's shown in [8], this leads to the excitation of vibrations in hydraulic unit of hammer heads. The pressure fluctuations are transmitted foundation hammer and a source of seismic tremors.

OBJECT AND TASKS OF RESEARCH

To formulate the ram motion equation for double-sided drive hammers with increased lower ram mass, to calculate conditions on which harmonic component is absent in motions and velocities of the rams in a double-sided drive hammer fig1.

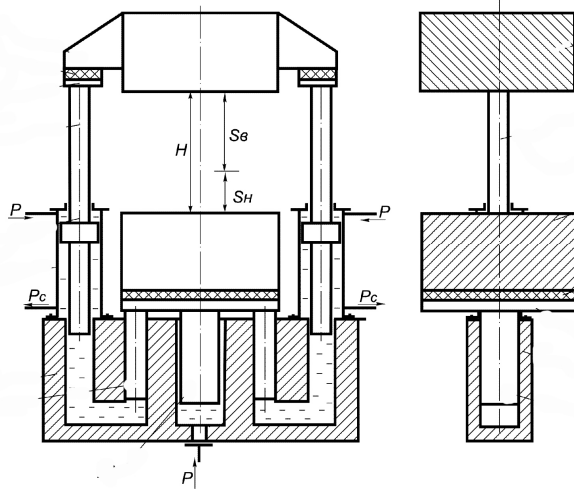


Fig. 1. Vertical hydraulic hammer with double-sided drive

MAIN PART WITH RESULT AND ANALYSIS

With increased lower ram mass, the plunger areas of the hydraulic connection unit are calculated according to the following dependence:

Total area of two side plungers:

$$S_1 = \frac{m_1 g}{p_{cr}}, \quad (1)$$

area of lower plunger

$$S_2 = \frac{m_2 g}{p_{cr}}, \quad (2)$$

where: m_1, m_2 - masses of upper and lower rams,

g - gravitational acceleration,

p_{cr} - hydraulic pressure in the hydraulic reservoir with fixed rams.

The rigidity of hydraulic unit plungers of under the the liquid is calculated with the following dependence:

$$C_B = \frac{S_1^2 \cdot E}{V}, \quad C_H = \frac{S_2^2 \cdot E}{V}, \quad (3)$$

where: C_B, C_H - the rigidity of hydraulic under side and lower dampers,

S_1, S_2 - total area of side plungers of the upper ram and area of plunger of the lower ram, correspondingly,

E - coefficient of elasticity of the liquid in hydraulic reservoir,

V - the volume of liquid in hydraulic reservoir.

Reduced rigidity of the ram stroke hydraulic connection unit can be derived from the following dependence:

$$K_1 = \frac{C_1 \cdot C_B \cdot C_2 \cdot \frac{s_1}{s_2}}{C_1 \cdot C_B + C_B \cdot C_2 \cdot \frac{s_1}{s_2} + C_1 \cdot C_2 \cdot \frac{s_1}{s_2}}, \quad (4)$$

$$K_2 = \frac{C_1 \cdot C_H \cdot C_2 \cdot \frac{s_2}{s_1}}{C_1 \cdot C_H \cdot \frac{s_2}{s_1} + C_H \cdot C_2 + C_1 \cdot C_H \cdot \frac{s_2}{s_1}},$$

where: K_1 - upper ram support rigidity,

K_2 - lower ram support rigidity,

C_1, C_2 - rigidity of dampers of upper and lower rams.

Taking into account the jet continuity the motion equation for ram stroke can take the following form:

$$\begin{aligned} m_1 x_1'' + k_1 \cdot \left(x_1 - x_2 \cdot \frac{s_2}{s_1} \right) &= F_1 \cdot \eta(t), \\ m_2 x_2'' + k_2 \cdot \left(x_2 - x_1 \cdot \frac{s_1}{s_2} \right) &= F_2 \cdot \eta(t), \end{aligned} \quad (5)$$

where: F_1, F_2 - upper and lower ram drive force;

$\eta(t)$ - Heavyside step function:

$$\eta(t) = \begin{cases} 1, & t \geq 0, \\ 0, & t < 0. \end{cases} \quad (6)$$

Transformation of this equation (6) into image space [Korn 1984] results in the following [3]:

$$\begin{aligned} X_1 \cdot (m_1 p^2 + k_1) - X_2 \cdot k_1 \cdot \frac{s_2}{s_1} &= F_1 \cdot \frac{1}{p}, \\ -X_1 \cdot k_2 \cdot \frac{s_1}{s_2} + X_2 \cdot (m_2 p^2 + k_2) &= F_2 \cdot \frac{1}{p}. \end{aligned} \quad (7)$$

Having solved the equation (7) in reference to X_1 and X_2 we receive the following values:

$$\begin{aligned} X_1 &= \frac{\frac{F_1}{p} (m_2 \cdot p^2 + k_2) + \frac{F_2}{p} \cdot k_1 \cdot \frac{s_2}{s_1}}{m_1 \cdot m_2 \cdot p^2 + k_1 \cdot m_2 \cdot p^2 + k_2 \cdot m_1 \cdot p^2}, \\ X_2 &= \frac{\frac{F_1}{p} \cdot k_2 \cdot \frac{s_1}{s_2} + \frac{F_2}{p} (m_1 \cdot p^2 + k_1)}{m_1 \cdot m_2 \cdot p^2 + k_1 \cdot m_2 \cdot p^2 + k_2 \cdot m_1 \cdot p^2}. \end{aligned} \quad (8)$$

Transforming the equation (8) into original function space allows us to receive ram stroke motion equation with a time variable.

$$X_1 = \frac{F_1 \cdot k_2 + F_2 \cdot k_1 \cdot \frac{s_2}{s_1}}{k_1 \cdot m_2 + k_2 \cdot m_1} \cdot \frac{t^2}{2} + \frac{F_1 \cdot k_1 \cdot m_2^2 \cdot s_1 - F_2 \cdot k_1 \cdot m_2 \cdot m_1 \cdot s_2}{(k_1 \cdot m_2 + k_2 \cdot m_1)^2} \cdot (1 - \cos(\omega t)), \quad (9)$$

$$X_2 = \frac{s_1}{s_2} \cdot \frac{F_1 \cdot k_2 + F_2 \cdot k_1 \cdot \frac{s_2}{s_1}}{k_1 \cdot m_2 + k_2 \cdot m_1} \cdot \frac{t^2}{2} + \frac{F_2 \cdot k_2 \cdot m_1^2 \cdot s_2 - F_1 \cdot k_2 \cdot m_2 \cdot m_1 \cdot s_1}{(k_1 \cdot m_2 + k_2 \cdot m_1)^2} \cdot (1 - \cos(\omega t)).$$

The harmonic component in the ram motion equations (9) will be absent when that $1 - \cos(\omega t)$ coefficients will be equal zero, i.e.:

$$\begin{cases} \frac{F_1 \cdot k_1 \cdot m_2^2 \cdot s_1 - F_2 \cdot k_1 \cdot m_2 \cdot m_1 \cdot s_2}{(k_1 \cdot m_2 + k_2 \cdot m_1)^2} = 0, \\ \frac{F_2 \cdot k_2 \cdot m_1^2 \cdot s_2 - F_1 \cdot k_2 \cdot m_2 \cdot m_1 \cdot s_1}{(k_1 \cdot m_2 + k_2 \cdot m_1)^2} = 0. \end{cases} \quad (10)$$

Simple mathematical transformations allow us to arrive at the following correlation:

$$\frac{F_1}{F_2} = \frac{m_1 \cdot s_2}{m_2 \cdot s_1}. \quad (11)$$

Juxtaposing (1) with (2) we see that $\frac{m_1}{s_1} = \frac{m_2}{s_2}$, taking into account values from (10) results $F_1 = F_2 = F$. This means that applying equal forces to the rams gives the rams equal momentum at any given movement time

$$F \cdot t = m_1 \cdot v_1 = m_2 \cdot v_2, \quad (12)$$

which ensures that the rams stop at impact regardless of their initial position and the height of forging.

With a double-sided drive and application of equal forces to the rams, the ram motion equation is the following:

$$X_1 = \frac{F_1 \cdot k_2 + F_2 \cdot k_1 \cdot \frac{s_2}{s_1}}{k_1 \cdot m_2 + k_2 \cdot m_1} \cdot \frac{t^2}{2}, \quad (13)$$

$$X_2 = \frac{s_1}{s_2} \cdot \frac{F_1 \cdot k_2 + F_2 \cdot k_1 \cdot \frac{s_2}{s_1}}{k_1 \cdot m_2 + k_2 \cdot m_1} \cdot \frac{t^2}{2}.$$

Differentiating (13) by time the equation is derived to determine ram velocity:

$$X'_1 = \frac{F_1 \cdot k_2 + F_2 \cdot k_1 \cdot \frac{s_2}{s_1}}{k_1 \cdot m_2 + k_2 \cdot m_1} \cdot t, \quad (14)$$

$$X'_2 = \frac{s_1}{s_2} \cdot \frac{F_1 \cdot k_2 + F_2 \cdot k_1 \cdot \frac{s_2}{s_1}}{k_1 \cdot m_2 + k_2 \cdot m_1} \cdot t.$$

Differentiating (14) the equation is derived to determine ram acceleration

$$X''_1 = \frac{F_1 \cdot k_2 + F_2 \cdot k_1 \cdot \frac{s_2}{s_1}}{k_1 \cdot m_2 + k_2 \cdot m_1}, \quad (15)$$

$$X''_2 = \frac{s_1}{s_2} \cdot \frac{F_1 \cdot k_2 + F_2 \cdot k_1 \cdot \frac{s_2}{s_1}}{k_1 \cdot m_2 + k_2 \cdot m_1}.$$

Let us calculate several parameters of the hammer with the following entry conditions: upper ram mass $m_1=20t$, lower ram mass $m_2 = 40t$, coefficient of elasticity of the liquid $E=2 \times 10^9 Pa$. Because the upper ram moves downward (one stroke) in free fall mode, its maximum acceleration can not exceed $9,8 \text{ m/s}^2$; we take $j_b = 0,9g = 8,8 \text{ m/s}^2$. The rigidity of side and central dampers $C_1 = C_2 = 3 \cdot 10^5 \text{ N/m}$, upper ram stroke is 1.6m, lower ram stroke 0.8m, volume of hydraulic reservoir $1,0 \text{ m}^3$.

Using the dependences stated above we can calculate the following values: rigidity of liquid support under side dampers $C_d = 3 \cdot 10^5 \text{ N/m}$, under lower damper damper $C_u = 12 \cdot 10^5 \text{ N/m}$. Reduced rigidity of hydraulic connection unit for upper ram $K_1 = 1,2 \cdot 10^5 \text{ N/m}$, for lower ram $K_2 = 1,7 \cdot 10^5 \text{ N/m}$. K_1 and K_2 substitution in (15) $X''_1 = 8,8 \text{ m/s}^2$ gives the force applied to each of the rams as $F=176 \text{ kN}$, idle stroke time $t=0,6 \text{ s}$, upper ram velocity on impact $X'_1 = 5,28 \text{ m/s}$, lower ram $X'_2 = 2,64 \text{ m/s}$. Impact energy is 418kJ, which corresponds to the impact energy generated by an anvil hammer with the mass of drop parts of approximately 25t and the mass of anvil not less than 500t. The total mass of impacting parts of an anvil hammer is not less than 525t, while the mass of these parts of a non-anvil hammer generating equal amount of energy is 60t. Moreover, the anvilless hammer does not generate post-impact vibrations unlike anvil hammers.

CONCLUSIONS

1. The article presents dependences for calculating ram motion values for a non-anvil hammer with increased lower ram mass, where areas of hydraulic unit plungers are proportional to ram masses.

2. It shows that when the drive applies equal forces to the rams at direct idle stroke, the rams have equal momentum at any given time of the stroke, the rams stop at impact, the hammer has minimum vibration activity.

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БЕСШАБОТНЫЙ ГИДРАВЛИЧЕСКИЙ МОЛОТ С ДВУСТОРОННИМ ПРИВОДОМ И УВЕЛИЧЕННОЙ МАССОЙ НИЖНЕЙ БАБЫ

Антон Рей, Юрий Гутько

Аннотация. В представленной работе определены зависимости для подсчета значения перемещения баб когда площади плунжеров пропорциональны массам баб. Показано что при приложении равных сил к бабам со стороны привода во время прямого холостого хода бабы будут иметь одинаковое количество движения в любой момент времени, что обеспечивает минимальный уровень виброактивности молота.

Ключевые слова: гидравлический молот, давление, сила, скорость, ускорение.

Data structures in models of informatively-administrative architecture of coal-mining enterprises

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Summary. The article suggests a data structures informatively-administrative architectures, these structures provide the opportunity to effectively and comprehensively monitor the coal-mining enterprises with use of information technologies, store and analyze the results of the monitoring. The developed models and database allow to determine the most effective architectures and distribute them, using modern information technology.

Key words: the informatively-administrative architecture, a layer, the information model, relations, data structures, structural division.

INTRODUCTION

Data structures are symbolic mathematical models, which are used in information view original objects, their elements and properties. Such models can be called information models.

The creation of such models requires a clear formalization of the components of the real objects.

The selection of efficient data structures is an important task because it allows you to create data processing technology, which will meet the requirements of performance and resource saving.

ANALYSIS OF THE PUBLICATIONS

The problem of definition of data structures to represent informatively-administrative architectures considered in the works on economic and mathematical modeling, monitoring of enterprises, in particular, in [1-4, 7-10, 12-15, 17].

Classes of elementary transformations have been allocated in the [6]. Mathematical formalisms of the description of informatively-administrative architectures were specified in [5]. But not defined the characteristics of the data structures for the storage of the results of monitoring IAA the coal-mining enterprises.

OBJECTS AND PROBLEMS

In [5] the basis of the informatively-administrative architecture adopted layer. Layer IAA is an set of many elements, which correspond to a specific characteristic propertie, and set of links between these elements. So, informatively-administrative architecture should be viewed as a set of layers:

$$A = \langle \langle E^1, C^1 \rangle, \langle E^2, C^2 \rangle, \dots, \langle E^n, C^n \rangle \rangle \quad (1)$$

were: n is the number of layers.

Analysis IAA allowed to identify key layers: posts, divisions. Their peculiarity is due to the following factors: for positions and divisions are fixed functions which depends on implementation of the company's strategic goal – specific and generic respectively. To implement these functions posts granted certain powers, tasks, roles, is subject to restrictions, provided clear reporting and administrative, disciplinary, material, or criminal liability for improper implementation or not implementation. Divisions also have the

responsibility, but indirectly, through their leaders and official person.

That is, division and post are dominant elements IYA, so, the layer of posts and divisions units are key or dominant layers of IAA. Elements of IAA other types - of software tools, features, information technology, equipment, documentation can be considered as separate layers or as specific attributes of posts or divisions.

Rapid changes in the economic situation, the legislative base, on the basis of which the enterprise operates, stipulate the requirements to timeliness and speed up changes in management information architectures, to accuracy in forecasting the consequences of these changes [6].

Adequate, accurate predictive models can be constructed on the basis of the analysis of a large number of the recorded state of the studied enterprises, which were obtained through monitoring.

For the presentation and subsequent manipulation of the results of monitoring needs relevant, adequate toolkit that not only allow to store and analyze the results of the monitoring of the enterprises, but also eliminates contradictions, inconsistencies in the information-software view of their structure, articulates the characteristics of the informational, technological, functional, will focus both on privacy layers and their interrelations.

Data structures to display IAA and its properties, such as multi-layered, hierarchy, variability are dynamic types and structured types (record, class). The type class fully reflects the property of hierarchy IAA, fields of type record may be structures.

Define the models of elements on a layer of enterprises.

The company is an independent subject that is managing with the right of a legal entity, which produces products, goods, services, carrying out work, engaged in various economic activities [18]. The main characteristics of the coal mining enterprises - the form of ownership, type of activity, its planned annual volume of coal production, organizational and legal form.

Form of ownership were considered in the monograph [8], in accordance with applicable at the time the law «On property», however, this law was cancelled with 27.04.2007. The new Civil code of Ukraine, does not use the category of „ownership”, but contains a separate article on the right of ownership of the Ukrainian people, the right of private property, the ownership right and the right of state property [19]. Thus, in the Civil code of Ukraine implemented the model according

to which there is a single ownership with the same for all the subjects of this right content and General signs, which may be different actors (the Ukrainian people, individuals, the state of Ukraine, the territorial community).

Contrary to the norms of the Civil code of Ukraine, Commercial code of Ukraine retains the category of „ownership” with the aim of identifying the types of enterprises. Of part 1 of article 63 of the Economic code of Ukraine that in Ukraine there are such forms of ownership: private ownership; the right of state ownership; the right to communal property; the right of collective ownership; mixed form of ownership; other forms of property [20].

The Economic code of Ukraine provides such kind of enterprises, as „foreign company”, which is wholly owned by foreigners. That is, in accordance with Economic code of Ukraine, you can select the form of ownership and foreign ownership.

In terms of the organizational form of the enterprise are defined as public, collective, and private businesses of the two or more forms of ownership (mixed).

Foreign enterprise – this legal form of enterprise based in Ukraine, was created as an entity under legislation of a foreign state, the property which is fully owned by foreign citizens, legal entities or the state.

The tree definition of layer enterprises is created using data types that serves object model. Class «enterprise», the heir to the class of «legal person» shall have the definition:

```
type enterprise = class (legal person)
  form_of_ownership: FO,
  organizational_legal_form: OLF,
  kind_of_economic_activity: KEA,
  position_of_the_head_of_the_enterprise:
  PHC,
  staff: staff,
  monthly_wages_fund: MFW,
  device_management: DM,
  monthly_wages_fund_device_manage:
  MFWDM,
  end.
```

Types of data used to describe the fields in the class, have the following meanings:

form_of_ownership – for the enterprises of the coal industry, there are the following forms of ownership: state and private. This means that the form of «ownership» (form of ownership – FO) will take the value from the following set: {state, private}; organizational_legal_form – this type elements that are listed (set);

kind_of_economic_activity – the list of types of economic activity for the license, since types of activities is more, the data type can be an array, the elements when a string, or set; position_of_the_head_of_the_enterprise – type string; staff – the total number of employees, the positive integer, type word; monthly_wages_fund – the positive integer, type word; device_management – the number of administration employees, the positive integer, type word; monthly_wages_fund_device_manage – the positive integer, type word.

The investigated subject area includes the enterprises, subordinated to the Ministry of energy and coal industry of Ukraine. For a database that contains enterprises of different departmental subordination, the class of «enterprise» must be contain the field «departmental subordination».

Depending of kind of economic activity a specific set of indicators describe the enterprise. For an objective assessment of the functioning of the coal enterprises used the planned and actual indices.

For example, the main characteristics of the coal-mining enterprises are the following:

- 1) planned annual coal output / actual annual volume of a coal mining,
- 2) planned daily coal output/ actual daily production of coal,
- 3) the planned number of employees/ the actual number of employees,
- 4) average dynamic take out capacity of the coal layer,
- 5) the number of sites on extraction,
- 6) the average effective number of stopes,
- 7) categories of mine on gas and on dust,
- 8) the angle of incidence of the developed layers,
- 9) the depth of reservoir development,
- 10) the number of fixed water pumping plants,
- 11) group payment.

The actual value of performance to take by necessary: for the previous period (day, year), or the average of several periods (for example, the average for the previous five years).

Class «a coal mining enterprise» is the successor of a class «enterprise», the following definition will be:

```
type coal_mining_enterprise= class
(enterprise),
    planned_annual_volume_of_a_coal_mining:P
AVCM,
    actual_annual_volume_of_a_coal_mining:
AAVCM,
```

planned_daily_production_of_coal:

PDVCM,

actual_daily_production_of_coal: FDVCM,

the_planned_number_of_employees: PNE,

the_actual_number_of_employees: ANE,

average_dynamic_takeout_capacity_of_the_

coal_layer: ADTCL,

the_number_of_sites_on_extraction: NSE,

the_average_effective_number_of_stopess:

AENS,

categories_of_mine_on_gas: CMG,

categories_of_mine_on_dust: CMD,

the_angle_of_incidence_of_the_developed_l

ayers: AIDL,

the_depth_of_reservoir_development: DRD,

the_number_of_fixed_water_pumping_plant

s: NFWPP,

group_payment: GP,

end.

Here PAVCM, AAVCM, PDVCM, ADVCM, PNE, ANE, NSE, AENS, NFWPP, GP – integer, positive types; CMG, CMD – gain value from the sets, defined list of items (set), AIDL – under the band the type of data or interval, DRD – consists of two parts: the name of the reservoir, for example, N8 and its depth, for example, 1080 m, such information to type record.

According to the Civil code of Ukraine «entity is an organization established and registered in accordance with the law» (article 80). For all legal entities is mandatory presence of constituent documents (the Charter or articles of incorporation (article 87, paragraph 1).

Civil code of Ukraine establishes certain requirements to the name of the legal entity - it should contain information about the legal form of the legal person, character of activity, it is possible to have abbreviated company name (article 90).

In turn, the Civil code defines the data that is entered into the state register: «...made information about the legal form of the legal entity, its name, location, management bodies, branches and representative offices, the aim of the institution» (article 89, paragraph 4).

Thus, the definition of a class «a legal person» will:

```
Type legal_person= class (...),
Identification_code_LP: IDLP,
name_LP: NLP,
abbreviated_name_LP: ANLP,
brand_name_LP: BNLP,
organizational_legal_form_LP: OLF,
date_of_registration_LP: DRLP,
location_LP: LLP,
constituent_document: CDLP,
```

license: LLP,
End.

For the enterprises of the coal industry, there are the following legal forms: public and private. This means that the attribute "organizational-legal form" (OLF) will be the value from the following set: {state, private}.

Location of the legal person is determined by several attributes: code, city, street, house number, etc., to display uses structured record-such types (record, class).

The constituent documents of a legal person is the articles of Association, Memorandum of Association or the deed of Foundation. For the characteristics of these documents need structured data types (record or class).

So classes «enterprise», «legal_person», «coal_mining_enterprise» and other classes that correspond to the types of enterprises by activity, are portraits of elements on a layer of enterprises. Classes of enterprises by kinds of activity are created during the development of the software product (SP). Instances of a class are created using a dynamic array whose elements are defined and added during the exploitation SP.

The peculiarity of this layer is the fact that enterprises have a connection only if they belong to the same state (territorial) of the enterprise. To reflect these links will use the adjacency matrix, in which the number of rows and number of columns is the same and is the number of enterprises. Clarification of the information about such relationships requires the introduction of a separate class that деталізуватиме their characteristics, e.g.:

```
Type communication_of_enterprises = class
(...)
enterprises_1: E1,
enterprises_2: E2,
Object_communication: CO; / material or
other
documentation: CD,
responsible: Resp,
performers: Perf,
start_date: SDate,
end_date: EDate,
End.
```

At the object-oriented approach modeled not the specific domain entity, but their portraits, which are relevant to the specific layer. Each portrait requires allocation of relevant characteristics, classification and integration to one class.

Consider layer divisions. Elements of this layer is the division, communications of that layer

show the transfer of tangible objects, normative documents, information flows. With the purpose of regulation of activities of structural subdivisions and their place in the organizational structure of the enterprise, the owner or authorized body shall develop, approve and implement the provisions of each of them. According to its status, provisions on structural subdivision is an internal regulatory document, on the basis of which organizes daily activities of the structural unit, evaluate the results, write job descriptions that define the tasks, functions, rights and duties, and the main responsibility of the employees [21].

Regulations about structural division of the enterprise, as a rule, develops a division head or a working group of specialists in the field of management, labour law and relevant activities of the company.

In the case of redistribution of functions between the divisions in connection with the reorganisation (change of structure) of an enterprise changes (amendments) in the regulation on structural subdivision can be made only by the manager of the enterprise.

Regulations on structural division replaced and re-approved in case of change of name of the enterprise or division.

Regulation about the division consists of the following parts: general provisions, tasks, functions, rights, responsibilities, relationships with other divisions.

Class «division» should have the following definition:

```
Type division= class ()
Direct_subordination_of_division: DSD;
The_position_of_the_head_of_division:
PHD;
The_position_of_the_deputy: PD;
Availability_of_printing: AP;
List_of_positions_division: LPD;
monthly_wages_fund: MWF;
End.
```

Types of data used to describe the fields in the class, have the following meanings: DSD – name of the position, which the division is subordinate, takes values from the set list of posts in the enterprise, the type of set; PHD, PD та LPD – similar to the previous one variable; AP – can have one of two values (yes or no), the type of boolean; MWF – the positive integer, the type of word.

Each division has its own intrinsic characteristics, for example, for the coal-mining division is planned average daily production volume, planned number of workers, average

dynamic take out capacity of the coal layer, the angle of incidence of the mined seam, the depth of the works, the type of mechanization, mode of operation, the group of the payment. In addition to the above it is necessary to take into account the actual indicators of activity, namely: the actual daily average volume of a coal mining, the actual number of workers, and the monthly wage fund. Such characteristics of the units have a different type, represent a separate class:

Type division_of_coal-mining = class (division),

Planned_average_daily_volume_of_extraction: PADVE,

Actual_daily_average_volume_of_production: ADAVP,

Planned_number_of_workers: PNW,

Actual_number_of_workers: ANW,

Average_dynamic_take_out_capacity_of_the_coal_layer: ADTCCL,

Angle_of_incidence_of_the_mined_seam:

AIMS,

Depth_of_the_works: DW,

Type_of_mechanization: TM,

Mode_of_operation: MO,

Group_of_the_payment: GP,

Monthly_wage_fund: MWF,

End.

Тут PADVE, ADAVP, PNW, ANW, ADTCCL, AIMS, DW, MO, GP, MWF – the positive integer type, for example, word; TM – can have the following values: «2 КД-90» or «2 КД-90, 1 К-101 Y», therefore, choose a data type string.

The basis for creating classes that define the essence of a «division» is a normative documentation. General, organizational information, take from the «Provisions about division» and technical, production data - from the staffing, technical documentation and other. Each document is a element layer document management, some of the attributes of these elements are used as element of attributes of other layers, for example, the monthly salary fund counts accounts department, adds to the staffing and such an attribute has a class of «division».

Developed DB model is static, so as adding new classes during operation SP impossible. The number of instances of classes is not limited. However, considering the following conditions: all enterprises have a close, a similar structure, this structure over time, changes slightly, the number of departments of all enterprises limited [3], use of the DB with a static definition of the types is reasonably.

CONCLUSIONS

Developed information model to store the results of the monitoring informatively-administrative architectures of the coal-mining enterprises, allocated object-oriented data structures. Marked features information models, databases for the coal-mining enterprises.

Certain data structures reflect the informational, technological, functional characteristics of the entity IAA, take into account both the separation of the layers and their interrelation. Built information model reflects the coherence between and interrelation of characteristics of information and administrative subsystems. Such a data structure is the basis for building databases, models of the dynamics of IAA, predicting its further development.

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СТРУКТУРЫ ДАННЫХ В МОДЕЛЯХ ИНФОРМАЦИОННО-УПРАВЛЕНЧЕСКИХ АРХИТЕКТУР УГЛЕДОБЫВАЮЩИХ ПРЕДПРИЯТИЙ

Светлана Шевченко

А н н о т а ц и я . В статье представлены структуры данных информационно-управленческих архитектур, эти структуры обеспечивают возможность эффективно и всесторонне исследовать угледобывающие предприятия с использованием информационных технологий, хранить и анализировать результаты мониторинга. Разработанные модели и структуры данных позволяют определить наиболее эффективные архитектуры и распространять их с использованием современных информационных технологий.

К л ю ч е в ы е с л о в а : информационно-управленческая архитектура, слой, информационная модель, отношения, структуры данных, структурное подразделение.

Internal geometry of active surfaces of teeth of cylindrical gear arch mixed gearing

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Summary. In the article analytical dependences are got for determination of indexes of internal geometry of the arched indents, form an instrument with an asymmetrical initial contour that will allow to define the quality indexes of capacity of such transmissions.

Key words. arched gearing, mixed gearing, initial contour, productive surface.

INTRODUCTION

Operability of machines in many branches is defined by quality of the mechanical drives entering into their composition [4]. The destiny of tooth gearings is thus great. Therefore enhancement of toothed drives will allow to increase operability of machines and consequently is the actual task. One of methods of enhancement of transmissions is geometry synthesis on quality indicators of working capacity [1, 2, 9, 10, 14, 16]. For implementation of such synthesis the dependences, connecting measure values with geometry of teeth or the tool are necessary. Such dependences for synthesis of geometry of the tool were received in work [7, 8, 18] for different types of transmissions, and in work [5, 19] it was for transmissions with arch teeth. Synthesized in the work [3, 6, 19] symmetric output circuits synthesized in operation have limited application in view of some technological shortcomings, but provide the powerful benefit on working capacity over traditional transmissions. The combination in one transmission of advantages of different types of linkages will allow to expand an area of their application [13, 21, 22].

OBJECTS AND PROBLEMS

Article purpose is to receive the equation for a measure definition of internal geometry of the arch teeths formed by the asymmetrical output circuit.

In case of determination of criteria of operability of tooth gearings with arch teeth the equations of surfaces of teeths, and also indexes of internal geometry of these surfaces are used.

The equation of the active surfaces can be received [18, 19], writing coordinates of surfaces of a linkage in coordinate systems $X_1Y_1Z_1$ and $X_2Y_2Z_2$ which are connected to a gearwheel and a wheel. Realizing transition from fixed coordinate system XYZ to systems $X_1Y_1Z_1$ and $X_2Y_2Z_2$, we will receive:

1) the equations of surfaces of fingers of arch wheels in systems $X_1Y_1Z_1$ and $X_2Y_2Z_2$ for the convex side:

$$\vec{r}_{1f} = \begin{cases} x_1 = (f_1 + R_1) \cos \varphi_1 + \Omega_{1f} \cos \beta \sin \varphi_1, \\ y_1 = (f_1 + R_1) \sin \varphi_1 - \Omega_{1f} \cos \beta \cos \varphi_1, \\ z_1 = z_0 - f_2 \sin \beta; \end{cases} \quad (\text{gearwheel head}); \quad (1)$$

$$\vec{r}_{1\phi} = \begin{cases} x_1 = (\Phi_1 + R_1) \cos \varphi_1 + \Omega_{1\phi} \cos \beta \sin \varphi_1, \\ y_1 = (\Phi_1 + R_1) \sin \varphi_1 - \Omega_{1\phi} \cos \beta \cos \varphi_1, \\ z_1 = z_0 - \Phi_2 \sin \beta; \end{cases} \quad (\text{gearwheel pinch}); \quad (2)$$

$$\vec{r}_{2f} = \begin{cases} x_2 = (f_1 - R_2) \cos \varphi_2 - \Omega_{1f} \cos \beta \sin \varphi_2, \\ y_2 = -(f_1 - R_2) \sin \varphi_2 - \Omega_{1f} \cos \beta \cos \varphi_2, \\ z_2 = z_0 - f_2 \sin \beta; \end{cases} \quad (3)$$

(wheel head);

$$\vec{r}_{2\phi} = \begin{cases} x_2 = (\Phi_1 - R_2) \cos \varphi_2 - \Omega_{1\phi} \cos \beta \sin \varphi_2, \\ y_2 = -(\Phi_1 - R_2) \sin \varphi_2 - \Omega_{1\phi} \cos \beta \cos \varphi_2, \\ z_2 = z_0 - \Phi_2 \sin \beta; \end{cases} \quad (4)$$

(wheel pinch);

2) the equations of surfaces of fingers of arch wheels in systems $X_1Y_1Z_1$ and $X_2Y_2Z_2$ for the concave side:

$$\vec{r}_{1f} = \begin{cases} x_1 = (f_1 + R_1) \cos \varphi_1 - \Omega_{1f} \cos \beta \sin \varphi_1, \\ y_1 = (f_1 + R_1) \sin \varphi_1 + \Omega_{1f} \cos \beta \cos \varphi_1, \\ z_1 = z_0 + f_2 \sin \beta; \end{cases} \quad (5)$$

(gearwheel head);

$$\vec{r}_{1\phi} = \begin{cases} x_1 = (\Phi_1 + R_1) \cos \varphi_1 - \Omega_{1\phi} \cos \beta \sin \varphi_1, \\ y_1 = (\Phi_1 + R_1) \sin \varphi_1 + \Omega_{1\phi} \cos \beta \cos \varphi_1, \\ z_1 = z_0 + \Phi_2 \sin \beta; \end{cases} \quad (6)$$

(gearwheel pinch);

$$\vec{r}_{2f} = \begin{cases} x_2 = (f_1 - R_2) \cos \varphi_2 + \Omega_{1f} \cos \beta \sin \varphi_2, \\ y_2 = -(f_1 - R_2) \sin \varphi_2 + \Omega_{1f} \cos \beta \cos \varphi_2, \\ z_2 = z_0 + f_2 \sin \beta; \end{cases} \quad (7)$$

(wheel head);

$$\vec{r}_{2\phi} = \begin{cases} x_2 = (\Phi_1 - R_2) \cos \varphi_2 + \Omega_{1\phi} \cos \beta \sin \varphi_2, \\ y_2 = -(\Phi_1 - R_2) \sin \varphi_2 + \Omega_{1\phi} \cos \beta \cos \varphi_2, \\ z_2 = z_0 + \Phi_2 \sin \beta; \end{cases} \quad (8)$$

(wheel pinch).

In the received equations the variables λ , μ , φ_i connected by ratios, the described equations of a linkage F_1^* and F_2^* [11, 19, 20].

Let's write also in mobile coordinate systems of a projection of unit vector of a normal [12, 19, 20]. In coordinate system $X_1Y_1Z_1$ we have projections of unit vector of a normal to a surface of teeth of a gearwheel (according to a head and a pinch):

$$\vec{e}_f = \begin{cases} e_{x1} = e_{xn} \cos \varphi_1 - e_{yn} \sin \varphi_1, \\ e_{y1} = e_{xn} \sin \varphi_1 + e_{yn} \cos \varphi_1, \\ e_{z1} = e_{zn}; \end{cases} \quad (9)$$

$$\vec{e}_\phi = \begin{cases} e_{x1} = e_{xn} \cos \varphi_1 - e_{yn} \sin \varphi_1, \\ e_{y1} = e_{xn} \sin \varphi_1 + e_{yn} \cos \varphi_1, \\ e_{z1} = e_{zn}. \end{cases}$$

In coordinate system $X_2Y_2Z_2$ we have projections of unit vector of a normal to a surface of teeth of a wheel (according to a head and a pinch):

$$\vec{e}_f = \begin{cases} e_{x2} = e_{xn} \cos \varphi_2 + e_{yn} \sin \varphi_2, \\ e_{y2} = -e_{xn} \sin \varphi_2 + e_{yn} \cos \varphi_2, \\ e_{z2} = e_{zn}; \end{cases} \quad (10)$$

$$\vec{e}_\phi = \begin{cases} e_{x2} = e_{xn} \cos \varphi_2 + e_{yn} \sin \varphi_2, \\ e_{y2} = -e_{xn} \sin \varphi_2 + e_{yn} \cos \varphi_2, \\ e_{z2} = e_{zn}. \end{cases}$$

In formulas (9), (10) e_{xn} , e_{yn} , e_{zn} , means:

$$\vec{e}_f = \begin{cases} e_{xn} = \frac{\pm f'_2}{n_f}, \\ e_{yn} = -\frac{f'_1}{n_f} \cos \beta, \\ e_{zn} = \frac{f'_1}{n_f} \sin \beta; \end{cases}, \quad \vec{e}_\phi = \begin{cases} e_{xn} = \frac{\pm \Phi'_2}{n_\phi}, \\ e_{yn} = -\frac{\Phi'_1}{n_\phi} \cos \beta, \\ e_{zn} = \frac{\Phi'_1}{n_\phi} \sin \beta. \end{cases} \quad (11)$$

Here:

$$n_f = \sqrt{(f'_1)^2 + (f'_2)^2}, \quad n_\phi = \sqrt{(\Phi'_1)^2 + (\Phi'_2)^2}.$$

The upper sign undertakes for the convex side, lower is for concave.

For determination of criteria of operability of tooth gearings it is necessary to have coefficients of the first and second quadratic forms. For determination of coefficients private derivatives of radius vectors and vectors of normals to the active of surfaces of teeth of a gearwheel ($n=1$) and wheel ($n=2$) are necessary.

Differentiating the equation (1)-(8) on λ and φ , considering also the linkage equations, we have:

$$\vec{r}_{1f}^\lambda = \begin{cases} x_1^\lambda = f'_1 \cos \varphi_1 \pm (\Omega_{1f} \cos \beta)^\lambda \sin \varphi_1, \\ y_1^\lambda = f'_1 \sin \varphi_1 \mp (\Omega_{1f} \cos \beta)^\lambda \cos \varphi_1, \\ z_1^\lambda = z_0 \cdot \frac{d\mu}{d\lambda} \mp (f_2 \sin \beta)^\lambda; \end{cases}$$

$$\vec{r}_{1\phi}^\lambda = \begin{cases} x_1^\lambda = \Phi'_1 \cos \varphi_1 \pm (\Omega_{1\phi} \cos \beta)^\lambda \sin \varphi_1, \\ y_1^\lambda = \Phi'_1 \sin \varphi_1 \mp (\Omega_{1\phi} \cos \beta)^\lambda \cos \varphi_1, \\ z_1^\lambda = z_0 \cdot \frac{d\mu}{d\lambda} \mp (\Phi_2 \sin \beta)^\lambda; \end{cases}$$

$$\begin{aligned}
{}^{-\lambda}r_{2f} &= \begin{cases} x_2^\lambda = f_1' \cos \varphi_2 \mp (\Omega_{1f} \cos \beta)^\lambda \sin \varphi_2, \\ y_2^\lambda = -f_1' \sin \varphi_2 \mp (\Omega_{1f} \cos \beta)^\lambda \cos \varphi_2, \\ z_2^\lambda = \dot{z}_0 \cdot \frac{d\mu}{d\lambda} \mp (f_2 \sin \beta)^\lambda; \end{cases} \\
{}^{-\lambda}r_{2\phi} &= \begin{cases} x_2^\lambda = \Phi_1' \cos \varphi_2 \mp (\Omega_{1\phi} \cos \beta)^\lambda \sin \varphi_2, \\ y_2^\lambda = -\Phi_1' \sin \varphi_2 \mp (\Omega_{1\phi} \cos \beta)^\lambda \cos \varphi_2, \\ z_2^\lambda = \dot{z}_0 \cdot \frac{d\mu}{d\lambda} \mp (\Phi_2 \sin \beta)^\lambda; \end{cases} \\
{}^{-\phi}r_{1f} &= \begin{cases} x_1^\phi = -(f_1 + R_1) \sin \varphi_1 \pm \Omega_{1f} \cos \beta \cos \varphi_1 \pm \\ \pm \Omega_{1f} \sin \varphi_1 (\cos \beta)^\phi, \\ y_1^\phi = (f_1 + R_1) \cos \varphi_1 \pm \Omega_{1f} \cos \beta \sin \varphi_1 \mp \\ \mp \Omega_{1f} \cos \varphi_1 (\cos \beta)^\phi, \\ z_1^\phi = \dot{z}_0 \cdot \frac{d\mu}{d\lambda} \mp f_2 (\sin \beta)^\phi; \end{cases} \\
{}^{-\phi}r_{1\phi} &= \begin{cases} x_1^\phi = -(\Phi_1 + R_1) \sin \varphi_1 \pm \Omega_{1\phi} \cos \beta \cos \varphi_1 \pm \\ \pm \Omega_{1\phi} \sin \varphi_1 (\cos \beta)^\phi, \\ y_1^\phi = (\Phi_1 + R_1) \cos \varphi_1 \pm \Omega_{1\phi} \cos \beta \sin \varphi_1 \mp \\ \mp \Omega_{1\phi} \cos \varphi_1 (\cos \beta)^\phi, \\ z_1^\phi = \dot{z}_0 \cdot \frac{d\mu}{d\lambda} \mp \Phi_2 (\sin \beta)^\phi; \end{cases} \\
{}^{-\phi}r_{2f} &= \begin{cases} x_2^\phi = -(f_1 - R_2) \sin \varphi_2 \mp \Omega_{1f} \cos \beta \cos \varphi_2 \mp \\ \mp \Omega_{1f} \sin \varphi_2 (\cos \beta)^\phi, \\ y_2^\phi = -(f_1 - R_2) \cos \varphi_2 \pm \Omega_{1f} \cos \beta \sin \varphi_2 \mp \\ \mp \Omega_{1f} \cos \varphi_2 (\cos \beta)^\phi, \\ z_2^\phi = \dot{z}_0 \cdot \frac{d\mu}{d\lambda} \mp f_2 (\sin \beta)^\phi; \end{cases} \\
{}^{-\phi}r_{2\phi} &= \begin{cases} x_2^\phi = -(\Phi_1 - R_2) \sin \varphi_2 \mp \Omega_{1\phi} \cos \beta \cos \varphi_2 \mp \\ \mp \Omega_{1\phi} \sin \varphi_2 (\cos \beta)^\phi, \\ y_2^\phi = -(\Phi_1 - R_2) \cos \varphi_2 \pm \Omega_{1\phi} \cos \beta \sin \varphi_2 \mp \\ \mp \Omega_{1\phi} \cos \varphi_2 (\cos \beta)^\phi, \\ z_2^\phi = \dot{z}_0 \cdot \frac{d\mu}{d\lambda} \mp \Phi_2 (\sin \beta)^\phi; \end{cases}
\end{aligned}$$

Here the upper sign corresponds to the convex side of tooth, lower is concave.

Differentiating the equation (9), (10) on λ and ϕ , we have private derivatives of vectors of normals to a surface of teeth of a gearwheel ($n=1$) and wheels ($n=2$) for a head and a pinch respectively:

$$\begin{aligned}
{}^{-\lambda}e_{1f} &= \begin{cases} e_{x1}^\lambda = e_{xn}^\lambda \cos \varphi_1 - e_{yn}^\lambda \sin \varphi_1, \\ e_{y1}^\lambda = e_{xn}^\lambda \sin \varphi_1 + e_{yn}^\lambda \cos \varphi_1, \\ e_{z1}^\lambda = e_{zn}^\lambda; \end{cases} \\
{}^{-\lambda}e_{1\phi} &= \begin{cases} e_{x1}^\lambda = e_{xn}^\lambda \cos \varphi_1 - e_{yn}^\lambda \sin \varphi_1, \\ e_{y1}^\lambda = e_{xn}^\lambda \sin \varphi_1 + e_{yn}^\lambda \cos \varphi_1, \\ e_{z1}^\lambda = e_{zn}^\lambda; \end{cases} \\
{}^{-\lambda}e_{2f} &= \begin{cases} e_{x2}^\lambda = e_{xn}^\lambda \cos \varphi_2 + e_{yn}^\lambda \sin \varphi_2, \\ e_{y2}^\lambda = -e_{xn}^\lambda \sin \varphi_2 + e_{yn}^\lambda \cos \varphi_2, \\ e_{z2}^\lambda = e_{zn}^\lambda; \end{cases} \\
{}^{-\lambda}e_{2\phi} &= \begin{cases} e_{x2}^\lambda = e_{xn}^\lambda \cos \varphi_2 + e_{yn}^\lambda \sin \varphi_2, \\ e_{y2}^\lambda = -e_{xn}^\lambda \sin \varphi_2 + e_{yn}^\lambda \cos \varphi_2, \\ e_{z2}^\lambda = e_{zn}^\lambda; \end{cases} \\
{}^{-\phi}e_{1f} &= \begin{cases} e_{x1}^\phi = (e_{xn}^\phi - e_{yn}^\phi) \cos \varphi_1 - (e_{xn}^\phi + e_{yn}^\phi) \sin \varphi_1, \\ e_{y1}^\phi = (e_{xn}^\phi - e_{yn}^\phi) \sin \varphi_1 + (e_{xn}^\phi + e_{yn}^\phi) \cos \varphi_1, \\ e_{z1}^\phi = e_{zn}^\phi; \end{cases} \\
{}^{-\phi}e_{1\phi} &= \begin{cases} e_{x1}^\phi = (e_{xn}^\phi - e_{yn}^\phi) \cos \varphi_1 - (e_{xn}^\phi + e_{yn}^\phi) \sin \varphi_1, \\ e_{y1}^\phi = (e_{xn}^\phi - e_{yn}^\phi) \sin \varphi_1 + (e_{xn}^\phi + e_{yn}^\phi) \cos \varphi_1, \\ e_{z1}^\phi = e_{zn}^\phi; \end{cases} \\
{}^{-\phi}e_{2f} &= \begin{cases} e_{x2}^\phi = (e_{xn}^\phi + e_{yn}^\phi) \cos \varphi_2 + (e_{yn}^\phi - e_{xn}^\phi) \sin \varphi_2, \\ e_{y2}^\phi = -(e_{xn}^\phi + e_{yn}^\phi) \sin \varphi_2 + (e_{yn}^\phi - e_{xn}^\phi) \cos \varphi_2, \\ e_{z2}^\phi = e_{zn}^\phi; \end{cases} \\
{}^{-\phi}e_{2\phi} &= \begin{cases} e_{x2}^\phi = (e_{xn}^\phi + e_{yn}^\phi) \cos \varphi_2 + (e_{yn}^\phi - e_{xn}^\phi) \sin \varphi_2, \\ e_{y2}^\phi = -(e_{xn}^\phi + e_{yn}^\phi) \sin \varphi_2 + (e_{yn}^\phi - e_{xn}^\phi) \cos \varphi_2, \\ e_{z2}^\phi = e_{zn}^\phi. \end{cases}
\end{aligned}$$

Using everything higher explained, and also elements of differential geometry [15, 17], we will receive coefficients of the quadratic form of a surface of teeth of a gearwheel (for a head):

$$\begin{aligned}
E_1 &= (f_1')^2 + (\Omega_{1f} \cos \beta)^\lambda{}^2 + (z_1^\lambda)^\lambda{}^2, \\
F_1 &= \pm f_1' \Omega_{1f} \cos \beta \mp (\Omega_{1f} \cos \beta)^\lambda \left((f_1 + R_1) \mp \Omega_{1f} (\cos \beta)^\phi \right) + z_1^\lambda z_1^\phi, \\
G_1 &= \left((f_1 + R_1) \mp \Omega_{1f} (\cos \beta)^\phi \right)^2 + (\Omega_{1f} \cos \beta)^\lambda{}^2 + (z_1^\lambda)^\lambda{}^2, \\
L_1 &= -f_1' e_{xn}^\lambda \pm (\Omega_{1f} \cos \beta)^\lambda e_{yn}^\lambda - z_1^\lambda e_{zn}^\lambda, \\
2M_1 &= -f_1' (e_{xn}^\phi - e_{yn}^\phi) \pm (\Omega_{1f} \cos \beta)^\lambda (e_{xn}^\phi + e_{yn}^\phi) - z_1^\lambda e_{zn}^\phi \mp \\ &\mp \Omega_{1f} \cos \beta \cdot e_{xn}^\lambda - \left((f_1 + R_1) \mp \Omega_{1f} (\cos \beta)^\phi \right) e_{yn}^\lambda - z_1^\phi e_{zn}^\lambda,
\end{aligned}$$

$$N_1 = \mp \Omega_{1f} \cos \beta (e_{xn}^p - e_{yn}^p) - ((f_1 + R_1) \mp \Omega_{1f} (\cos \beta)^p) (e_{zn}^p + e_{yn}^p) - z_1^p e_{zn}^p. \quad (12)$$

Similarly for a pinch of a gearwheel it is had:

$$\begin{aligned} E_1 &= (\Phi_1')^2 + ((\Omega_{1\phi} \cos \beta)^\lambda)^2 + (z_1^\lambda)^2, \\ F_1 &= \pm \Phi_1' \Omega_{1\phi} \cos \beta \mp (\Omega_{1\phi} \cos \beta)^\lambda ((\Phi_1 + R_1) \mp \Omega_{1\phi} (\cos \beta)^p) + z_1^\lambda z_1^p, \\ G_1 &= ((\Phi_1 + R_1) \mp \Omega_{1\phi} (\cos \beta)^p)^2 + (\Omega_{1\phi} \cos \beta)^2 + (z_1^p)^2, \\ L_1 &= -\Phi_1' e_{xn}^\lambda \pm (\Omega_{1\phi} \cos \beta)^\lambda e_{yn}^\lambda - z_1^\lambda e_{zn}^\lambda, \\ 2M_1 &= -\Phi_1' (e_{xn}^p - e_{yn}^p) \pm (\Omega_{1\phi} \cos \beta)^\lambda (e_{zn}^p + e_{yn}^p) - z_1^\lambda e_{zn}^p \mp \\ &\quad \mp \Omega_{1\phi} \cos \beta \cdot e_{xn}^\lambda - ((\Phi_1 + R_1) \mp \Omega_{1\phi} (\cos \beta)^p) e_{yn}^\lambda - z_1^\lambda e_{zn}^\lambda, \\ N_1 &= \mp \Omega_{1\phi} \cos \beta (e_{xn}^p - e_{yn}^p) - ((\Phi_1 + R_1) \mp \Omega_{1\phi} (\cos \beta)^p) (e_{zn}^p + e_{yn}^p) - \\ &\quad - z_1^\lambda e_{zn}^p. \end{aligned} \quad (13)$$

Coefficients of the quadratic form of a surface of teeth of a wheel (head):

$$\begin{aligned} E_2 &= (f_1')^2 + ((\Omega_{1f} \cos \beta)^\lambda)^2 + (z_2^\lambda)^2, \\ F_2 &= \pm f_1' \Omega_{1f} \cos \beta \mp (\Omega_{1f} \cos \beta)^\lambda ((f_1 - R_2) \mp \Omega_{1f} (\cos \beta)^p) + z_2^\lambda z_2^p, \\ G_2 &= ((f_1 - R_2) \mp \Omega_{1f} (\cos \beta)^p)^2 + (\Omega_{1f} \cos \beta)^2 + (z_2^p)^2, \\ L_2 &= -f_1' e_{xn}^\lambda \mp (\Omega_{1f} \cos \beta)^\lambda e_{yn}^\lambda - z_2^\lambda e_{zn}^\lambda, \\ 2M_2 &= -f_1' (e_{xn}^p + e_{yn}^p) \mp (\Omega_{1f} \cos \beta)^\lambda (e_{zn}^p - e_{yn}^p) - z_2^\lambda e_{zn}^p \mp \\ &\quad \mp \Omega_{1f} \cos \beta \cdot e_{xn}^\lambda + ((f_1 - R_2) \mp \Omega_{1f} (\cos \beta)^p) e_{yn}^\lambda - z_2^\lambda e_{zn}^\lambda, \\ N_2 &= \mp \Omega_{1f} \cos \beta (e_{xn}^p + e_{yn}^p) + ((f_1 - R_2) \mp \Omega_{1f} (\cos \beta)^p) (e_{zn}^p - e_{yn}^p) - \\ &\quad - z_2^\lambda e_{zn}^p. \end{aligned} \quad (14)$$

Similarly for a pinch of a wheel it is had:

$$\begin{aligned} E_2 &= (\Phi_1')^2 + ((\Omega_{1\phi} \cos \beta)^\lambda)^2 + (z_2^\lambda)^2, \\ F_2 &= \pm \Phi_1' \Omega_{1\phi} \cos \beta \mp (\Omega_{1\phi} \cos \beta)^\lambda ((\Phi_1 - R_2) \mp \Omega_{1\phi} (\cos \beta)^p) + z_2^\lambda z_2^p, \\ G_2 &= ((\Phi_1 - R_2) \mp \Omega_{1\phi} (\cos \beta)^p)^2 + (\Omega_{1\phi} \cos \beta)^2 + (z_2^p)^2, \\ L_2 &= -\Phi_1' e_{xn}^\lambda \mp (\Omega_{1\phi} \cos \beta)^\lambda e_{yn}^\lambda - z_2^\lambda e_{zn}^\lambda, \\ 2M_2 &= -\Phi_1' (e_{xn}^p + e_{yn}^p) \mp (\Omega_{1\phi} \cos \beta)^\lambda (e_{zn}^p - e_{yn}^p) - z_2^\lambda e_{zn}^p \mp \\ &\quad \mp \Omega_{1\phi} \cos \beta \cdot e_{xn}^\lambda + ((\Phi_1 - R_2) \mp \Omega_{1\phi} (\cos \beta)^p) e_{yn}^\lambda - z_2^\lambda e_{zn}^\lambda, \\ N_2 &= \mp \Omega_{1\phi} \cos \beta (e_{xn}^p + e_{yn}^p) + ((\Phi_1 - R_2) \mp \Omega_{1\phi} (\cos \beta)^p) (e_{zn}^p - e_{yn}^p) - \\ &\quad - z_2^\lambda e_{zn}^p. \end{aligned} \quad (15)$$

In the received ratios for coefficients of quadratic forms upper the sign undertakes for the convex side, the lower sign is for concave. Value e_{xn} , e_{yn} , e_{zn} are undertaken from received before formulas with the upper sign for the convex side of tooth of a wheel (gearwheel), with the lower is for the concave side respectively. Others, not defined above a parameter value, taking into account the equations of a linkage have the following appearance (for a head and a pinch respectively):

$$\begin{aligned} (\cos \beta)^p &= \frac{R_i K}{1 \pm \Omega_{2f} K}, \quad (\cos \beta)^p = \frac{R_i K}{1 \pm \Omega_{2\phi} K}, \\ (\sin \beta)^p &= -\frac{KR_i \operatorname{ctg} \beta}{1 \pm \Omega_{2f} K}, \quad (\sin \beta)^p = -\frac{KR_i \operatorname{ctg} \beta}{1 \pm \Omega_{2\phi} K}, \\ \frac{d\mu}{d\varphi} &= \frac{R_i}{\dot{y}_0 (1 \pm \Omega_{2f} K)}, \quad \frac{d\mu}{d\varphi} = \frac{R_i}{\dot{y}_0 (1 \pm \Omega_{2\phi} K)}, \\ \frac{d\mu}{d\lambda} &= \frac{\mp \Omega_{2f}' \cos \beta}{\dot{y}_0 (1 \pm \Omega_{2f} K)}, \quad \frac{d\mu}{d\lambda} = \frac{\mp \Omega_{2\phi}' \cos \beta}{\dot{y}_0 (1 \pm \Omega_{2\phi} K)}, \\ (\Omega_1 \cos \beta)^\lambda &= \Omega_1' \cos \beta \mp \frac{\Omega_{2f}' \Omega_1 K \cos \beta}{1 \pm \Omega_{2f} K}, \end{aligned} \quad (16)$$

$$\begin{aligned} (\Omega_2 \cos \beta)^\lambda &= \Omega_2' \cos \beta \mp \frac{\Omega_{2\phi}' \Omega_2 K \cos \beta}{1 \pm \Omega_{2\phi} K}, \\ e_{xn}^p &= 0, \quad e_{yn}^p = -\frac{f_1'}{n} \cdot \frac{R_i K}{1 \pm \Omega_{2f} K}, \quad e_{zn}^p = -\frac{\Phi_1'}{n} \cdot \frac{R_i K}{1 \pm \Omega_{2\phi} K}, \\ e_{xn}^p &= -\frac{f_1'}{n} \cdot \frac{R_i K \operatorname{ctg} \beta}{1 \pm \Omega_{2f} K}, \quad e_{zn}^p = -\frac{\Phi_1'}{n} \cdot \frac{R_i K \operatorname{ctg} \beta}{1 \pm \Omega_{2\phi} K}. \end{aligned}$$

In the private derivatives given here for gearwheel teeth $i=1$, for wheel teeth $i=2$, the upper sign corresponds to the convex side of tooth, lower is for concave; formulas for e_{xn}^λ , e_{yn}^λ , e_{zn}^λ were given above. Besides, designations take place: $\Omega_{2f} = \Omega_{1f} + f_2$, $\Omega_{2\phi} = \Omega_{1\phi} + \Phi_2$.

Using coefficients of the quadratic form (12)-(15), it is possible to define normal curvatures of surfaces of teeth of a gearwheel and a wheel [19, 20]. For this purpose we use the ratio received earlier for determination of curvature of the forming surface in which instead of $d\mu$ it is necessary to add $d\varphi$, instead of E_n , F_n , G_n , L_n , M_n , N_n are appropriate coefficients for a gearwheel (12), (13) and wheels (14), (15).

Normal curvatures of surfaces of teeth of a gearwheel and wheel in the direction of contact lines $\varphi_i = \text{const}$ in case of will be equal:

$$K_{\varphi i} = \frac{L_i}{E_i}.$$

Normal curvatures if $\lambda = \text{const}$ (along screw lines) are equal:

$$K_{\lambda i} = \frac{N_i}{G_i}.$$

From the last ratio it is visible that if $K = 0$, $\beta = 0$, normal curvatures $K_{\lambda i}$ along screw lines are equal to zero.

Using the linkage equations for convex (the upper sign) and bent (the lower sign) the tooth sides, we will receive if $\mu = \text{const}$ (for a head and a pinch respectively):

$$\left(\frac{d\varphi}{d\lambda}\right)_{\mu} = \pm \frac{\Omega_{2f}' \cos \beta}{R_i}, \quad \left(\frac{d\varphi}{d\lambda}\right)_{\mu} = \pm \frac{\Omega_{2\phi}' \cos \beta}{R_i}. \quad (17)$$

Then in the normal section of teeth the normal curvature if $\mu = \text{const}$ looks like:

$$K_{\mu i} = \frac{L_i d\lambda^2 + 2M_i d\lambda d\varphi + N_i d\varphi^2}{E_i d\lambda^2 + 2F_i d\lambda d\varphi + G_i d\varphi^2}. \quad (18)$$

Having separated numerator and a denominator of equality (18) on $d\lambda^2$, and using a ratio (17), we will receive:

$$K_{\mu i} = \frac{R_i^2 L_i \pm 2M_i R_i \Omega_{2f}' \cos \beta + N_i (\Omega_{2f}' \cos \beta)^2}{R_i^2 E_i \pm 2F_i R_i \Omega_{2f}' \cos \beta + G_i (\Omega_{2f}' \cos \beta)^2},$$

(for a head);

$$K_{\mu i} = \frac{R_i^2 L_i \pm 2M_i R_i \Omega_{2\phi}' \cos \beta + N_i (\Omega_{2\phi}' \cos \beta)^2}{R_i^2 E_i \pm 2F_i R_i \Omega_{2\phi}' \cos \beta + G_i (\Omega_{2\phi}' \cos \beta)^2}.$$

(for a pinch).

In edge sections of cogwheels $z_1 = \text{const}$, $z_2 = \text{const}$. Then from the last equations (1)-(4) for the active surfaces of arch teeth, considering that $z_0 = \text{const}$ we will receive (for a head and a pinch respectively):

$$dz_i = \mp \left(f_2' \sin \beta \right) d\lambda \mp f_2 \cdot \frac{\partial \sin \beta}{\partial \mu} d\mu = 0, \quad (19)$$

$$dz_i = \mp \left(\Phi_2' \sin \beta \right) d\lambda \mp \Phi_2 \cdot \frac{\partial \sin \beta}{\partial \mu} d\mu = 0. \quad (20)$$

Using the linkage equation for the convex and concave sides of arch teeth, we have respectively for a head and a pinch:

$$dF_i = \dot{y}_0 d\mu - R_i d\varphi \pm \Omega_{2f}' \cos \beta d\lambda \pm \Omega_{2f} \cdot \frac{\partial \cos \beta}{\partial \mu} d\mu = 0 \quad (21)$$

$$dF_i = \dot{y}_0 d\mu - R_i d\varphi \pm \Omega_{2\phi}' \cos \beta d\lambda \pm \Omega_{2\phi} \cdot \frac{\partial \cos \beta}{\partial \mu} d\mu = 0 \quad (22)$$

Deciding systems of equations (19) and (21) for a head, (20) and (22) for a pinch, we find for edge sections of cogwheels (for a head and a pinch respectively):

$$\left(\frac{d\varphi}{d\lambda}\right)_{Ti} = \frac{f_2' \sin \beta \operatorname{tg} \beta (1 \pm \Omega_{2f} K) \pm f_2 K \Omega_{2f}' \cos \beta}{f_2 K R_i},$$

$$\left(\frac{d\varphi}{d\lambda}\right)_{Ti} = \frac{\Phi_2' \sin \beta \operatorname{tg} \beta (1 \pm \Omega_{2\phi} K) \pm \Phi_2 K \Omega_{2\phi}' \cos \beta}{\Phi_2 K R_i}.$$

Normal curvature of surfaces of teeth will be equal in edge section:

$$K_T = \frac{L_i + 2M_i \left(\frac{d\varphi}{d\lambda}\right)_{Ti} + N_i \left(\frac{d\varphi}{d\lambda}\right)_{Ti}^2}{E_i + 2F_i \left(\frac{d\varphi}{d\lambda}\right)_{Ti} + G_i \left(\frac{d\varphi}{d\lambda}\right)_{Ti}^2}.$$

CONCLUSIONS

1. Received analytical dependences for coefficients of the first and second quadratic forms are necessary for determination of criteria of operability of tooth gearings.

2. The received values of normal curvatures of surfaces of teeth in the characteristic directions can be used in case of synthesis of transmissions with arch tooth by these criteria.

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ВНУТРЕННЯЯ ГЕОМЕТРИЯ АКТИВНЫХ ПОВЕРХНОСТЕЙ ЗУБЦОВ ЦИЛИНДРИЧЕСКИХ АРОЧНЫХ ПЕРЕДАЧ СМЕШАННОГО ЗАЦЕПЛЕНИЯ

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Аннотация. В статье получены аналитические зависимости для определения показателей внутренней геометрии арочных зубцов, образованных инструментом с несимметричным исходным контуром, который позволит определить качественные показатели работоспособности таких передач.

Ключевые слова. Арочные зубчатые передачи, исходный контур, производящая поверхность, инструментальная рейка, система координат, коэффициенты квадратичных форм, нормальная кривизна, главные кривизны.

Ukrainian - Russian border experiment international transport crossing point "Deakovo - Kujbyshevo - 2"

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Summary. In the article the next problems are reviewed: the question of work of Ukrainian and Russian customs border services in the frames of the experiment carried out on the territory of Russia, which has the aim to optimize the control procedures of crossing the border by vehicles, passengers and local residents. Also examined the problem of poor state of the Ukrainian road - transport system, especially in border areas the lack of modern-points, areas of service, including sites of international importance, as well as roads that meet the requirements of the European Standards. These factors have a negative impact on the logistics of planning and passing traffic in the Eurasian transport system - communication and information environment.

Key words: state border, international border crossing point, customs procedure.

INTRODUCTION

Analysis of the effectiveness of border – customs control procedure, the road condition and cross-border infrastructure are components that affect the acceleration of the border crossing process by freight and passenger vehicles, as well as local residents, optimization of control procedure implemented by personnel check points of each neighboring countries [1]. However, the implementation of this type of research activities faces difficulties due to the lack of both individual buildings, pavilions and actually the whole border crossing check points for the vehicles and passengers, that affects the quality of the scientific analysis, the performance of border - customs procedures, in-depth inspection of vehicles and passengers transportation [14]. The reliability of this process is greatly influenced by the fact that

the quality of service within the crossing points and the adjacent areas of access, which is provided, for example by freight carriers, is defined by the state of a large number of different factors which are difficult to take into account as part of an integrated approach [17].

The purpose of this work is to determine the engagement terms of the border crossing point staff and - customs procedures in the course of experiment, that will assess the quality of the customs border and services, which are provided to carriers and passengers within the particular border check - point "Djakovo (Ukraine) - Kuibyshev (Russian Federation) [16].

The peculiarity of the experiment novelty is that for the first time in the cross-border mutual cooperation practice the work of Ukrainian customs border personnel and other control services is held not on its own territory, but within the buildings and communication facilities of the checkpoint, located on Russian territory, at the distance of 1 km. to the state border. [3]

OBJECTS AND PROBLEMS

The list of documents that characterize the area, buildings and other structures of the international automobile checkpoint was examined during the work on the research [2].

I. Among the primary documents were examined those of them that characterize the

process of construction organization and preparation the project for operation, including:

1.1 Act of State Acceptance Committee "On taking in exploitation the completed construction of automobile checkpoint" Kuybyshevo - 2 "of Taganrog customs –border control which indicates:

1.2 Taking in exploitation the completed construction of buildings and structures of automobile checkpoint (ACP) on Russian - Ukrainian border carried on the 29.09.2004 [24].

1.3 For exploitation on the Russian - Ukrainian border the complex of buildings and facilities presented by the customer FSUE "Rostek" together with the general contractor LLC "Stroyinvest ENGINEERING SC - 848.

1.4 The work was done in accordance with the resolution on the construction from 23.10.2002 № 113, issued by the State Inspectorate of Architecture - Construction Supervision of Kuibyshev district of Rostov region [20].

1.5 The work was carried out on the basis of a feasibility study for the construction of the road checkpoint "Kuybyshevo - Djakovo" (ACP), designed by CJSC "Rostovgiproavtotrans" Rostov - na- Donu and working papers done by Institute of "Rostov Promstroy NIiproekt" (accession number 170865, order №2986).

1.6 Feasibility Study (FS) approved by the order of the State Customs Committee of the Russian Federation dated 29.03.2002, № 285.

1.7 Construction - installation works carried out in the periods:

- the beginning of work - III decade of 2002.;
- the end of work - III decade of 2004.

1.8 Presented for the acceptance object has the following key performance indicators, which are presented in the table [19].

Table. The basic operational indicators of the border crossing checkpoint "Kuybyshevo - 2 - Dyakovo"

Capacity Indicators	Units of measure	On draft (units)	In fact (units)
Passing capacity	auto/day	400	400
Including: -passenger automobiles	auto/day	360	360
-busses	auto/day	12	12
-trucks	auto/day	28	28

II. The study of the documents and inspection of the buildings, structures shows that the technological and architectural - building

solutions for the international automobile checkpoint are characterized by the following data:

2.1. ACP "Kuybyshevo - 2 - Djakovo" conducts border customs, immigration, sanitary - quarantine, veterinary, phytosanitary, radiation monitoring and control of Rostransinspection of the vehicles, passengers and cargo. Taking into consideration the terrain and road specifics conditions on the Ukrainian part of the road, ensures the passage of the total weight of trucks up to 3.5 tons.

2.2. The restricted area is 2.85 hectares., which includes the bus station, a tent for the passenger traffic, a tent for the border control, in-depth examination pavilions for trucks with a warehouse for temporary storage of detained goods, in-depth examination pavilions for diesel, passenger cars, the building of sanitary – quarantine control, intakes, treatment facilities, communication tower of the control - crossing checkpoints and other buildings.

2.3. Foundations of the buildings and structures – are made of pile, the frame is from steel, the exterior walls – 3 layers panels of piecemeal assembly, the roof is from sheeting with insulation «URSA», the cover of driveways and grounds are made of asphalt, the fencing of the restricted area is metal mesh with alarms.

2.4. The established on the object equipment is under the draft and has passed the individual test and comprehensive testing.

2.5. The arrangements of labor, environmental protection which are provided by the project are fully implemented.

2.6. Normative operation of the facilities is provided:

- external communication of hot and cold water,
- sewerage facilities, heating, electricity and communications [12].

III. 3.1. The total estimated cost of the approved design - budget documentation (in 1991 prices.) is:

Total 8567.0 thous.rubles, including:

- the cost of construction and installation works - 4778.0 thous. rubles.,
- equipment - 3152.0 thous. rubles.

3.2. The taken into operation estimated cost of the fixed assets at current prices (2004) is 256,313,915 rubles [18].

Characteristic features of the transport process are presented by the complex of buildings, including:

- international automobile checkpoint "Djakovo - Kuibyshevo -2", which is situated on

the T-1320 highway, at the distance of 11 km. from Ukrainian settlement "Djakovo" (Antratsit district, Luhansk region), 22 km from the customs-border checkpoint Kuibyshevo (Kuibyshev district, Rostov region);

• the road route in the pre-perestroika period, from Ukrainian and Russian part was used to transport cargo and passengers through the territory of Lugansk region by automobile transport in the direction of Taganrog - (Kuibyshev, Dyakovo) - Antratsyt - Lugansk - (Starobelsk, Bielorodsk) with the access to the Russian Federation border towards Melovoe - Chertkovo (Rostov region) Prosianoe - Bugaevka (Voronezh region); Novobelaya - Novobelaya (Voronezh region); Tanyushevka - Rovenky (Belgorod region). [4]

Built by the Russian side, the crossing checkpoint "Kuibyshevo -2-Djakovo" being put into operation, almost at the same time was closed by the Ukrainian side unilaterally and is not used until now. This is done despite the fact that since 2004 this route could have been used by the owners of industrial and agricultural cargo of the nearby Ukrainian cities: Krasnyi Luch, Antratsyt, Rovenky, Sverdlovsk, and by the residents of the settlements adjacent directly to the border of Antratsyt and Kuibyshev district (up to 30 thousand people) [23]. This automobile route is particularly advantageous for the owners of the vehicles and cargo of Taganrog, in the seaport of which a comprehensive reconstruction has recently been carried out; vehicles passing through the checkpoint "Djakovo - Kuibyshevo-2" in the direction of the central regions of the Russian Federation, will shorten the distance for one-third, save the transportation time, reduce the load on the most loaded ramp to Rostov - na - Donu – Moscow [11].

These conclusions are supported by concrete data that characterizes the stability of the vehicles and people traffic intensity across the border within Luhansk region. Despite the political instability that occurred in Ukraine in the period of closing the checkpoint "Diakovo - Kuibyshevo -2", constantly, almost at all levels of the government, the proposal of the Russian side, which initiated discussions regarding the reconstitution of the object is supported. As a result of the checkpoint "Diakovo Kuibyshevo -2" opening event a number of systemic measures were organized in Luhansk Regional State Administration, Antratsyt district administration as well as in the municipality "Kuibyshev district" [12]. In the frames of the experiment the basic requirements of the joint

work of Russian and Ukrainian customs - border and other control authorities on the use of the objects IACP "Kuibyshevo-2 - Diakovo" were worked. For the first time in 2010, in the practice of cross-border mutual cooperation agreements of friendship and cooperation were signed on the one hand, between Kuibyshev district and Krasnyi Luch as well as Antratsyt district. During the meeting, which took place on 15.07.2010, in the presence of the head of Kuibyshev district Lukyanchuk V.N. and the head of Antratsyt district administration Golovenko G.B., a set of activities related to the development of cross-border connections and transboundary cooperation was discussed. The Russian side, in particular, within the framework of the integration of bilateral economic relations proposed a trade - economic operation on the selling of products, including - building bricks M-125 plastic plates, feed chalk; corn and sunflower seeds (on condition of the joint venture or work through intermediaries) [7].

The main stages of joint actions of the customs border officials in the monitoring of vehicles and passengers traveling from Russia to Ukraine have also been worked.

These and other working contacts between the heads of the local government of Ukrainian and Russian side at all levels of government gave the opportunity to update and even to create new permanent mechanisms for mutual cooperation of the regions [21]. The work on the intergovernmental level of the two Parties has been reestablished. In particular, in the city of Sochi, on the 04/01/10 the sixth meeting of the Economic Cooperation Committee of Russian - Ukrainian interstate commission took place, where the questions regarding the resumption of trade - economic and other types of relationships were discussed, including:

- scientific - technical cooperation;
- space and aviation industries;
- area of regional cooperation;
- agro - industrial complex;
- inter-regional and cross-border cooperation.

To restore the inter-regional and cross-border cooperation the problem of implementation the Memorandum of Intentions between the Federal Road Agency of the Russian Federation Ministry of Transport and the State Road Service of Ukraine, regarding the development of the motorway in the direction of Moscow - Kyiv and Moscow - Simferopol from 2.02.2007 has become an important area [5].

The next issues were identified as the priority areas of the Program in the field of regional cooperation:

- improvement of the regulatory - legal framework of mutual cooperation,
- improvement of cooperation in the border field, including the field of customs and other controls implemented at the state border,
- cooperation in law enforcement sphere and labor migration, transnational spatial planning policy,
- development of inter-municipal cooperation and patriotic connections between small and medium-sized cities, especially border regions of the Russian Federation and administrative - territorial units of Ukraine,
- development of modern road - transport and communication infrastructure, exchange of experiences in various fields of activity, development of other institutions of cooperation [6].

As a result of the agreements at the level of the heads of the states the Euroregion "Donbass" was established within Lugansk, Donetsk and Rostov regions in October 2011, to which, at the present time, Voronezh region intends to enter as a full member.

The session of the subcommittee on border issues, the subcommittee on International mutual cooperation of the Ukrainian - Russian Intergovernmental Commission were restored. Within this framework, on the 28-29 February 2012 in Taganrog the retreat joint Russian - Ukrainian conference on open road points Kuibyshev (Diakovo) was held [15].

Over the past period in the cities of Kiev, Kharkiv in December 20-21, 2012 in Moscow the next meetings (workshops) were held: the eighth regular meeting of the Subcommittee on Border Affairs, Subcommittee on International Cooperation of Ukrainian - Russian Intergovernmental Commission. Minutes of the Subcommittee meeting have a long list of questions about Ukrainian - Russian mutual cooperation [10].

For Lugansk region, which was presented in the Subcommittee by its permanent representative - the head of the Regional Administration of Transport, Communication and Tourism Schastlivyi M.A., was important the question of the experiment taking place from March 2012 on the territory of the Russian Federation within the checkpoint "Kuibyshevo -2". The essence of the discussed experiment is that for the first time the border - customs and other

control services of Ukraine will perform with Russian customs-border service control of the vehicles, passengers and local residents passage at the facility, which is owned by the Russian Federation and is located within the state border. At the meeting of the Subcommittee the Parties agreed to complete the preparation of the checkpoint in the first decade of 2013, and to finalize the regulations data, that is necessary for its launch and implementation [17].

As the main the project experimental technological scheme of joint control of persons, vehicles, cargoes, goods and animals in the road checkpoint Kuibyshev (Diakovo), among the others, contains factors relating to:

description of the checkpoint facilities, including:

- ✓ location of customs - border services personnel of Ukrainian and Russian sides;
- ✓ specifying the significance of the concepts concerning the location of the customs-border services, procedures of controls and operation of responsibilities of the officials and their full powers;

✓ as a result of the implemented actions considering Russian and Ukrainian legislation the next actions were implemented: the agreement about the aim, place and time of activities related to the forms and methods of control or refusal of its implementation while crossing the border by vehicles, individuals; cross-border movement of goods and the exchange of information between supervisory authorities;

✓ the procedure and methods of placing the product in experimental box for a joint in-depth examination on the base of risk analysis, if the relevant information is available, or in case of necessity to carry out the examination of goods or vehicles for safety purposes, including possible cyber attacks;

✓ proposed the procedure of organization of joint control of persons, vehicles, the movement of goods, animals, on their way from the Russian Federation to Ukraine and back, as a system of terms and requirements for individual officials and controlling border services of each country that participates in the experiment [8].

In joint documents and a separate Protocol the next points are specified:

✓ parties carry out the control measures in the following sequence:

- customs control, including a documentary one;
- stationary, phytosanitary, transport, environmental (if necessary);
- border control.

✓ It is established that after control - security activities officials from Russian and Ukrainian sides put down the necessary marks in the "control pass" for leaving the Russian Federation to Ukraine or in the opposite direction. In this case, filed papers with the results of official control are passed over to a concrete official - the participant of a standard control procedure within the control - crossing checkpoint of Russia or Ukraine [9];

✓ the project of vehicles movement from the Russian Federation to Ukraine and from Ukraine to the Russian Federation, as well as the Plan – scheme of the International automobile checkpoint Kuibyshevo -2 - Diakovo with demarcated zones of traffic modes are designed;

✓ taking into account the fact that Ukrainian side doesn't have finished buildings, own sources of electricity, telecommunications, water and special equipment, the conditions of use of the existing equipment, including the one for personal work, its operation by Ukrainian side are defined, the conditions will be fixed at the end of the experiment in the Special Agreement of the parties [13].

CONCLUSIONS

The joint work of public authorities at all the levels in Ukraine and the Russian Federation, as well as the scientists, non-governmental organizations contributes to the development of cross-border mutual cooperation and cross-border activities. Herewith, a variety of special mechanisms of cooperation between the states are created and are functioning, including – the one at the level of local authorities of border areas. As a result of the joint actions of Ukrainian and Russian sides it becomes important to carry out an experiment, which has the aim to reopen the route Taganrog - Luhansk region - central regions of the Russian Federation – and in the opposite direction – on account of the use of Russian checkpoint "Kuibyshevo -2" facilities, creating the conditions for work of Ukrainian customs- border control services with the use of the territory and equipment of the neighboring state.

Simultaneously, this experiment highlights the problem of unsatisfactory state of Ukrainian road - transport system, especially in border areas, the lack of modern border crossing points, areas of service, including sites of international importance, as well as highways, which meet the requirements of European Standards. These factors have a

negative impact on the logistics of planning and implementing the traffic passing in the Eurasian transport system - communication and information space.

In the work of mechanisms on compliance the requirements for implementation of demarcation qualified procedure at the border some drawbacks were identified; providing of land needed for the construction of public facilities, particularly roads, communications in order to build Ukrainian border points, areas of service that meet the requirements of the European Standards.

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УКРАИНСКО – РОССИЙСКИЙ ПОГРАНИЧНЫЙ
ЭКСПЕРИМЕНТ МЕЖДУНАРОДНОГО
АВТОМОБИЛЬНОГО ПУНКТА ПРОПУСКА
«ДЬЯКОВО – КУЙБЫШЕВО - 2»

Максим Слободянюк, Елена Лапаева

Аннотация. В статье рассматриваются следующем проблемы: вопрос о работе украинских и русских таможенных пограничных служб в рамках эксперимента, проведенного на территории России, которая имеет целью оптимизации процедур контроля пересечения границы транспортными средствами, пассажиров и местных жителей. Факторы влияющие на развитие приграничных районов такие как: состояния автомобильных дорог, отсутствие современных пунктов пропуска, центров обслуживания, в том числе международного значения. Эти факторы оказывают негативное влияние на логистику планирования и прохождения трафика в евразийскую транспортную систему - связи и информационной среды. Ключевые слова: государственные границы, международные пункт пересечения границы, таможенные процедуры.

Research of management efficiency designer preproduction by method of analysis of hierarchies of electronic vehicles

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S u m m a r y . In-process the index of management efficiency offers designer preproduction. The analysis of benefits and management expenses is considered preproduction by the method of analysis of hierarchies. Benefits and expenses carry economic and administrative character. Developing the system of support of making decision of designer preproduction of electronic vehicles examines next classifying signs at the prospected objects: cost effectiveness due to the exception of returns on a revision, achievement of the greater productivity, etc.

Key words: management, process of designer preproduction, electronic vehicle, mathematical model, method of analysis of hierarchies, management efficiency, economic and administrative parameters, system of support of making decision.

innovation touching the examined system of support of making decision [1, 15].

Similar family an innovation is entailed by a change as economic [2, 3-7], so administrative parameters [8] managements designer preproduction, in particular has benefits and expenses. On this stage it is necessary to decide an important task, touching determination of management efficiency designer preproduction of electronic vehicles and determination of border terms of admission of application of similar sort of innovation for the producible objects of the different setting and external environments.

INTRODUCTION

Introduction of the offered system of support of making decision in a management entails the change of row of indexes of management process designer preproduction of electronic vehicles and influences on: time of flowing of process of designer preproduction, productivity etc. By general description for research of management designer preproduction is efficiency, it is therefore necessary to prospect the maximum values of efficiency, turn-downs of parameters and to test general methodology of management designer preproduction of electronic vehicles. Introduction to the existent process of management designer preproduction of block of electronic vehicle of function of design, tuning and offered intellectual management supposes in a management designer preproduction of electronic vehicle of the offered

OBJECTS AND PROBLEMS

Examining a management designer preproduction of electronic vehicles, it is necessary to distinguish the row of vagueness related first of all to the necessity to execute the process of design of behavior of electronic vehicle in the conditions of exploitation, stipulating the necessity of correction of maintenance of designer preproduction, economic expenses and administrative expenses, abutting upon a vagueness exposure and removal of reasons of failures and refuses of electronic vehicle in the process of exploitation, and also by a vagueness in the choice of strategy of removal of the undesirable phenomena and effects, differentiating for the certain types of electronic vehicles [9-11, 13].

The order of arrangement of good, process of design of parameters, come forward in the removal of similar sort of situations a not insignificant factor, properties and arrangement of good on the stage of designer preproduction, and also the formalization of decision-making process, based on systematization of model project decisions, model sequences of improvement of parameters and arrangement of electronic vehicle, model scenarios of analysis, sequences of inferencing of rules, models of knowledge and mechanism of receipt of new knowledge on present by means of rules of transformation of knowledge.

From one side, we have a task of improvement of parameters and arrangement of electronic vehicle on the basis of systematized in the offered system of support of making decision of methods, characteristic for the group of experts working not dependency upon each other and based in most cases on long-term experience [12, 14 - 16]. On the other hand, for different on purpose and the presence of row of basic possible parameters is characteristic the object of exploitation of electronic vehicles, as that: reliability, cost, time of implementation of designer preproduction etc. If the first indexes are systematized, algorithms are programmed, then last it is necessary in every case to compare, find priorities and search some their optimal combinations [17].

As a result, at research of possible situations arising up in the examined difficult system, we get, that in it is the beginning necessary to realize strategy of exposure potentially of dangerous and harmful situations, and then to apply strategy of removal of primary causes and consequences of these phenomena.

Thus, it is necessary to answer questions, that to search: maximal reliability, resonant, oscillation, mechanical stability, productivity, economic efficiency or providing of model variant of structural and construction execution of electronic vehicle, and then how to provide the chosen index of quality of electronic vehicle [18].

Introduction of the offered programmatic-technical complexes and system of support of making decision in a management entails the change of row of technical and economic indexes of management process existent designer preproduction of electronic vehicles, that can result in the loss of expediency of realization of designer preproduction or management efficiency in general, it is therefore necessary to investigate the offered directions of modernization on the basis of mechanisms of research of benefits and expenses,

that maybe by application of method of analysis of hierarchies.

Benefits and expenses carry economic and administrative character. In particular, cost effectiveness comes forward the example of economic values due to the exception of returns on a revision, economic expenses - expenses on educating of personnel, administrative benefits are formalization of knowledge and experience of experts, administrative expenses is a necessity of concordance of the recommendations given out by the system with the supposed type and external of electronic vehicles environments[19, 22].

Examining, driven to work, levels of analysis of the system of support of making decision of designer preproduction of electronic vehicles and doing an accent on introduction of the offered modernization in the existent process of management on the basis of programmatic-technical complexes for the design of the mechanical loading of electronic vehicle, it is necessary to distinguish research of the set factors influencing on the decision of the put problem.

Research, development and introduction of the offered system of support of making decision, has a hierarchy of benefits and expenses. Nature of the prospected factors has economic and administrative character, and the display of each of them is related to setting, external environments and features of management of designer preproduction of electronic vehicles, that in turn it is also necessary to take into account and systematize [20, 21].

Developing the system of support of making decision of designer preproduction of electronic vehicles, we enter in consideration next classifying signs at the prospected objects: cost effectiveness due to the exception of return on a revision, achievement of the greater productivity, use of model decisions and structural elements, production of wares high-reliability, bringing in of ordinary personnel, use of single scenario for a management designer preproduction of different objects, formalization of knowledge and experience of experts, duration of process of collection of statistics, heavy economic tolls on formalization, educating of personnel, expenses on adaptation of scenarios of improvement of parameters and arrangement of wares, appearance of additional "loop" in designer preproduction of good, necessity of bringing in of experts, necessity to involve plenty of enterprises for collection of statistics, necessity of concordance of the recommendations given out by the system with the supposed management designer preproduction of electronic vehicles.

The classification signs entered in consideration make properties of object, carrying economic and administrative character, determined by the method of analysis of hierarchies. The sign of classification of objects, adopted by functional dependence for research of efficiency of management of designer preproduction of electronic vehicles, looks like:

$$J = P_1 \cdot \left(K_1 \cdot \left(L_1 \cdot y_1 + L_2 \cdot y_2 + \right. \right. \\ \left. \left. + L_3 \cdot y_3 + L_4 \cdot y_4 \right) + \right. \\ \left. + K_2 \cdot \left(L_5 \cdot y_5 + L_6 \cdot y_6 + L_7 \cdot y_7 \right) \right) + \\ + P_2 \cdot \left(K_3 \cdot \left(L_8 \cdot y_8 + L_9 \cdot y_9 + \right. \right. \\ \left. \left. + L_{10} \cdot y_{10} + L_{11} \cdot y_{11} + L_{12} \cdot y_{12} \right) + \right. \\ \left. + K_4 \cdot \left(L_{13} \cdot y_{13} + L_{14} \cdot y_{14} + L_{15} \cdot y_{15} \right) \right), \quad (1)$$

where: P_i , K_j , L_f – coefficients, y_f – signs.

Analyzing (1), note should be taken on that this functional dependence has an additive kind, free of superfluous complication for the examined case of estimation of priorities and, except the estimation of efficiency of management of designer preproduction of electronic vehicles, can be used for research of management processes by designer preproduction of objects of different nature for the purpose the analysis of the distinguished classification signs.

The sizes of model coefficients are individual for the objects of different nature and built on the basis of expert estimations and method of analysis of hierarchies. A kind (1) corresponds to the additive type of criterion and supposes simplicity of realization at the simultaneous sufficient level of exactness, comporting here with hierarchical presentations of method of analysis of hierarchies. An amount and character of classification signs correspond to the most complete idea about the analysis of technical and economic indexes of management of designer preproduction.

The aim of researches is systematization of the requirements, produced to the electronic vehicles of the different setting, external environments, management scenarios designer preproduction of electronic vehicles of the different setting, application of the offered automated management domain.

Similar family systematization is possible by means of statistical treatment of results of the expert questioning, formalization of procedure of management and forming of case frames for the certain types of electronic vehicles. Introduction of the offered innovations in the existent chart of management of designer preproduction of

electronic vehicles will give an opportunity to tune the prospected management under the certain setting of the produced good and condition of exploitation, to attain optimal combinations of economic and administrative parameters of management designer preproduction of electronic vehicles.

For the achievement of the put aim it is necessary to organize questioning of experts concerning the estimations of priorities of results of application of the offered methodology of management of designer preproduction for different objects with subsequent statistical treatment of results of questioning. It is also necessary to estimate adequacy of the got experimental data, define priorities of parameters and their functional intercommunications and on them to produce the analysis of the got results with organization of feed-back for the estimation of efficiency of management of designer preproduction of electronic vehicles. As a method of decision of this task the method of analysis of hierarchies is applied.

CONCLUSIONS

In-process the index of management efficiency offers designer preproduction. The analysis of benefits and management expenses is considered preproduction by the method of analysis of hierarchies. Benefits and expenses carry economic and administrative character. Developing the system of support of making decision of designer preproduction of electronic vehicles examines next classifying signs at the prospected objects: cost effectiveness due to the exception of returns on a revision, achievement of the greater productivity, etc.

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ИССЛЕДОВАНИЕ ЭФФЕКТИВНОСТИ
УПРАВЛЕНИЯ КОНСТРУКТОРСКОЙ
ПОДГОТОВКОЙ ПРОИЗВОДСТВА
ЭЛЕКТРОННЫХ АППАРАТОВ МЕТОДОМ
АНАЛИЗА ИЕРАРХИЙ

Виктория Смолий

Аннотация. В работе предложен показатель эффективности управления конструкторской подготовкой производства. Рассмотрен анализ выгод и издержек управления подготовкой производства методом анализа иерархий. Выгоды и издержки носят экономический и управленческий характер. Разрабатывая система поддержки принятия решений конструкторской подготовки производства электронных аппаратов рассматривает следующие классифицирующие признаки у исследуемых объектов: экономия средств за счет исключения отбраковок, достижение большей производительности и пр.

Ключевые слова: управление, процесс конструкторской подготовки производства, электронный аппарат, математическая модель, метод анализа иерархий, эффективность управления, экономические и управленческие параметры, система поддержки принятия решений.

Limited contact dynamic solution tasks of horizontal vibrations of the stamp on the elastic half-space

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Summary. The results of theoretical research of dynamic contact problems for isotropic elastic semi-space swing joint and totally hard punch under the action of horizontal forces, changing in time for the harmonic law have been given. A limited solution tangent contact stresses in the characteristic points on the ends of the section of contact interaction, has been received.

Key words: elastic half-space, integral transforms, tangents, contact voltage oscillation frequency.

INTRODUCTION

Contact Mechanics of deformable solid body interaction is currently the most active and growing field of continuum mechanics. It is constantly the focus of researchers. This is because all the mechanisms and structures are composed of interacting components and the distribution of effort between the contact details is not known in advance and can only be found as a result of the contact problems. Static contact problems have been pretty well researched at the same time the problem is solving dynamic contact tasks which have a scientific and practical value.

Major publications on the subject are in the works [1-18] developed methods for solving problems of statics are insufficient in solving integral equations of dynamic contact problems, which are oscillating engine, resulting in the development of new problem solving techniques of dynamic contact problems.

OBJECT AND PROBLEMS

The purpose of work is theoretical study of dynamic contact problems of horizontal vibrations of the stamp, tightly bound with elastic poluprostranstvom (flat task) under the influence of the horizontal loads varies in harmonic $T = T_0 \exp(i\omega t)$ law taking into account the terms of the limited tangential contact stresses, in the characteristic points on the ends of the plot surface area (fig. 1).

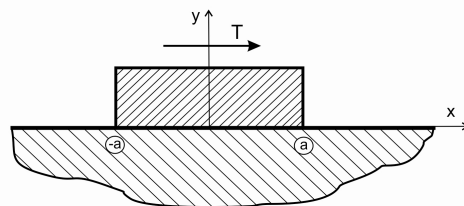


Fig. 1. Design scheme

Problem statement. Using the principle of maximum absorption and integral Fourier transform leads to the following integral equation in dimensionless variables relative to the amplitude value of the unknown strain of tangent $\tau_\varepsilon(x)$ [12]:

$$\int_{-1}^1 \tau_\varepsilon(\xi) k_\varepsilon[\kappa(\xi - x)] d\xi = 2\pi\beta_\varepsilon(x), |x| \leq 1, \Delta = \mu a^{-1}, \quad (1)$$

$$k_\varepsilon(t) = \int_{-\infty}^{\infty} K_\varepsilon(u) \exp(-i|t|u) du, \quad \kappa = \omega a(\rho/\mu)^{1/2}, \quad (2)$$

$$K_\varepsilon(u) = \frac{\sqrt{u^2 - (1 - i\varepsilon)}}{4u^2 \sqrt{u^2 - (1 - i\varepsilon)b^2} \cdot \sqrt{u^2 - (1 - i\varepsilon)} - [2u^2 - (1 - i\varepsilon)]^2}, \quad (3)$$

where: $\tau_\varepsilon(x, t) = \tau_\varepsilon(x) \exp(i\omega t)$ – unknown distribution function tangential contact stresses; $\beta_\varepsilon \exp(i\omega t)$ – the horizontal movement of a stamp called the applied force; ρ, μ – material density and modulus elastic half-space; ω – the oscillation frequency; t – time; ν – Poisson's ratio, when $\nu = 0.3$, $b = [(1-2\nu)/(2(1-\nu))]^{1/2} = 0.5345$, $\tau_\varepsilon(x) = \tau_{1\varepsilon}(x) + i\tau_{2\varepsilon}(x)$, $\beta_\varepsilon(x) = \beta_{1\varepsilon}(x) + i\beta_{2\varepsilon}(x)$.

To find a uniform limit of functions $\beta_\varepsilon(x)$ when $\varepsilon \rightarrow 0$ the path of integration in the view (2) under [12] deformiruem so that when the $\varepsilon \rightarrow 0$ on the real axis of Poles and branching point functions $K_\varepsilon(u)$ do not cross it. From equations, (1) and (3) will take the following form:

$$\int_{-1}^1 \tau(\xi) k[\kappa(\xi - x)] d\xi = 2\pi\beta(x), (|x| \leq 1, \Delta = \mu a^{-1}), \quad (4)$$

$$k(t) = \int_{\Gamma} K(u) \exp(-i|t|u) \cdot du, \quad (5)$$

$$K(u) = \frac{\sqrt{u^2 - 1}}{4u^2 \sqrt{u^2 - b^2} \sqrt{u^2 - 1} - (2u^2 - 1)^2}. \quad (6)$$

The path, in the ratio (5) is the same as the real axis deviating from it, bypassing all the positive and negative features from top to bottom.

Function $K(u)$ -even with the real axis two poles and two pairs of points, branching symmetrically arranged about the origin. Kernel of the integral equation is of the form [12]:

$$k(t) = A + Bt^2 + Ct^4 + (D + Et^2 + Ft^4) - (L + Mt^2 + Nt^4) \cdot i, \quad (7)$$

$A=0,2819$, $C=0,01416$, $E=-0,1325$, $L=1,09056$, $B=-0,1490$, $D=0,6999$, $F=0,009403$, $M=-0,2081$, $N=0,01477$. (8)

Then the solution of integral equation (4) takes the form:

$$\tau_1(x) = \frac{1}{\pi\sqrt{1-x^2}} \cdot \left[T_1 - \int_{-1}^1 \frac{\psi'_1(\tau)\sqrt{1-\tau^2}d\tau}{\tau-x} \right], \quad (9)$$

$$\tau_2(x) = \frac{1}{\pi\sqrt{1-x^2}} \cdot \left[T_2 - \int_{-1}^1 \frac{\psi'_2(\tau)\sqrt{1-\tau^2}d\tau}{\tau-x} \right]. \quad (10)$$

According to the decision by equations (9) and (10) voltage $\tau(x) = \tau_1(x) + i\tau_2(x)$ at the ends of the section of contact interaction (with the $x = \pm 1$) is unrestricted. The decision to keep physical meaning in the vicinity of characteristic points of contact interaction, stress condition is limited at the points indicated ($x = \pm 1$) [11]:

$$\int_{-1}^1 \frac{\psi'_1(\tau)d\tau}{\sqrt{1-\tau^2}} = 0, \quad T_1 = -\frac{1}{\pi} \cdot \int_{-1}^1 \frac{\psi'_1(\tau)\tau d\tau}{\sqrt{1-\tau^2}}, \quad (11)$$

$$\int_{-1}^1 \frac{\psi'_2(\tau)d\tau}{\sqrt{1-\tau^2}} = 0, \quad T_2 = -\frac{1}{\pi} \cdot \int_{-1}^1 \frac{\psi'_2(\tau)\tau d\tau}{\sqrt{1-\tau^2}}. \quad (12)$$

Then limited solution for determining tangential contact stresses takes the form:

$$\tau_1(x) = -\frac{1}{\pi} \sqrt{1-x^2} \cdot \int_{-1}^1 \frac{\psi'_1(\tau)d\tau}{\sqrt{1-\tau^2}(\tau-x)}, \quad (13)$$

$$\tau_2(x) = -\frac{1}{\pi} \sqrt{1-x^2} \cdot \int_{-1}^1 \frac{\psi'_2(\tau)d\tau}{\sqrt{1-\tau^2}(\tau-x)}, \quad (14)$$

$$\begin{aligned} \psi'_1(\tau) = & -\frac{1}{\pi D} \int_{-1}^1 \left\langle \tau_1(\xi) \left\{ \kappa^2 [2(\xi - \tau) \times \right. \right. \\ & \times \left(B + \frac{1}{2}E + E \ln \kappa + E \ln |\xi - \tau| \right) \right\} + \\ & + \kappa^4 \left[4(\xi - \tau)^3 \left(C + \frac{1}{4}F + F \ln \kappa + F \ln |\xi - \tau| \right) \right] \right\rangle + \\ & + \tau_2(\xi) [2M(\xi - \tau)\kappa^2 + 4N(\xi - \tau)^3 \kappa^4] \Big\rangle d\xi, \end{aligned} \quad (15)$$

$$\begin{aligned} \psi'_2(\tau) = & -\frac{1}{\pi D} \cdot \int_{-1}^1 \left\langle \tau_2(\xi) \left\{ \kappa^2 [(\xi - \tau) \times \right. \right. \\ & \times \left(B + \frac{1}{2}E + E \ln \kappa + E \ln |\xi - \tau| \right) \right\} + \\ & + \kappa^4 [4(\xi - \tau)^3 \left(C + \frac{1}{4}F + F \ln \kappa + F \ln |\xi - \tau| \right)] \Big\rangle - \\ & - \tau_1(\xi) [2M(\xi - \tau)\kappa^2 + 4N(\xi - \tau)^3 \kappa^4] \Big\rangle d\xi. \end{aligned} \quad (16)$$

Substituting (15) and (16) respectively (13) and (14) and then searching for solutions to these equations in the form:

$$\tau_j(x) = \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} \tau_{jmn}(x) \kappa^{2m} \ln^n \kappa, \quad (17)$$

We obtain an infinite system of ratios to determine $\tau_{jmn}(x)$ in the form of:

$$\begin{aligned} \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} \tau_{jmn}(x) \kappa^{2m} \ln^n \kappa = & \frac{1}{\pi} \sqrt{1-x^2} + \frac{1}{\pi D} \times \\ \times \int_{-1}^1 \frac{d\tau}{\sqrt{1-\tau^2}(\tau-x)} \cdot \int_{-1}^1 \left\langle \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} \tau_{jmn}(\xi) \kappa^{2m} \ln^n \kappa \left\{ \kappa^2 [2 \times \right. \right. \\ \times (\xi - \tau) \cdot (B + \frac{1}{2}E + E \ln \kappa + E \ln |\xi - \tau|)] + \kappa^4 [4(\xi - \tau)^3 \times \\ \times (C + \frac{1}{4}F + F \ln 2 + F \ln |\xi - \tau|)] \Big\rangle \pm \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} \tau_{smn}(\xi) \kappa^{2m} \times \\ \times \ln^n \kappa \cdot [2M(\xi - \tau)\kappa^2 + 4N(\xi - \tau)^3 \kappa^4] \Big\rangle d\xi \Big\rangle, \end{aligned} \quad (18)$$

($j = 1, 2; s = 1, 2$).

Index $j=1$ fits indexed $s=2$ and a plus sign, and index $j=2$ fits indexed $s=1$ and minus sign. Defining $\tau_{jmn}(x)$ from equations (18) and substituting into equation (17) we get up to $\kappa^4 \ln^2 \kappa$ the following asymptotic formulas:

$$\tau_1(x) = 2\Delta D^{-2} \cdot \beta_1 \sqrt{1-x^2} [A_1 + B_1 x^2 + C_1 x^4 + O(\kappa^6 \ln^3 \kappa)] + 2\Delta D^{-2} \cdot \beta_2 \sqrt{1-x^2} [A_2 + B_2 x^2 + O(\kappa^6 \ln^3 \kappa)], \quad (19)$$

$$\tau_2(x) = 2\Delta D^{-2} \cdot \beta_2 \sqrt{1-x^2} [A_1 + B_1 x^2 + C_1 x^4 + O(\kappa^6 \ln^3 \kappa)] - 2\Delta D^{-2} \cdot \beta_1 \sqrt{1-x^2} [A_2 + B_2 x^2 + O(\kappa^6 \ln^3 \kappa)]. \quad (20)$$

Here $\tau(x) = \tau_1(x) + i\tau_2(x)$ - tangential contact stresses amplitude value, $\beta(x) = \beta_1 + i\beta_2$, $\beta = \text{const}$ - the amount of amplitude values move stamp κ - relative frequency of oscillation of the stamp, ρ and μ - density and modulus elastic half-space.

Options A_1, A_2, B_1, B_2, C_1 - are determined from expressions of

$$\begin{aligned} A_1 &= D - (B + \frac{7}{6}E - E \ln 2 / \kappa) \kappa^2 + \left\{ \frac{1}{D} \left[B + \frac{29}{12}E - \right. \right. \\ &\quad \left. \left. - 2E \ln 2 / \kappa + E^2 \times \left(\ln^2 2 / \kappa - \frac{29}{12} \ln 2 / \kappa + \frac{179}{120} \right) - M^2 \right] - \right. \\ &\quad \left. - \frac{5}{2} \left(C + \frac{349}{300}F - F \ln 2 / \kappa \right) \right\} \kappa^4, \\ B_1 &= \frac{1}{3}E \kappa^2 + \left[-2(C + \frac{49}{30}F - F \ln 2 / \kappa) + \frac{1}{3} \frac{E}{D} \times \right. \\ &\quad \left. \times \left(B + \frac{21}{20}E - E \ln 2 / \kappa \right) \right] \kappa^4, \\ C_1 &= -\frac{1}{5} \left(F - \frac{1}{6} \frac{E^2}{D} \right) \kappa^4, \quad B_2 = -2 \left(N - \frac{1}{6} \frac{EM}{D} \right) \kappa^4, \\ A_2 &= -M \kappa^2 + \left[\frac{2M}{D} \left(B + \frac{29}{24}E - E \ln 2 / \kappa \right) - \frac{5}{2}N \right] \kappa^4. \end{aligned}$$

CONCLUSIONS

Solution of integral equation of the dynamic contact interaction of tasks for a hard punch with elastic isotropic poluprostranstvom when imposing conditions limited stresses in the characteristic points $\ln x = \pm 1$ to receive a valid evaluation values of amplitude values of the tangential contact stresses and their distribution along the length of the surface area of the asymptotic formulas can be used not only for determining tangential contact stresses depending on lateral moves hard punch when interacting with elastic poluprostranstvom,

but also on dynamic contact problems of other units and mechanisms of transport and General machinery.

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ОГРАНИЧЕННОЕ РЕШЕНИЕ ДИНАМИЧЕСКОЙ
КОНТАКТНОЙ ЗАДАЧИ ГОРИЗОНТАЛЬНЫХ
КОЛЕБАНИЙ ШТАМПА НА УПРУГОМ
ПОЛУПРОСТРАНСТВЕ

Валерий Старченко, В'ячеслав Буряк

Аннотация. В работе приведены результаты теоретического исследования динамической контактной задачи о совместном колебании упругого изотропного полупространства и абсолютно жесткого штампа под действием горизонтальной силы, изменяющейся во времени по гармоническому закону. Получено ограниченное решение касательных контактных напряжений в характерных точках на концах участка контактного взаимодействия.

Ключевые слова: упругое полупространство, интегральные преобразования, касательные контактные напряжения, частота колебаний.

Assessment of efficiency of cascade power machines of locomotives

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Summary. Approach is given to determination of efficiency of power installations of cascade type for railway transport. The interrelation of the various efficiency used at determination of power efficiency of cascade power machines is presented. Efficiency of the transformer of energy of compressor type is estimated.

Key words: cascade power machines, pressure exchanger, mass exchange, recovery, efficiency.

exchanger, as well as in wave exchangers of pressure of known system of pressurization of "Comprex" is carried out as a result of direct contact with squeezing gases, however with essential difference of the organization of working process.

INTRODUCTION

Search of ways of improvement of operational properties of power plants of railway transport isn't limited to improvement of indicators of working process of traditional designs of diesel diesels.

The perspective direction of improvement of fuel profitability of the power plant of the locomotive contacts use of heat reformative devices of cascade and thermal compression in systems of utilization of "waste" warmth of the fulfilled gases and cooling liquid [1, 2, 3].

Possibility of increase of efficiency [4-6] and simplification of a design of heat power cars contacts use of the principles of a cascade exchange by pressure for implementation of process of compression of gaseous environments in a running cycle of installation. The units realizing such compression – the cascade exchangers of pressure (CEP) – represent a new version of exchangers of pressure, in a particular approved in systems of pressurization of internal combustion engines [7-18]. Air compression in a cascade

OBJECTS AND PROBLEMS

The principle of action of a cascade exchanger is illustrated by fig. 1 where development of cells of a rotor of rather gas-distributing ports and pressure exchanging channels is schematized.

Arriving through a port of the gas of a high pressure (GHP) squeezing compress gas previously 1 air charge squeezed in a cell also forces out it through a port 8 of the air of a high pressure (AHP) to the consumer. Potential energy of the squeezing gas filling a cell after its dissociation with ports of a high pressure, it is useful it is spent for preliminary compression of a fresh charge in cells in the course of a cascade mass exchange via the pressure exchanging channels 3 which are periodically reporting adjacent cells of a rotor of sites of compression and expansion.

The purge of cells a fresh charge is carried out by compulsory aeration during their connection to ports of low pressure of 5 and 7 (ALP and GLP).

In a cascade exchanger of pressure, unlike wave, compression of air is carried out in

energetically more rational quasi-stationary processes with insignificant amplitude of formed waves. In this case not only the dissipative phenomena of wave interaction of gas environments are leveled, but also sensitivity of working process the CEP to a picture of interaction of primary waves with forward edges of the gas-distributing ports, frequency of rotation of a rotor easily destroyed at a deviation or parameters of squeezing gas from calculated values considerably decreases.

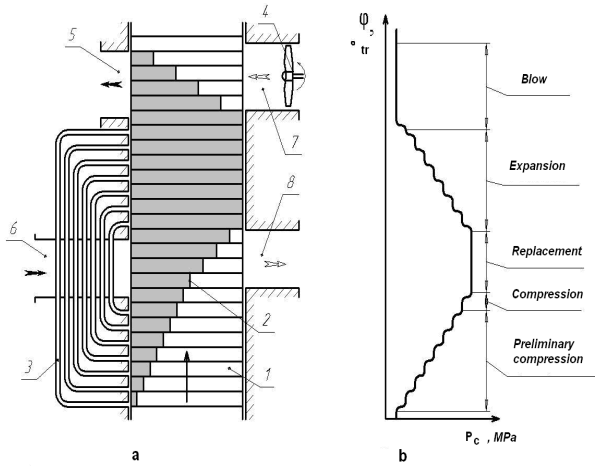


Fig. 1. Schematic diagram CEP:

a – rotor involute the CEP concerning ports and stator channels; b – the chart of change of pressure in cell on a rotor angle of rotation; 1 – rotor cells; 2 – conditional contact border of squeezing and squeezed environments; 3 – mass-exchanged channels of a stator; 4 – blowing-off fan; 5 – port of the gases of low pressure (GLP); 6 – port of the gases of a high pressure (GHP); 7 – port of the air of low pressure (ALP); 8 – port of the air of a high pressure (AHP)

Simplicity of production, absence of discretely operated locking bodies and displacement elements belong to number of the main advantages of rotor units of cascade type of continuous action. Low costs of energy of the drive of a rotor are caused by that compression of a working body is carried out at the expense of processes of a cascade heat mass exchange between adjacent cells of a rotor, as a result of use of energy of expansion of a working body of some volume at its heating. The received thus, compressed air can be used for further expansion in the turbine (in this case a cascade power exchange it is considered as the gas generator) or as the ICE supercharging air [19-23].

PURPOSE AND RESEARCH PROBLEMS

The purpose of the real research is definition of criteria of efficiency which provide an assessment of losses in structural to elements of cascade transformers of energy at various options of their use.

RESULTS OF RESEARCH

Essentially new organization of working process of such device predetermines need of use of specific criteria of efficiency of the power reformative processes to which consideration the real work is devoted.

Let's consider criteria of efficiency of units of a cascade power exchange of different function.

In case of use of the cascade transformer of energy as the generator of gases (used, for example, in broad cars for receiving mechanical work) the adiabatic efficiency is determined by a formula:

$$\eta_{gg}^{ad} = \frac{G_o \cdot \frac{k}{k-1} R \cdot T_{zk} \cdot \left[1 - \left(\frac{P_{zk}}{P_o} \right)^{\frac{1-k}{k}} \right]}{Q_{int}}, \quad (1)$$

where: G_o – a consumption of the gases which are taken away to the consumer; k – air adiabatic curve index; R – air gas constant; P_{zk} and T_{zk} – the cycle maximum pressure and temperature; P_o – atmospheric pressure; Q_{int} – a thermal stream between a working body and walls of the utilization heat exchanger.

In case of use of the unit of the cascade transformer as the compressor (a source of the compressed air) expression of adiabatic efficiency looks like:

$$\eta^{ad} = \frac{G_o \frac{k}{k-1} R \cdot T_o \cdot \left[\left(\frac{P_{zk}}{P_o} \right)^{\frac{k-1}{k}} - 1 \right]}{Q_{int}}, \quad (2)$$

where: T_o – ambient temperature.

Passing to real installation with cascade transformers of energy it is necessary to consider additional costs of energy of the drive of a rotor of the unit. Thus it must be kept in mind some ambiguity of determination of effective efficiency, in view of need of use of uncertain efficiency of the conditional broad car which capacity is

equivalent to costs of the drive of a rotor of an exchanger.

Let's dwell upon a conclusion of expression of efficiency for two cases of use of the cascade compressor or the gas generator.

By consideration of physical essence of effective efficiency of the unit of the exchanger used as the compressor or the generator of gases the analogy to work of gas-turbine engine (GTE), according to intended for forcing of air or generating of hot gases, i.e. GTE in which the capacity of the turbine is spent only for the compressor drive is pertinent.

For convenience of carrying out parallel analogy further in the text we use braces; for designation of the GTE elements which are functionally corresponding to elements of the cascade transformer of energy [24-27].

a) Case of use of the cascade transformer of energy as the generator of gases.

All air which is taken away from an exchanger (GTE compressor) to the consumer of G_o passes through a source of a supply of warmth (GTE combustion chamber) where heats up to the maximum temperature of T_{zk} .

At determination of effective efficiency as useful energy it is necessary to consider only "refined" part of a generated stream, after an exception of it the "expensive" part which is energetically equivalent to power of the drive of a rotor of an exchanger (GTE compressor) taking into account efficiency of transformation in the conditional broad car (BC) (turbine GTE).

The expense of a working body (gas) via the conditional broad machine of the drive makes:

$$G_{em} = \frac{N}{H_{zk}\eta_{em}}, \quad (3)$$

where: N_{dr} – the power spent for the drive of a rotor of an exchanger (GTE compressor); η_{em} – efficiency of the conditional broad machine; H_{zk} – located heat difference of gases at a temperature T_{zk} determined by a formula:

$$H_{zk} = \frac{k}{k-1} RT_{zk} \left[1 - \left(\frac{P_{zk}}{P_o} \right)^{\frac{1-k}{k}} \right].$$

The expense corresponding to a useful component of generated energy, is defined as $G_g = G_o G_{em}$.

Thus, the effective efficiency of the cascade generator of gas can be expressed as follows:

$$\eta_{gg}^e = \frac{G_g H_{zk}}{Q_{int}} = \frac{G_o H_{zk} - G_{em} H_{zk}}{Q_{int}}.$$

Taking in account (3) we will receive:

$$\eta_{gg}^e = \frac{G_o H_{zk} - \frac{N_{dr}}{\eta_{em}}}{Q_{int}} = \frac{G_o \frac{k}{k-1} RT_{zk} \left[1 - \left(\frac{P_{zk}}{P_o} \right)^{\frac{1-k}{k}} \right] - \frac{N_{dr}}{\eta_{em}}}{Q_{int}}.$$

b) Case of use of a cascade exchanger as the compressor.

The air compressed in exchanger, is brought to the consumer with a temperature of compression end T_{ck} , passing a source of a supply of warmth (GTE combustion chamber). However the conditional consumption of air which is energetically equivalent to expenses of power on the drive of a rotor (GTE compressor) has to be calculated taking into account its heating in a source of a supply of warmth (GTE combustion chamber) up to T_{zk} temperature. Thus located heat difference of the stream which is taken away to the conditional broad car (turbine GTE) increases in proportion to T_{zk}/T_{ck} .

The condition of power equivalence of a stream through EM to costs of power of the drive of a rotor can be written down in a look:

$$G_{em} H_{ck} T_{zk} / T_{ck} \eta_{em} = N_{dr},$$

$$\text{where: } H_{ck} = \frac{k}{k-1} RT_{ck} \left[1 - \left(\frac{P_{zk}}{P_o} \right)^{\frac{1-k}{k}} \right] -$$

located heat difference of the air which has been taken away to the conditional broad machine. From where:

$$G_{em} = \frac{N_{dr} T_{ck}}{\eta_{em} H_{ck} T_{zk}}. \quad (4)$$

As in the cascade transformer of energy, unlike GTE, the drive of a rotor is carried out from an external source and warmly for heating of the stream which is taken away to EM in real process isn't spent, at definition of potential expenses of thermal energy (taking into account need of the drive of a rotor) it is necessary to consider additional heat on heating of a stream of G_{em} by means of composed in a denominator of a formula of effective efficiency:

$$\eta_e = \frac{(G_o - G_{em}) H_{\kappa}^{ad}}{Q_{int} + Q_{dr}} = \frac{G_o H_{\kappa}^{ad} - G_{em} H_{\kappa}^{ad}}{Q_{int} + Q_{dr}},$$

here
$$H_k^{ad} = \frac{k}{k-1} R \cdot T_0 \cdot \left[\left(\frac{P_{zk}}{P_o} \right)^{\frac{k-1}{k}} - 1 \right]$$

adiabatic heat difference in the compressor.

In view of $Q_{dr} = G_{em} C_p (T_{zk} - T_{ck})$ and taking in account (4) we will finally receive:

$$\eta_e = \frac{G_o \frac{kRT_0}{(k-1)} \left[\left(\frac{P_{zk}}{P_o} \right)^{\frac{k-1}{k}} - 1 \right] - \frac{N_{dr} T_0 \left(\frac{P_{zk}}{P_o} \right)^{\frac{k-1}{k}}}{\eta_{em} T_{zk}}}{Q_{int} + \frac{C_p N_{dr} (T_{zk} - T_{ck})}{\eta_{em} \frac{k}{(k-1)} R T_{zk} \left[1 - \left(\frac{P_{zk}}{P_o} \right)^{\frac{1-k}{k}} \right]}}. \quad (5)$$

Expediency of simultaneous consideration of adiabatic and effective efficiency at an assessment of a thermodynamic cycle is caused by possibility of identification of specific "contribution" of different types of the brought energy in production of unit of useful work. For example, direct comparison also allows to estimate components of expenses for the rotor drive.

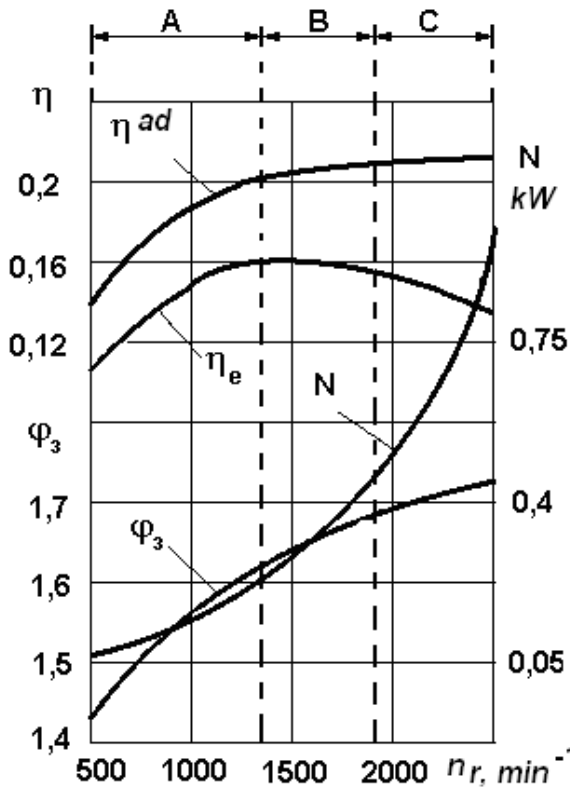


Fig. 2. Influence of rotor rotation frequency on thermal compressor indicators at temperature $T_z = 650$ K mode

Feature of working process of an exchanger is essential dependence of indicator transformation of thermal energy on quality of a purge of cells fresh air (fig. 2). The analysis of curves of change and depending on the frequency of rotation of a rotor, at an invariable maximum temperature of a cycle shows that in area "A" increase of η_r is unambiguously expedient as provides prevailing influence of coefficient of a purge on to what intensive growth testifies.

In area "C" the purge intensification (at the expense of increase in rotation frequency) doesn't provide noticeable influence on efficiency of indicator transformation, but is accompanied by essential increase in expenses of power at the drive of a rotor that causes decrease.

Expedient degree of an intensification of a purge in area "B" depends on the relative value of two types of energy in the conditions of the concrete power plant of the locomotive.

CONCLUSIONS

Thus, comparison of characteristics of the considered efficiency gives an idea of resource opportunities of increase of system effectiveness of cascade transformation of energy at the expense of various factors.

The presented efficiency estimation criteria of energy cascade transformers are approved on thermal compressor example, can be applied practically for any power machines of cascade type, applied on railway transport.

At creation of aggregates type-dimension row, based on direct co-operation of air-gas environments principles of cascade type it is expedient to use a mine-out criterion on the stages of losses prognostication in structural elements.

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ОЦЕНКА ЭФФЕКТИВНОСТИ КАСКАДНЫХ
ЭНЕРГЕТИЧЕСКИХ УСТАНОВОК
ЛОКОМОТИВОВ

Юрий Сторчеус, Олег Воронов, Александр Ковтун

Аннотация. Приведен подход к определению эффективности энергетических установок каскадного типа для железнодорожного транспорта. Представлена взаимосвязь различных коэффициентов полезного действия, используемых при определении энергетической эффективности каскадных энергоустановок. Оценена эффективность трансформатора энергии компрессорного типа.

Ключевые слова: каскадные энергетические установки, обменник давления, массообмен, рекуперация, коэффициент полезного действия.

Technology and the tools of management of the potential of foreign economic activity of the enterprise

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Summary. The potential of foreign economic activity in the management system was analyzed and identified. The interconnection and relation between applied categories that identify potential of foreign economic activity of an enterprise was described. Theoretical-factor model of forming and development of foreign economic potential of an enterprise was proposed.

Key words: potential, management, foreign economic activity, enterprise, region, model.

factors and conditions of internal and foreign environment, opportunities, resources, capabilities and readiness to participate in foreign economic activity and international relations of a region, play an important role in the organization and management of foreign economic activity of a region.

INTRODUCTION

Intensification of globalization processes in the world makes a significant impact on all areas of activity in the world and the development of the world markets. By influencing the development of national economies and increasing the level of their interaction, globalization creates new tendencies of the development of the countries and regions conditioned by specific features, forms and levels of socialization of manufacturing and economic networks.

Besides, tendencies and opportunities for foreign economic activity of the regional enterprises, and factors influencing the strategy formulation and potential opportunities for its realization, define the development perspectives of national and regional economies, especially in the conditions of globalization, to the great extent.

RESEARCH OBJECT

Potential opportunities and the potential of foreign economic activity that is identified by the

RESEARCH RESULTS

Consideration of the issue of foreign economic activity potential is possible due to the evolution and expansion of the directions of foreign economic links of the regions and international economic relations in whole.

Until recently, foreign economic potential of an enterprise was exceptionally considered by leading scientists in the framework of terminological identification of export potential [2-5] as summation of opportunities for realization of export activity.

The activities related foreign economic activity had significantly broadened with the development of globalization and integration processes both on macro- and mesolevels, and, to some extent, they also influenced the development of foreign economic activity on the microlevel.

In whole, potential of foreign economic activity is the ability of an enterprise to produce competitive goods, create and strengthen competitive advantages, and to effectively participate in various forms of international cooperation on the basement of this activity. The

extent of using this potential defines competitive positions of an enterprise [1, 7-9].

Considering this category from the perspective of an economic object, identification and utilization of potential of foreign economic activity of a region should be taken into account. The potential of the foreign economic activity differs from the foreign economic potential of a region by the component that provides fulfillment of foreign economic links of a region and can be measured by a result concept, namely, by volume and outcomes of the regional foreign economic activity.

Besides, taking into account that the activity was mentioned, the potential suggests the ability and readiness of a region to widen interaction of its economic entities with international partners, and intensification of their foreign economic activity.

Hence, the potential of the foreign economic activity of regional enterprises can be identified as summation of potential opportunities, capabilities and resources of enterprises and a region in whole that allows fulfillment of the foreign economic activity, provides its development and widens its presence in the world markets, increasing its competitiveness by forming global and strategic

competitive advantages, and effective management of the foreign economic activity.

Taking into account the statements mentioned above, and interactions and relation between the concepts of “enterprise”, “activity”, “foreign economic activity”, “potential”, “foreign economic potential”, “potential of foreign economic activity of regional enterprises”, let us represent the sequence of their connection in the fig 1.

It is worth to mention that one of the most important features of potential and potential of foreign economic activity of the regional enterprises is its ability for development meaning appropriate managing qualitative and quantitative improvement towards certain goal [10-12].

Thus, according to the goals set by this research, effective utilization of the potential of foreign economic activity of the regional enterprises and provision of its development should not be considered as solely the opportunity for utilization of own resources and potential opportunities, but as resources, opportunities, and sources for the development of the foreign economic activity of a region.

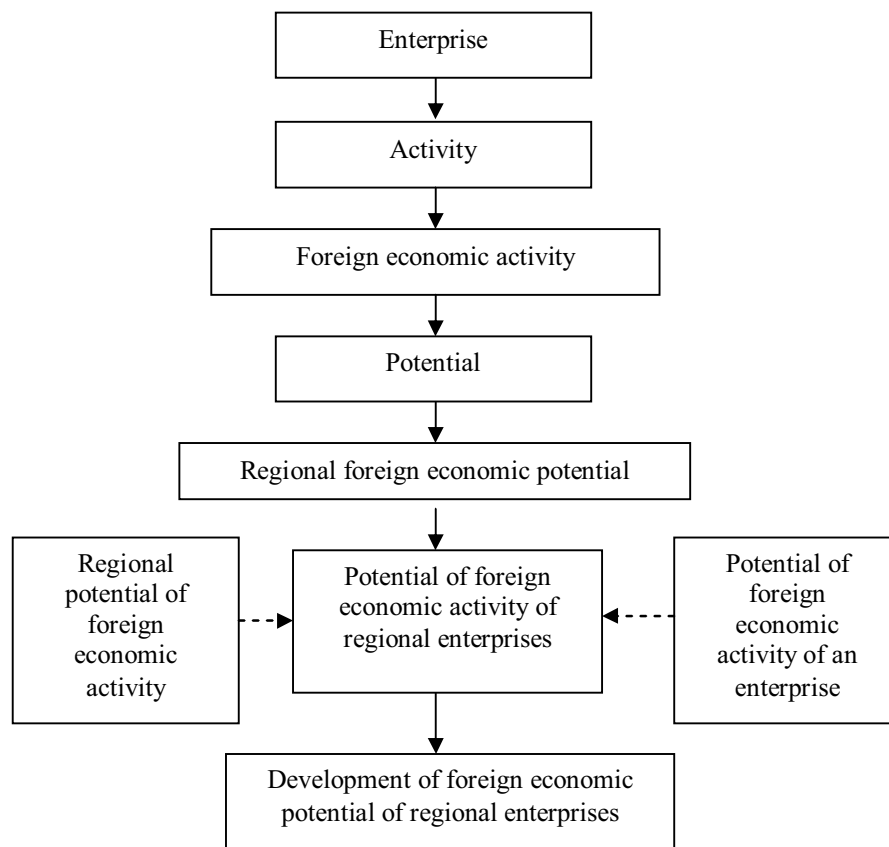


Fig 1. Relation between applied categories “enterprise”, “activity”, “foreign economic activity”, “potential”, “regional foreign economic potential”, “potential of foreign economic activity”, “development of foreign economic potential”

The development of the potential of the foreign economic activity of an enterprise is an ongoing process since the end of this development means gradual and inevitable decrease and decay of potential of enterprise in whole, not only potential of the foreign economic activity. The development and gradual qualitative and quantitative changes in potential of foreign economic activity of an enterprise will lead to emerging of new characteristics, opportunities, and capabilities of the enterprise development, expansion to new markets, production of new assortment of goods for export, and the development of the new forms of foreign economic activity [15, 19, 20].

Assuredly, the development of the foreign economic activity will allow increasing the level of competitiveness of an enterprise, its resistance to global foreign environment, and adaptation to global challenges. It is worth to emphasize that the development and gradual increase in potential of foreign economic activity of regional enterprises must be the basement of realization of globally-oriented strategy of the development of the foreign economic activity of the regional enterprises and the strategy of managed intensification of their foreign economic activity.

Obviously, the development of the potential of the foreign economic activity of the regional enterprises must clearly respond to the directions of the development of their foreign economic activity providing symmetric coherent changes according to the goals and the tasks set. It also has to take into account all potential opportunities and resources of a region, influential factors on all strategic levels of implementation of the foreign economic activity and the principles of its management.

A number of influential factors that act on different levels and define managing principles should be taken into consideration when forming and developing the potential of the foreign economic activity of the regional enterprises. In whole, the researchers specify main groups of factors that identify directions and components of the foreign economic activity of an enterprise [1]:

potential of international market. First of all, this factor is characterized by volumes of potential sales by the export-oriented enterprises and by the indicators of pace changes in capacity of international market;

foreign economic policy of the export-oriented and import-oriented countries. This factor is characterized by the parameters of export and import barriers, legislation, and political factors;

competitive advantages of an enterprise that are identified by these factors and were formed in the country of origin reflect productivity of utilization of all types of resources. Productivity of utilization of resources is directly connected with reducing manufacturing expenditures from the one side, and with increase in adaptive characteristics of enterprise functioning from the other side;

a system that provides the opportunity of timely and adequate reflection of the situations that occur in the external market. This system includes scanning and monitoring of external market, and the forecasts;

a system of synchronization of all the departments of an enterprise that are linked to the fulfillment of export functions. This factor is specific for large complex export manufacturers. As a rule, fulfillment of export orders is connected with clear schedules of manufacturing, order forming, transportation, and timely delivery of export goods.

The factors described above make direct impact on forming and development of the potential of the foreign economic activity of the regional enterprises; identify its structure and main components. Besides, it is necessary to take into account the influential factors on each level and market type where an enterprise fulfills its foreign economic activity or plan to expand. The general theoretical-factor model of forming and development of the potential of foreign economic activity of the regional enterprises is represented in the fig 2.

Obviously, effectiveness of utilization of the potential of the foreign economic activity of the regional enterprises and the results of its development will identify the effectiveness and results of the foreign economic activity in whole, their competitive positions in the global environment, the level of competitive resistance, and, what is more important, widening of foreign economic operations of an enterprise and increase in level of their income and profitability [13, 14, 16-18].

One of the main tasks of the management of the potential of the foreign economic activity, except for the management of the potential, is the management of the potential development. It means that the management of the development of the potential of the foreign economic activity of the regional enterprises can be marked out as one of the main processes in managing potential. The tasks that are resolved in the framework of the managing processes mentioned above should be classified as follows:

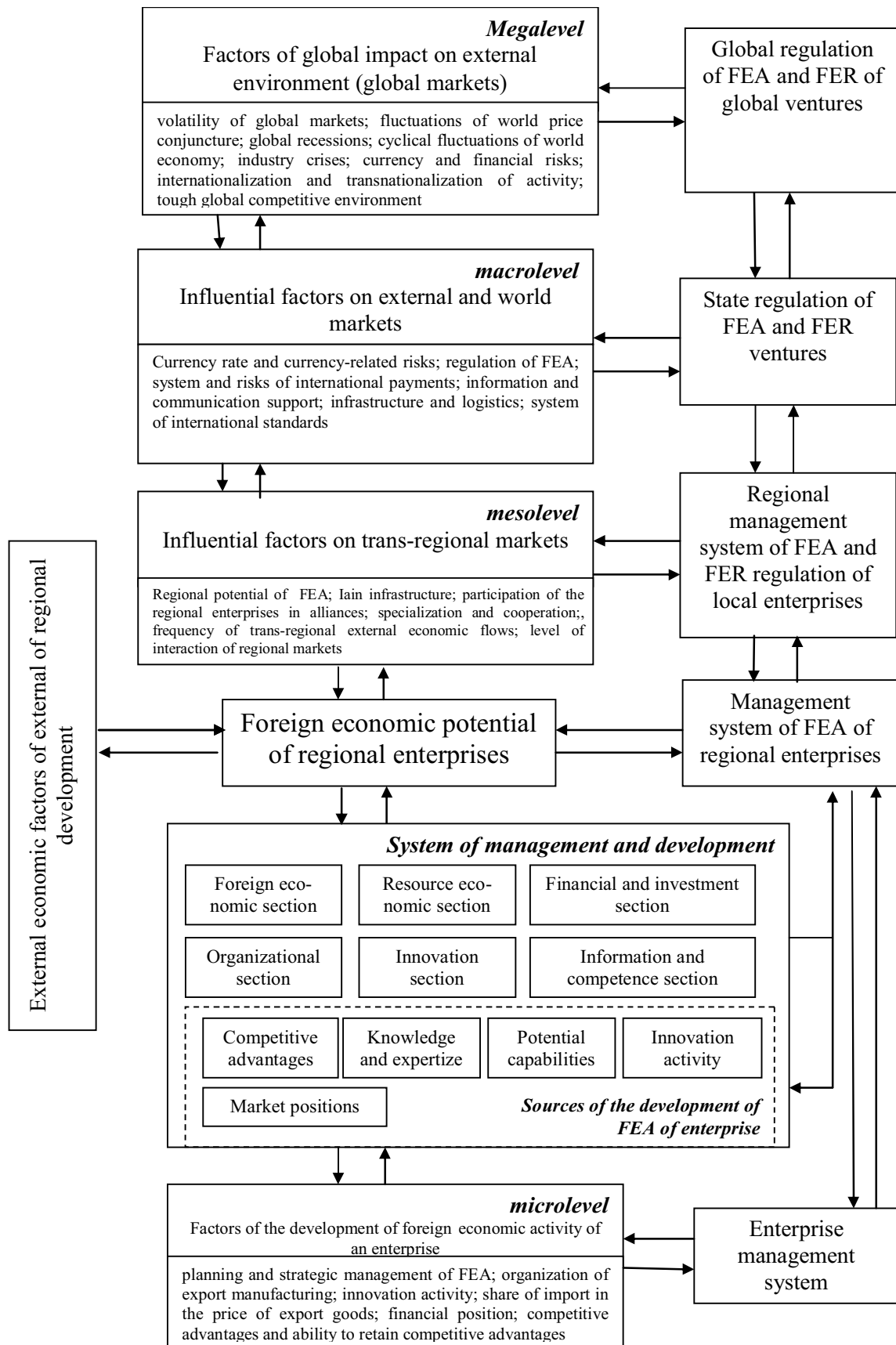


Fig 2. Theoretical-factor model of forming and development of foreign economic potential of enterprise activity

1. the tasks aimed at resolving the issues of overall management of the FEA potential in a region:

forming and renewing potential of the foreign economic activity of the regional enterprises suggests primary creation of the structure and identification of the elements of the potential or their renewal and modernization according to the goals set with regard to the development of the FEA;

the development and increase in potential of the foreign economic activity of the regional enterprises that suggests quantitative and qualitative improvement of its structure, elements, and transfunctional links;

effective utilization of the potential in the process of fulfillment of the foreign economic activity of the regional enterprises, its intensification and widening;

2. the tasks directed at resolving the issues related the management of the development of the potential of the foreign economic activity of the regional enterprises:

identification, analysis and evaluation of the main components of the potential, the extent of its utilization in the foreign economic activity;

planning of the development of the potential according to the directions and goals of the development of the foreign economic activity of an enterprise and a region;

goal-centered and well-managed development of the potential, change of its qualitative and quantitative characteristics by implementation of appropriate transformations, especially transforming potential opportunities of an enterprise into its global and strategic competitive advantages in the external markets;

creating of growth reserves for further development of potential of the foreign economic activity of an enterprise;

monitoring of changes and its correcting according to the development goals set.

CONCLUSIONS

The development of foreign economic activity of the regional enterprises, maintenance of their presence, and strengthening their presence in international markets is identified by their potential related foreign economic activity and the degree of its utilization to a large extent.

Obviously, the extent of utilization of the potential depends not only on the enterprise, but multiple external and internal conditions

influencing enterprise activity and opportunity to fulfill its foreign economic activity.

Assessment of the potential of foreign economic activity and the extent of its utilization should be fulfilled on the basement of implementation of a number of indicators that allow identifying different aspects of its utilization in the foreign economic activity. Managerial decisions related foreign economic activity can be made on the basement of this assessment in order to define opportunities for the development of potential of foreign economic activity of regional enterprises.

Moreover, the activities that were identified are one of the stages of the management process of potential of foreign economic activity of the regional enterprises as an important component of its management.

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ТЕХНОЛОГИЯ И ИНСТРУМЕНТАРИЙ УПРАВЛЕНИЯ ПОТЕНЦИАЛОМ ВНЕШНЕЭКОНОМИЧЕСКОЙ ДЕЯТЕЛЬНОСТИ ПРЕДПРИЯТИЯ

Елена Сущенко

Аннотация. Проанализирован и определен потенциал внешнеэкономической деятельности предприятий региона в системе ее управления. Предложена последовательность связи и соотношения между предметно-прикладными категориями, определяющими потенциал внешнеэкономической деятельности предприятия. Разработана теоретико-факторная модель формирования и развития потенциала внешнеэкономической деятельности предприятия.
Ключевые слова: потенциал, управление, внешне-экономическая деятельность, предприятие, регион, модель

Operation of the road transport network in the presence of various options of freight shipping by automobile transport

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S u m m a r y. In the paper the features of the road transport network functioning in the presence of alternative variants of freight delivery to the consumer are reviewed. The regularities of changes in the state of the system in the long term perspective are specified, and the need of periodic restoration of the road surface in order to reduce operating costs across the entire transport system is shown.

K e y w o r d s. automobile, transport network, route, freight, information, probability.

INTRODUCTION

Freight delivery by road to costumers is widely practiced due to its advantages such as efficiency, flexibility, opportunity to strategically change the route and to provide the required delivery time [1, 2]. However, the process of operating motor vehicles is accompanied by their failures, and the need to carry out repair work, to restore their functionality [3-20]. The existing road networks allow to perform the freight delivery by different routes, the choice of which is made according to the road conditions in the presence of appropriate information. At the same time durability and operability of the road transport is associated with the state of the road surface and the conditions of its operation [21, 22].

Thus, while choosing the route of delivery the information component is extremely important, but in the technical literature there is no data on how on its basis to chose and evaluate the option of freight transportation and how such decisions affect the overall condition of the transport network in the medium and long term perspective.

OBJECT OF RESEARCH

The purpose of this paper is to analyze the characteristics of the road transport network operation in the presence of information about its current state, in the conditions of a possible choice of freight delivery route to the customers.

RESEARCH RESULTS

To solve the set problem, we consider the designed scheme shown on fig. 1. We suppose that from point C to point B the regular freight delivery by road is performed, with the traffic volumes Q [t / d].

Transportation of freight in the section between points A and B is possible in two ways. In this case, option 1 is characterized by the route length $L_1 = 100$ [km], and option 2, respectively, by the length $L_2 = 310$ [km] (fig. 1).

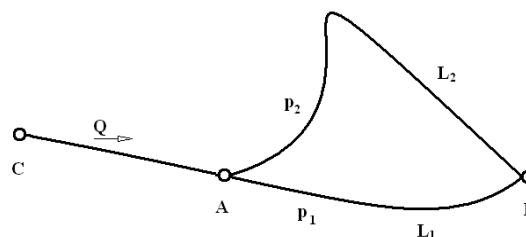


Fig. 1. Scheme of the possible routes of freight delivery

We assume that drivers have full information on the state of the routes and, basing on this data they make a choice of movement options. In this case option 1 will be selected with a probability p_1 , and option 2 with a probability p_2 . Obviously, the condition $p_1 + p_2 = 1$ is considered for the designed scheme.

Besides, we assume that the probability of choosing a particular route is proportional to the quality level of the roadway, and inversely proportional to the length of the route.

Then:

$$p_i = k \frac{A_i}{L_i} \quad (i=1, 2). \quad (1)$$

where: the proportionality coefficient k :

$$k = \frac{1}{\sum_{i=1}^2 \frac{A_i}{L_i}}.$$

In general, the indicator of the selected transport route roadbed can be defined as:

$$A = e^{-\alpha \mu},$$

where: α - the coefficient of proportionality;

μ - the number of damaged sections of the road for one kilometer length of the route, the presence of which leads to the need to brake and change the car speed limit [pc / km].

If $\mu = 0$, then $A = 1$ and the state of the selected route is considered to be the best. We suppose that μ_x - it's a coefficient of number of damaged areas on a kilometer length of the route, which reduces the possibility of its use in half, comparing with the best conditions.

After completing the necessary transformations, we obtain:

$$A = e^{\frac{\ln 0,5}{\mu_x} \cdot \mu}.$$

The fact that the road surface condition degrades over time, it influences the route selection and consequently the possibility of its use should also be considered.

Thus, analyzing the condition of the transport system, the possibility to change the value of μ over time should be considered.

We assume that the value of $\mu(t)$ in the result of the impact load flow q influence increases linearly with time. We assume that through the

period t_x the value of $\mu(t)$ increases on $\Delta\mu$ relatively to the starting level μ_H .

Then:

$$\mu(t) = \mu_H + \beta \cdot t \cdot q.$$

Or:

$$\mu(t) = \mu_H + \frac{\Delta\mu}{t_x q_x} \cdot t \cdot q.$$

where: q - the quantity of actually observed freight flow on the route under consideration [t / d];

q_x - conditional freight flow on the route [t / d], leading to increase of road surface damage in time t_x for the amount of $\Delta\mu$.

Then for the analyzed i -th route:

$$\mu_i(t) = \mu_{Hi} + \frac{\Delta\mu}{t_x q_x} Q \cdot p_i \cdot t.$$

The system of nonlinear equations (1) in this case will be:

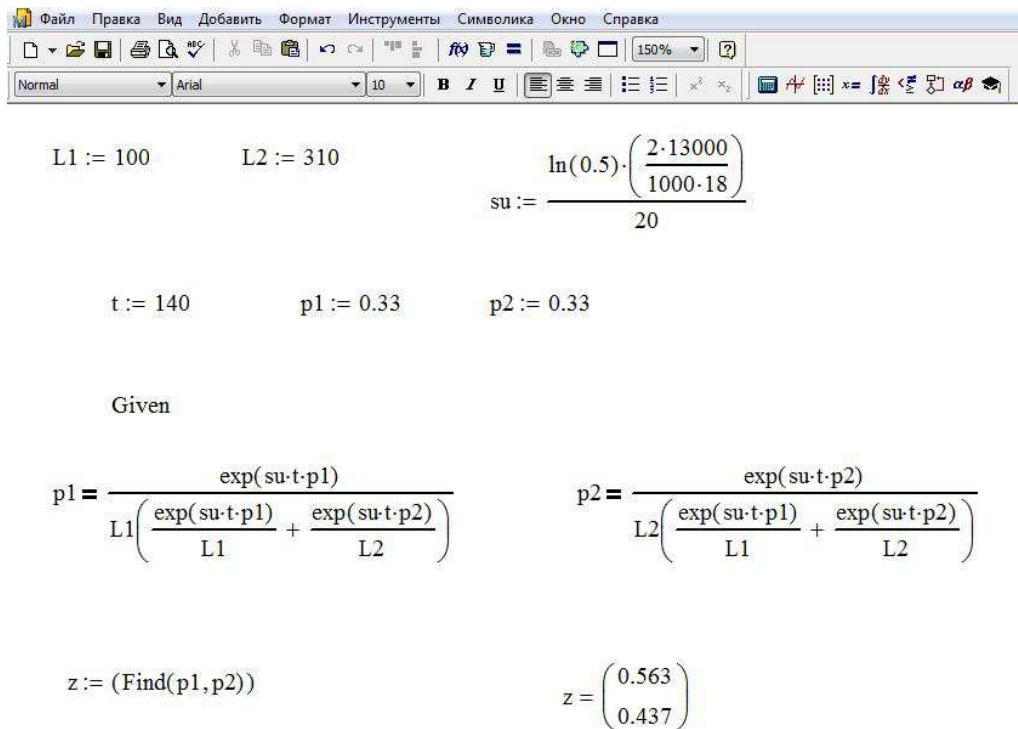
$$p_i = \frac{\exp \left\{ \frac{\ln(0,5)}{\mu_x} \cdot \left[\mu_{Hi} + \frac{\Delta\mu}{t_x \cdot q_x} Q \cdot p_i \cdot t \right] \right\}}{L_i \cdot \sum_{i=1}^2 \frac{\exp \left\{ \frac{\ln(0,5)}{\mu_x} \cdot \left[\mu_{Hi} + \frac{\Delta\mu}{t_x \cdot q_x} Q \cdot p_i \cdot t \right] \right\}}{L_i}} \quad (i=1, 2). \quad (2)$$

To identify the patterns of change in the state of the analyzed road network the equations system (2) was solved with the use of calculating system MathCAD for the assumed values of the parameters:

$\mu_{H1} = \mu_{H2} = \mu_{H3} = 0$ [km⁻¹]; $\mu_x = 20$ [km⁻¹]; $\Delta\mu = 2$ [km⁻¹]; $t_x = 1000$ [d], $q_x = 18$ [t/d]; $Q = 13000$ [T/d]. A fragment of calculating program is shown on fig. 2.

The results of solving the system of equations is presented in graphic form on fig. 3, and allows us to conclude the following.

At the initial stage of the system operation the first route is the most attractive, and it accounts over 75% of choices. However, due to the large freight flow the condition of the roadbed on this route gradually deteriorates and its attractiveness decreases. At the same time, with the time increases attractiveness (and therefore the selection probability) of the alternative route.



$L1 := 100$ $L2 := 310$ $su := \frac{\ln(0.5) \cdot \left(\frac{2 \cdot 13000}{1000 \cdot 18} \right)}{20}$

$t := 140$ $p1 := 0.33$ $p2 := 0.33$

Given

$$p1 = \frac{\exp(su \cdot t \cdot p1)}{L1 \left(\frac{\exp(su \cdot t \cdot p1)}{L1} + \frac{\exp(su \cdot t \cdot p2)}{L2} \right)}$$

$$p2 = \frac{\exp(su \cdot t \cdot p2)}{L2 \left(\frac{\exp(su \cdot t \cdot p1)}{L1} + \frac{\exp(su \cdot t \cdot p2)}{L2} \right)}$$

$$z := (\text{Find}(p1, p2))$$

$$z = \begin{pmatrix} 0.563 \\ 0.437 \end{pmatrix}$$

Fig. 2. A fragment of the calculating program to determine the probability

For this reason, the dependence of $p_1(t)$ is reduced continuously over time, and the dependence $p_2(t)$ increases, lining to a level $p_1(t) = p_2(t) = 0.5$.

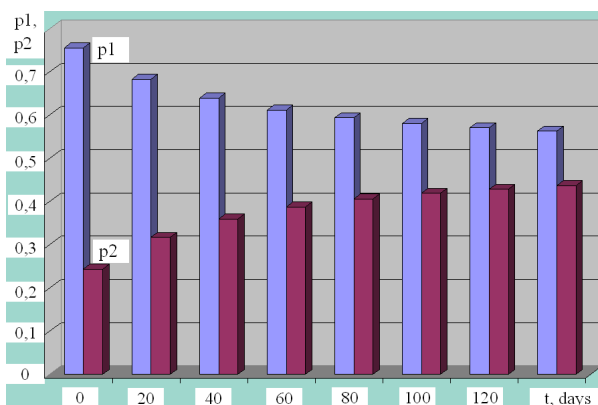


Fig. 3. Changing of the route usage probability in the analyzed transport system

Thus, in the extreme case, when the condition of the road surface for each of the possible routes is critically low, the appeal of all the options (and the probability of their usage) becomes even.

CONCLUSIONS

1. At the initial stage of the road transport system operation the shortest route is the most attractive. However, the state of the road surface on this route deteriorates over time due to the large cargo flow, and the probability of its use gradually reduces. This is accompanied by increase of the alternative route attractiveness and increase of the probability of its use.

2. The increase of the freight traffic volume on the detour route leads to an overall increase of operating costs in the scale of the analyzed transport system and can be seen as an objective factor which determines the need to perform repair work and restoration of the road surface.

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ФУНКЦИОНИРОВАНИЕ ДОРОЖНОЙ
ТРАНСПОРТНОЙ СЕТИ ПРИ НАЛИЧИИ
РАЗЛИЧНЫХ ВАРИАНТОВ ДОСТАВКИ ГРУЗОВ
АВТОМОБИЛЬНЫМ ТРАНСПОРТОМ

*Игорь Тарарычкин, Григорий Нечаев,
Максим Слободянюк.*

А н н о т а ц и я . Рассмотрены особенности функционирования автодорожной транспортной сети при наличии альтернативных вариантов доставки грузов потребителю. Установлены закономерности изменения состояния системы в долгосрочной перспективе и показана необходимость периодического восстановления состояния дорожного покрытия для снижения эксплуатационных затрат в масштабе всей транспортной системы.

К л ю ч е в ы е с л о в а : автомобиль, транспортная сеть, маршрут, грузы, информация, вероятность.

Ensuring the competitiveness of the enterprise on external market

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Summary. Ensuring the competitiveness of enterprises on the external market is the foundation of the enterprise's existence in the conditions of globalization. A possibility for a company to compete on the market directly depends on the competitive advantages and the set of economic methods of activity of the company affecting the results of the competition.

Key words: competitiveness, competitive advantages, TNC, enterprise.

INTRODUCTION

In a market economy, a crucial role for the success of the enterprise plays competitiveness, and the solution of the problems of ensuring the competitiveness on external markets today - the main thing in a number of main directions of development of the national economy. The problem of competitive advantage takes central place in the theory and practice of competitiveness, so as to survive and achieve their goals in a fierce competitive struggle every company must have certain advantages. Competitive advantages are necessary for the enterprise to build a mediated relationship with such a subject of the external environment as a competitor.

OBJECTS AND PROBLEMS

Analysis of the latest research. Today there is a great number of works devoted to the problem of ensuring the competitiveness of enterprises on the external market. In the works G.L.Azoev., L.G. Ramenska, R.A.Ratkutdinov,

A.Youdanova and a number of other authors some aspects of development of administrative and organizational-economic mechanisms of providing of competitiveness are considered. Issues on ensuring of competitiveness of the enterprise in the strategic aspect were covered in the works of V.Efremov, A.Savtugin, A.Yudanov and many others.

The aim of the article is the development of theoretical and methodological approaches of ensuring the competitiveness of business activities on the external market.

RESULTS OF INVESTIGATIONS

The modern stage of economic development is characterized by increased international competition, the transfer of the centre of gravity of the struggle between the companies from the national to the regional and international levels. Competition tends to strengthen both on the domestic market between domestic manufacturers and their foreign competitors, and foreign - between separate enterprises, functioning in the structure of the industries that are most effective in economic and technological terms. Competition is a delicate mixture of creative and adaptive actions of participants of the market game, is the cause of the long standardizing the behavior of economic entities, which is essential to the survival and conservation of the market position of the enterprise in the conditions of globalization.

Thus, on the one hand, the competition at any level is intended to serve for increase of

competitiveness and efficiency of economic entities, and on the other, in terms of the dominance of global monopolies, is an instrument of oppression of the weak participants stronger due to the incompatibility of fundamental interests.

Main features of this competition are [8]:

- The emergence and development of competitive relations in the integrated space.

- The emergence of new subjects of competition, in connection with this evolved the new levels - among civilizations and outwardly civilized.

- Changing ultimate goals of activity of the actors of the global economy, which leads to the orientation of the not for profit, and on the scale of the release of liquid resources to perform certain strategic objectives.

- Increased competition at all levels and the dominance of destructive component of global competition, sharply slows down the development of some countries.

- The need for coordination of control over the institutions of state power between representatives of transnational and national capital.

- The creation of integrated global industries by means of the vertical organization and diversification of production on the basis of the model of oligopoly.

- Increase of the role of TNCs in a competitive global struggle at the expense of intensification of the processes of mergers and acquisitions with the expansion of the range of financial instruments, methods and techniques.

- Transformation of TNCs in the global companies and ensure their competitive advantages on the basis of unique corporate strategies and synergistic opportunities for integrating local and global competition.

The company's entry to the world market must rely on its competitive advantages in international competition. Formation of competitive advantage is the process of ensuring competitiveness of the firm, in other words, is the process of capturing advantageous competitive positions using any parameters for assessing the condition of the enterprise [10].

Competitive advantages are concentrated demonstration of superiority over competitors in the economic, technical, organizational spheres of activity of the enterprise which can be measured by economic indicators (additional profit, higher profitability, market share, sales volume).

The interaction of the main characteristics, which provide competitiveness of the enterprise and competitive advantages shown in figure 1 [11].

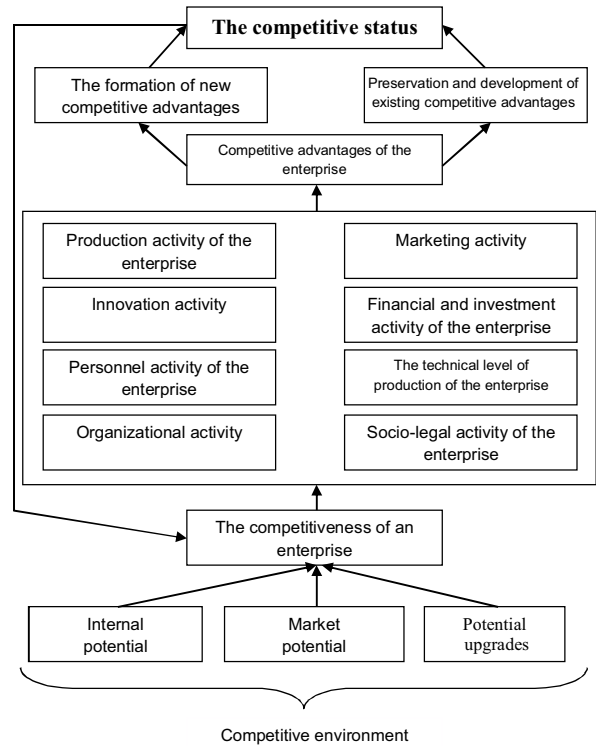


Fig. 1. The relationship of the main characteristics of the competitiveness of enterprises, competitive advantage and competitive status of the business entity

Thus, competitive advantage lies in forestalling of its competitors through the implementation of a significant (from the point of view of a particular industry) factors of the market and resource orientation, which may affect the long-term success of the enterprise.

Competitive advantages of the enterprise, sources of their origin, can be divided into internal and external. Internal are the characteristics of the internal aspects of the enterprise (level of costs, productivity, organization of processes, management system, etc) that exceed similar characteristics of priority competitors. External competitive advantages are based on the ability of the company to create more meaningful value for consumers of its products, creating opportunities better meet their needs, a decrease or increase of efficiency of their activity [12].

Organizational-economic mechanism of the formation of competitive advantages of enterprises is a subsystem of the General economic mechanism; the system of organizational, technological, economic leverage, and management practices which provide the competitiveness of the enterprise and sustainability of its development in the long term in the process of interaction and correlation.

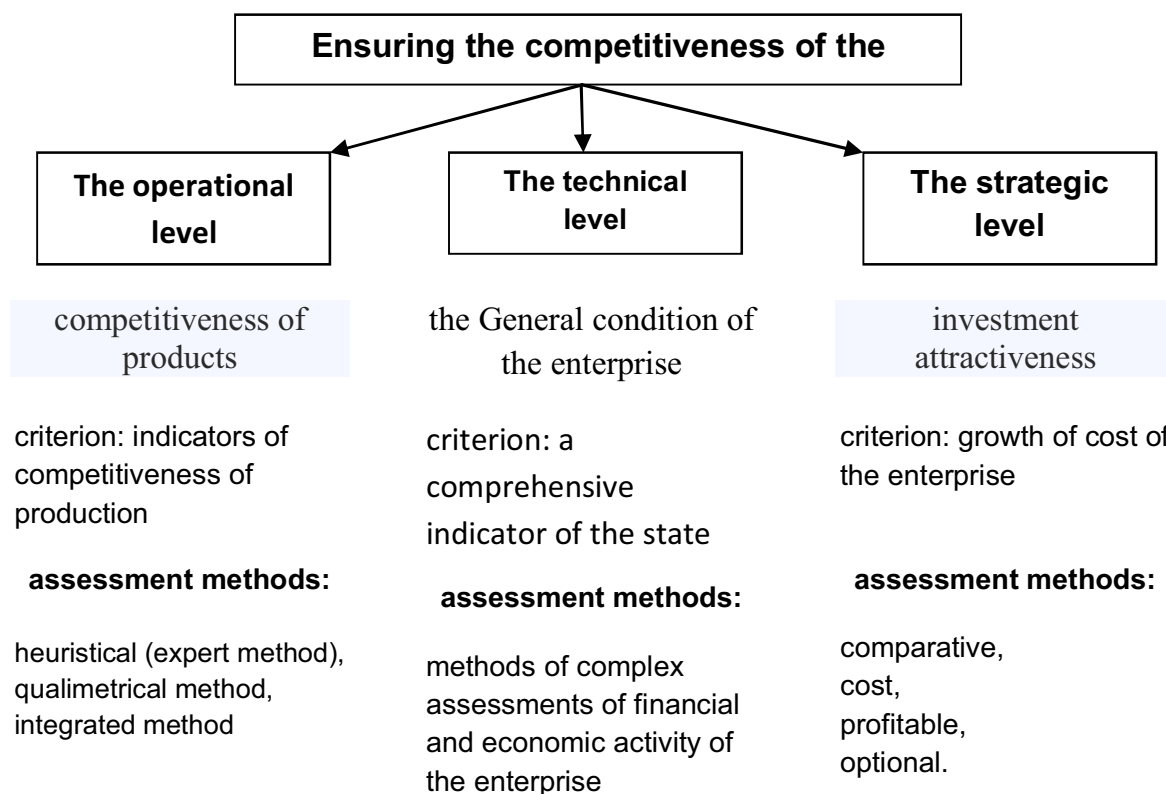


Fig. 2. Ensuring competitiveness of the enterprise at different levels [1]

Analyzing the key characteristics of a state enterprise and known approaches to the evaluation and improvement of its competitiveness, we can formulate the main principles of the concept of ensuring of the competitiveness of enterprises (fig. 2).

The task of ensuring competitiveness of the company includes providing of competitiveness of production and the actual enterprises on the domestic and foreign markets. This should highlight the different criteria of competitiveness of the company depending on the scope of planning and management. The main indicator of the competitiveness of enterprises at the operational level is an integral indicator of the competitiveness of products. At the tactical level of competitiveness of the enterprise ensuring its general financial and economic condition and is characterized by a comprehensive indicator of his condition. At the strategic level, the competitiveness of the enterprise is characterized investment attractiveness, the criteria of which is the growth of business value. Competitiveness of products is an important indicator of the competitiveness of enterprises because the production and sale of competitive products provide continuous cash flow. Estimation of

competitiveness of production is realized through 3 main methods: heuristic (expert.), qualimetric, integrational.

The sequence of the implementation of the system for ensuring competitiveness consists of the following stages:

- establishment of target orientation system and framework for its functioning;
- formation and analysis of the factors influencing the competitiveness and value of the enterprise;
- definition and decomposition of control levels (strategic, tactical and operational) specific goals, objects and criteria for the operation of system;
- development of basic indicators determining the effectiveness of functioning of system of each object and control level;
- forming of the composition of the objectives of the system;
- development of the functional structure of the system;
- establishment of algorithms and organizational regulations of formation of management actions and redistribution of resources during the change of indicators of activities of the system;

- development of information design, system interaction of competitiveness [5].

The purpose of the system creation is to increase the enterprise's competitiveness in external markets at the strategic level through the development of a mechanism of complex assessment of the validity of all management decisions with respect to their influence on the formation of competitive advantages.

CONCLUSIONS

A high level of competitiveness in the long term stipulate for obtaining, maintaining or freeze competitive advantages on the international market. At certain times of competitive advantages are supported by effective use of resources, strategic marketing orientation and powerful business potential of the enterprise. It is the totality of all material and non-material, financial, labor, intellectual, informational and moral assets of the company.

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ОБЕСПЕЧЕНИЕ КОНКУРЕНТОСПОСОБНОСТИ ПРЕДПРИНИМАТЕЛЬСКОЙ ДЕЯТЕЛЬНОСТИ НА ВНЕШНЕМ РЫНКЕ

Ирина Трунина

Аннотация. Обеспечение конкурентоспособности предпринимательской деятельности на внешнем рынке это основа существования предприятия в условиях глобализации. Возможность предприятия действовать на внешнем рынке на прямую зависит от наличия конкурентных преимуществ и набора экономических методов, влияющих на результаты конкурентоспособности.

Ключевые слова: конкурентоспособность, конкурентные преимущества, ТНК, предприятие.

Improvement of tribotechnical characteristics of the main engine's pairings at electrochemical-mechanical running-in

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Summary. One of the running-in processes is the electrochemical-mechanical running-in (ECMR). The processes of ECMR pass in the environment of electrolyte, which influences efficiency of process, mode of friction at running-in pair and speed of electrochemical reactions. The essence of ECMR consists of the following: working motion for details of mechanism is given, between details an electrolyte is pumping and cutoff alternating current. Due to joint electrochemical-mechanical influence there is a rapid adaptation of one surface to other. The most effective factor of ECMR is electrochemical, at which it is easy to electrochemical stripping of material from the run-in surface due to anodal dissolution at the hydrodynamic lubrication rate.
Key words: running-in, electrochemical-mechanical running-in (ECMR), engines, friction torque

INTRODUCTION

Running-in is a process of change geometry of surface of friction and physical and mechanical properties of upper layers of material in an initial period of friction, showing up at permanent external terms in diminishing of friction force, temperature and intensity of wear. A concept "geometry of friction surface" is plugged in itself micro-roughness of surface and form (macro-geometry) of detail [12]. Conformities to the law of process of running-in of the ground interfaces are most full studied depending on the roughness of surface [18]. A general conclusion is position about optimum micro-geometry of the running-in surfaces. During running-in the drastic alternations of characteristics of micro-relief of surface and

structure-phase state of upper layer are taking place (process of structural adaptation goes). After running-in termination there is an "even roughness of surface". As Kragel'skiy marks, it does not depend on a size and character of roughness of surface in the initial state [13]. The roughness of surface of detail (height, form and direction of micro-roughness) is rendered by influence on wear resistance only in the period of running-in. Duration of this period also depends from roughness. It is necessary optimum to count a roughness, near to «even roughness of surface ". But Valetov specifies on that talking about the real optimization of micro-geometry of surface is possible only in case if only one micro-relief of surface can describe the set value of criteria (criterion) of its estimation with possible unimportant rejections [19]. For sufficient self-reactance description of micro-geometry of the real surfaces, 3 to 25 criteria can be required. The standardized parameters of roughness of such description do not give and offered approach non-parametric to the estimation and control of micro-geometry of surface.

It follows from the formulated hypothesis of forming of roughness in the process of running-in flows out, that "even roughness " a roughness can be attainable, when surfaces of friction will be family of equidistant surfaces, and that is why the final running-in on a micro-level is possible only after macro-running-in of units [12, 13].

Unfortunately, macro-geometry of units of friction considerably differs from correct. In many cases space tapering of surfaces is broken. A roughness after tooling frequently falls short of optimum values. It results in higher specific pressures in the area of contact, to the direct contact of metal surfaces and, as a result of it, to the teasers, grasping and enhanceable wear of the running-in surfaces. Defects have an effect of increase of contact pressure on small area and further in more rapid tribological processes as compared to a contact without a defect. For example, by the result of the unlubricated contact of surface on a ring, in which warped steel on bronze, diminishing of the time of running-in with the increase of defect was marked. It talks about complication of flowing processes and necessity of further study of influence of defects on running-in of the grinding in surfaces.

For renewal of precision pairs, abrasive grinding in is used. At many positive moments, the abrasive grinding (polishing) has substantial failings. The conducted analysis allows exposing the following failings, related to the abrasive polishing of precision details: presence of technological contaminations; danger of caricaturing of abrasive particles in soft materials; disparity of roughness to the conditions of work; incomplete forming of actual area of spot of contact; negative gradient of mechanical properties on depth.

On this basis it is possible to conclude that the abrasive polishing does not allow to form necessary micro- and macro geometry, physical and mechanical properties that would allow shortening time of running-in and increasing quality of the recovered surfaces. In addition, a presence of technological contaminations is reason of enhance able wear of connections and decline of their technical and economical indexes of hydraulic aggregates.

Therefore the details of connections of machines must not be exposed to abrasive grinding in. One possible type of grinding in, there is the chemical– mechanical planarization (CMP) [3-10, 14, 16]. ECMP found a wide use as method of clean (final) grinding-in of details, workings in the conditions of friction, mechanical loadings, corrosions because this process is related to the change of micro roughness and physical and chemical state of surface. The electrochemical polishing provides the best friction properties of the ground pair, by comparison to the mechanical polishing; it is confirmed by a number of researchers.

ECMP requires application of special equipment (adaptation, instrument), exact maintenance of the mode of electrolysis, control and adjustment of solution, temperature condition of work of bath, careful cleaning of surfaces of details before treatment (chemical treatment is in organic solvents, electrochemical depriving of fat). For intensification of process, the electrochemical polishing must be conducted in a running electrolyte, and it requires more advanced equipment, than stationary baths. In addition, this method does not allow correcting macro geometrical defects.

One direction in polishing and reduction of time of running-in is a key-in of electric current directly through connections of details, part the layer of electrolyte which is give working motion. The electrochemical-mechanical running-in (ECMR) method is used for running-in of basic units of engines and is one of perspective directions in research [1].

Application of the electrochemical - mechanical running-in has a number of substantial advantages before other types of final grinding in. Unlike the abrasive polishing in ECMR formation, abrasive particles are fully eliminated as products of wear. Affecting material is made by imposition of current on an environment and details and takes a place at ionic level. As a result, products of output are in an environment as atoms and molecules. As well as at the electrochemical polishing, at ECMR there is a removal of internal tensions both in micro- and macro-volume of surface of material. ECMR allows making the local output of metal, but the surface passivation, characteristic for electrochemical process, absent here. In addition, ECMR provides joint running-in of details without application of the special instruments unlike abrasive and electrochemical processes, due to it there is rapid structural, micro- and macro-geometrical adaptation of the surfaces under friction.

Present efficiency of ECMR is enhanceable due to additions of oleic acid in an electrolyte. It enabled considerably to improve tribotechnical characteristics of the running-in surfaces at the different types of friction. Further research must be directed on opening of mechanism of forming of running-in surfaces of details of basic machines' units on the different types of friction.

A research object is choosing the process of the electrochemical - mechanical running-in of surfaces of details of basic machines' units. The most ground surfaces at ECMR pass three basic stages of running-in process. Knowing that the

Sommerfeld criterion which is evened $Sm = 10^{-5}$ corresponds transient regime of friction, easily to set the change of types of lubrication at running-in surfaces. In an initial period of time there is mechanical elimination or driving back of plastic materials, forming an initial area of contact (I stage). With its growth, a transition is possible from a semiliquid friction to hydrodynamic (II stage), and at the hydrodynamic regime of friction the spot of contact is finally formed in examined tribosystem (III stage).

Examining factors, influencing on a friction resistance and intensity of output of material, it is possible to see at ECMR, that on an intensity of wear influence: form of area of contact, type of friction, properties of the surfaces and factors of external influence. Obviously, that flowing process of running-in of the surfaces depends on initial geometry of surfaces. At ECMR tribotechnical characteristics of the running-in surfaces at the different types of friction are improved. Thus the change of surfaces takes place on all of three stages of running-in that is impossible at ordinary methods, being based on a mechanical wear or creation on the grinding surfaces of different type of tapes. Surface forming at ECMR takes place due to electrochemical and mechanical influence. Influence of different factors allows forming top surface relief of roughness of surfaces. The mechanical strengthening is instrumental in the etching of tops of ledges, and the presence of superficial tapes and gasification is diminished by creation of cavities.

OBJECTS AND PROBLEMS

The aim of this paper was to study the influence of electrochemical mechanical running-in to change the nature of friction and wear in a pair of friction with reciprocating characteristic of the piston-liner interface, working in conditions with distortions of their axes. Changes in friction, temperature and rate of wear are commonly observed shortly after the start of sliding contact between fresh, unworm solid surfaces [2]. The studies were conducted on a model representing the slider-crank mechanism that mimics the friction pair of cylinder-piston sleeve. The design system is shown in Fig. 1(a). Installation was mounted on the friction machine. Drive installation from the shaft friction machine. The effects of the friction in the slide were estimated friction torque, taken from the machine shaft potentiometer included with the machine. Friction torque

recorded on graph paper plotter N 306. For the initial (zero) value of the frictional moment taken its value corresponding to the time of friction with the shaft of the machine impaled on it without a crank rod. Assessing the friction and wear of the slide were performed on samples-rings, to strengthen it from both sides (Fig. 1(b)). Two rings made of aluminum (outer diameter of 42 mm and a width of 11 mm) are pushed on slider. Frictional resistance created by these rings and the amount of wear and tear are estimated.

The moment of friction and wear rings were determined at different skew axis slide and barrel. Skewed axes provides a turn of the stage in the horizontal plane perpendicular to the plane of the swing rod, using a micrometer screw (Fig. 1(a)). For the initial value of the distortion, value was taken within the clearance between the piston and the sleeve length in mm/100 mm piston ($\Delta n = 0.19$ mm/100 mm length).

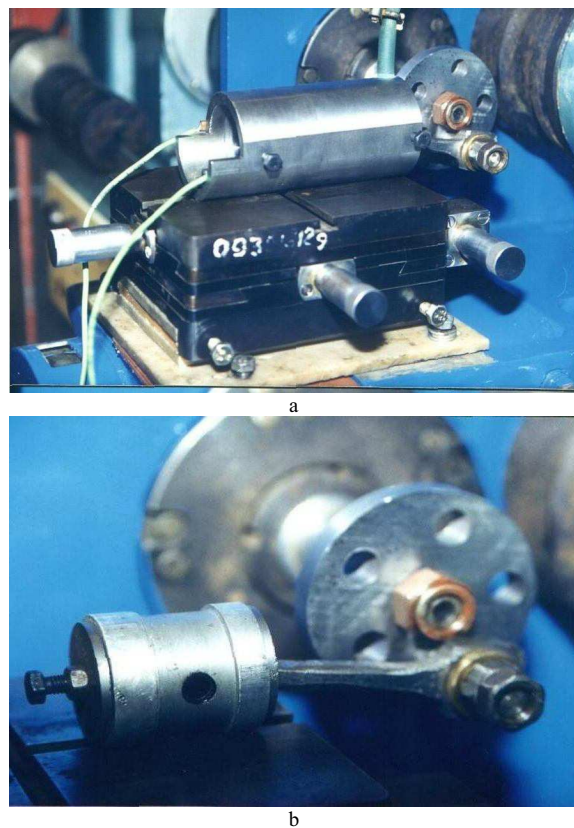


Fig. 1. Device for study the effect of piston warps to ECMR of slider-liner pairing (a) and the slider with two rings (b)

Before the experiment the ring was cleaned, thoroughly washed, dried, weighed on an analytical balance WA-31 with an accuracy of 0.1 mg, and then mounted on a slide. The slide was collected from the liner. Slider joint movements were performed with sleeve liner along its axis

together with the stage. An electrolyte was given in the area of friction. An alternative current (AC) was connected to the piston (slider) and liner (fig. 1(a)). For comparison, experiments were carried out under the same conditions, but without current flow between the friction surfaces.

In the latter case, the experiments showed that the time fixed by friction during operation without connecting current slide significantly depended on the tilt axis of slide and liner. The corresponding value of the friction torque was achieved almost immediately after starting the device for study the effect of piston warps to ECMR of slider-liner pairing and did not undergo further changes (fig. 2).

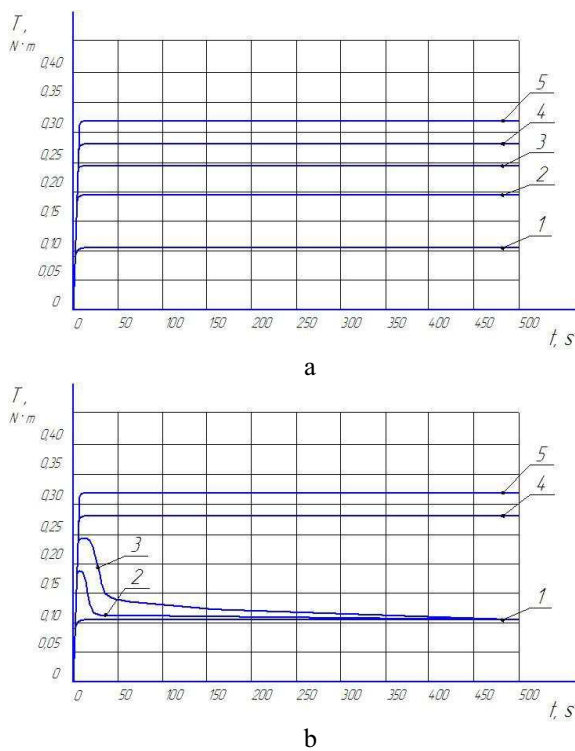


Fig. 2. The change in the friction torque versus time during running by the standard method (a) and with ECMR (b): 1,2,3,4,5 - for piston misalignments 0; 0.38; 0.76; 1.14; 1.52 mm to 100 mm in length

The friction torque is increased with increasing bias. Changing the friction torque in time in connection with the current pair had a different character with a small warp (0.38 and 0.76 mm/100 mm of long slide). As in the previous case, immediately after the start time, friction increased sharply and then decreased at these distortions to patterns shown in the diagram. However, during the experiment, the friction torque is not reached the value corresponding to a zero skew. The greater difference the greater the resulting distortion was observed. When distortions

1.14; 1.52 mm, length 100 mm (curves 4 and 5, fig.2(a)) decreased friction torque was observed. Pattern is similar to that observed in friction without current.

Character study of wear patterns energized and de-energized showed that more wear rings occurred in the experiments with the passage of current. This indicates that the action of the electrochemical process increases the material removal from rings, the removal increased with increasing bias to a greater extent than those without current. This phenomenon provides for a fast burn-rings to the sleeve, which leads to a decrease in the friction torque. The passing current through the bearing surfaces provided them quickly (within 4 minutes) macro running-in.

Changing the friction torque in time it is possible to explain of high speed of diminishing of macro-geometrical error of form of detail at ECMR.

It is known that the basic pair of friction of machines has different character of the mutual moving. The tribounits of piston-cylinder group are working at crank motion (fig. 3), and the sliding bearing – at rotator movement (fig. 4). Obviously in first case, speed of the mutual moving of details changes from zero to the maximum speed, determined the structural parameters of knot and frequency of rotation of crankshaft. In the second - speed depends only on frequency of rotation and on the set modes is constant.

For analytical determination of the mode of friction, presence and thickness of electrolyte film between the ground details apply the criterion of Sommerfeld S_m [17] For running- in of details of type of piston-rings in the interfaces of rings-liner (with the recurrently-forward mutual moving) it is equal:

$$S_m = \frac{\mu \cdot V}{P \cdot b}, \quad (1)$$

where: μ - dynamic viscosity of lubricating material (electrolyte), MPa·s; V - moving speed of piston, m/s; P - pressure of ring to the cylinder face from forces of resiliency, MPa; b - height of ring, m.

Knowing that $S_m = 10^{-5}$ corresponds to the transient behavior of friction to set the change of types of lubrication at moving of piston. For a double piston movement the detail surfaces operate at the different modes of friction: limiting mode, transitional and hydrodynamic.

Following the hydrodynamic theory of lubricating the thickness of tape, dividing a ring and cylinder, is based on formula [18]:

$$h = \sqrt{S_m} \quad (2)$$

It is possible to assert that at the hydrodynamic lubricating of running-in surfaces an electrochemical reaction flows cleanly: a current passes through details, part the layer of electrolyte. Investigation of it is an etched surface during their anodal polarization with frequency of alternating current. The mode of limiting and transitional friction, besides other, is activating surfaces that strengthen the effect of electrochemical reaction at a liquid friction.

From fig. 3 and 4 it is evident, that any process macro running-in of two surfaces is possible to take to running-in of surface, inclined with the corner of defect γ , in relation to other one. For the running-in of sliding bearings, it is necessary to take into account frequency of rotation of shaft ω and presence of macro-geometrical rejections δ (fig. 3).

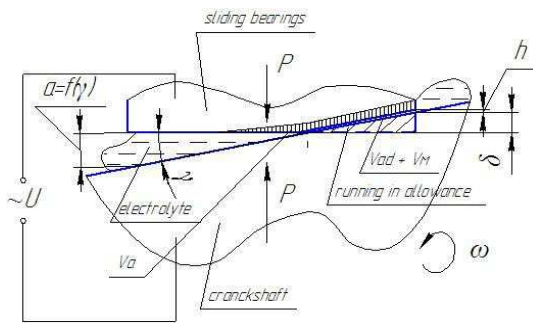


Fig. 3. Scheme of ECMR of details with rotation motion

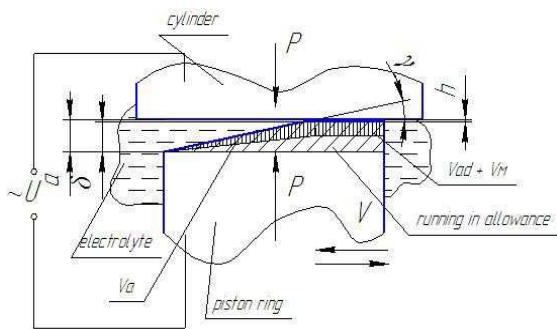


Fig. 4. Scheme of ECMR of details with reciprocal motion: δ – maximum size of a running-in allowance; V_a – electrochemical etching rate of material from detail surface on a gap; V_{ad} – electrochemical etching rate of material from detail surface at mechanical activation; s_m – mechanical wear rate from detail surface; h – radial electrode gap at fluid friction; γ – angle of obliquity of running-in surfaces; a – joint gap, dependent on γ

According to the hydrodynamic theory of friction, the thickness of tape between a shaft and journal bearing depends on frequency of rotation

of crankshaft. Except for it, important parameters are properties of lubricating environment and geometrical parameters of journal bearing. The laws of the hydrodynamic lubricating allow describing the minimum thickness of oily tape of the freely rotated crankshaft based on the formula:

$$h_{\min} = \frac{d^2 n \eta}{18,36 k S c}, \quad (3)$$

where: d – diameter of shaft, mm; n – frequency of rotation of shaft, min^{-1} ; η – dynamic viscosity of oil, Pa·s; k – loading on a shaft, Pa; S – gap, mm; c – amendment of Glyumbel.

By formula (3) it is possible to define the minimum thickness of electrolyte layer at ECMR in the area of direct contact of the running-in surfaces of shaft and bearing without the account of macro-geometrical rejections (fig.2).

To conduct error analysis, select factors, influencing on the change of size the error of form of detail $d\delta/dt$ and relation of speed of electrochemical output on an area with the depassivation of surface to speed of output on an area without a depassivation V_{ad}/V_a . Assume that material of detail on the area of the mechanical activating is taken off as micro-volumes of metal, then:

$$V_{\max} = \frac{d\delta_{\max}}{dt} = V_m + V_{elc} = V_m + V_{ad} - V_a, \quad (4)$$

where: V_m – speed of mechanical output; V_{elc} – speed of electrochemical output; V_{ad} – speed of anodal dissolution of metal with mechanical depassivations; V_a – speed of anodal dissolution of metal without mechanical depassivations.

It is possible to express constituent V_{ad} coming from laws Faraday and Ohm [15] taking into account the periodic breaking of anodal dissolution in the examined point of surface of ring because of pickoff at the mechanical activating (in the areas of limiting friction mode). By analogy with expression speed, output of metal will make on the area of anodal dissolution. After the calculation of the equation takes the form:

$$V_{\max} = V_m + 0,5(1-k_1) \frac{\chi \varepsilon}{\rho} \cdot (\eta_{bo} \cdot (U - \varphi_{ao} + \varphi_k)) \sqrt{h_{\min}^2 + (1-k_1) \frac{\chi \varepsilon}{\rho} \cdot \eta_{bo} \cdot (U - \varphi_{ao} + \varphi_k) \cdot t - \eta_b \cdot (U - \varphi_a + \varphi_k) \sqrt{(h_{\min}^2 + \delta)^2 + (1-k_1) \frac{\chi \varepsilon}{\rho} \cdot \eta_b \cdot (U - \varphi_a + \varphi_k) \cdot t}} \quad (5)$$

where: 0,5- coefficient, taking into account an alternating current; k_1 – coefficient, taking into account the limiting friction mode ($S_m < 10^{-5}$) in

general time of cycle (one turn of crankshaft); U - working voltage, V; φ_{ad} - anodal potential at mechanical activation, V; φ_k - cathode potential, V; η_{ad} - anodal current output at the mechanical activating, %; χ - specific conductivity of electrolyte, $\text{Om}^{-1}\cdot\text{cm}^{-1}$; ρ - density of material, g/cm^3 ; c - electrochemical equivalent of material of anode, $\text{g}/\text{A}\cdot\text{h}$; h - a radial gap in the area of liquid friction, cm, η_a - anodal current output, %; φ_a - anodal potential, B; δ - maximal size of running-in allowance, cm, t - time of ECMR process.

It is clear that speed of diminishing of running-in allowance depends, except for mechanical (V_m), geometrical (δ) and from electrochemical factors, such as specific conductivity χ , values of anodal potentials φ_{ad} , φ_a and outputs on a current η_{ad} , η_a . The mechanical activating is reduced by anodal potential, and confirmation that an anodal output on a current increases as a result of periodic mechanical influence, present in [11].

Thus, the choice of the modes of ECMR can be carried out on the basis of information about sizes φ_{ad} and φ_a , η_{ad} and η_a at the certain conditions of running-in. Diminishing coefficient k accelerates the running-in details. The coefficient k depends on the criterion of Sommerfeld S_m .

Thickness of layer h is the function of piston speed V also and dynamic viscosity μ , however an increase of h will result in the increase of transitional resistance of layer of electrolyte. It is concordantly Eq. [5] necessary for the increase of speed of running-in details, that size h it was minimum, but the terms of the hydrodynamic lubricating would be provided here. Decline of bearing strength of electrolyte, with the purpose of diminishing h , possibly due to gasification. At electrochemical-mechanical running-in electrolyte is filled gas bubbles due to electrochemical processes, flowing on the surfaces of pair of friction. It is known that gasification depends on current parameters. A gas stream with a liquid provides a high degree of compressibility that can be used for diminishing h in the process of running-in with the use of ECMR. Several gas bubbles will be useful in localization of process of anodal dissolution, which is widely used in many processes of electrochemical size treatment of details of machines.

The evident picture of terms of transition of one mode of friction f in other gives diagram of Gersi, in which the coefficient of friction is related

to the parameter $\mu V/P$. This parameter is named description of the bearing mode. On diagram line $S_m = 10^{-5}$, passing through the point of a minimum of coefficient of friction, divides the areas of friction at a liquid and other types of lubricating (Fig. 5).

As obvious from Fig. 5, diminishing of macro-geometrical form defection $d\delta/dt$ due to a mechanical wear V_m possibly only at the dry and limiting types of friction. Thus, than more surfaces is divided the layer of lubricating, the less than influence of mechanical wear on the process of improvement of macro-geometry of details surface. The mechanical factor is absents at a liquid friction.

Influence of electrochemical factor increases with the division of the running-in surfaces the layer of electrolyte (V_{ad} increases at a limiting friction). However, it is necessary to provide a minimum gap; because resistance of layer of electrolyte grows with its increase those results in deceleration of electrochemical reactions (V_a goes down at a liquid friction with growth of thickness of electrolyte layer). Experimental confirmation of improvement of tribotechnical descriptions of friction surfaces at ECMR is presented in [20, 21]. The use of this high-efficiency method of forming of surfaces of details allows considerably increasing their resource

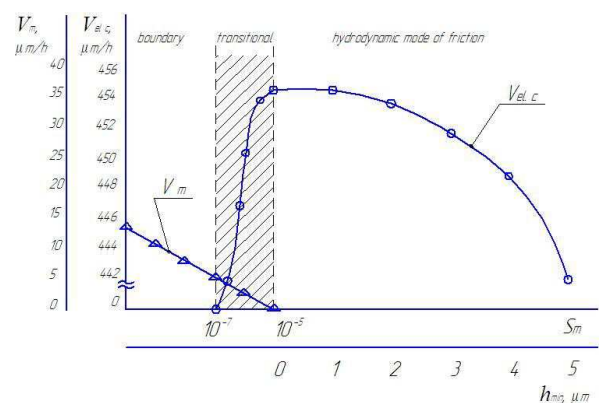


Fig. 5. Speed of diminishing of macro-geometrical error of form of detail at ECMR

Research of anodal output on a current η_{ad} in the pair of friction with the rotatory mutual moving present in [22].

Most intensively process of ECMR tribosystem shaft and journal bearing will be flows at outputs on a current η_{ad} near to 100%. Such values were observed at the closeness's of current less $1000\text{A}/\text{m}^2$. At the high-current density efficiency of process is minimal, a wear takes a

place due to a mechanical factor and an output on a current does not exceed 10%.

CONCLUSIONS

1. An alternating electric current on the friction surface coupling a piston-cylinder accelerates the running-in of the contact surfaces at the misalignment of their axes. With increasing tilt axis of piston and sleeve increases the friction torque.

2. Most of the wear rate of the samples at an alternating current leads to a decrease in the friction torque at the investigated distortions 0.38 and 0.76 mm, which to some extent eliminates misalignment axes to macro-geometry burnishing.

3. Biases of the piston and the cylinder axis of 1.14 and 1.52 mm did not provide running-surface even when applying current.

4. ECMR of the basic conjugations of engines is the high-efficiency process of running-in of the running-in surfaces: except for mechanical influence, characterized V_M , the process of running-in is accelerated due to electrochemical processes.

5. Macro running-in can be accelerated with the proper selection of optimum composition of electrolyte. It must possess low conductivity, passive properties, and also to provide the hydrodynamic mode of friction.

6. It is possible to control the processes of running-in due to the change of speed index are frequencies of crankshaft rotation and current parameters I and U . The mode of ECMR must provide a high output on a current η_{ad} and minimum gap h .

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УЛУЧШЕНИЕ ТРИБОТЕХНИЧЕСКИХ ХАРАКТЕРИСТИК ОСНОВНЫХ СОПРЯЖЕНИЙ ДВИГАТЕЛЯ ЭЛЕКТРОХИМИКО-МЕХАНИЧЕСКОЙ ПРИРАБОТКОЙ

Тарас Замота, Виктор Аулин

А н н о т а ц и я . Одним из способов приработки является электрохимико-механическая приработка (ЭХМП). ЭХМП осуществляется в среде электролита, который влияет на эффективность процесса, режим трения и скорость электрохимических реакций. Сущность ЭХМП следующая: деталям механизма придается рабочее движение, между ними прокачивается электролит и пропускается переменный электрический ток. Благодаря совместному электрохимико-механическому воздействию происходит быстрая приспособляемость одной поверхности к другой. Наиболее эффективным фактором является электрохимический, благодаря которому происходит стравливание металла поверхности при гидродинамическом режиме трения.

К л ю ч е в ы е с л о в а : электрохимико-механическая приработка, двигатели, момент трения

Research on water regime of the townsite Sutogan mine waste dump No1

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S u m m a r y . The paper presents the results of field studies of rock and soil-ground permeability to water of a typical Donbass waste dump on which emerged and developed strain. The analysis of the representativeness of the waste dump rock permeability to water data using conventional methods of statistical analysis was carried out. To further study of the patterns of change of waste dump rock hydrophysical properties the analysis of correlation with the physical and mechanical properties of rock and waste dump soil-ground was carried out.

Key words. Waste dump, permeability of water, granulometric composition, bulk rock density

INTRODUCTION

The waste dumps formed in the last century represent a significant threat now.

In the process of stacking, as well as after dumping rock into a dump, the array is moistened under the influence of rainfall, groundwater, and in some cases as a result of waste dumps artificial irrigation.

Permeability of water play an important role in both life of soils and in soil fertility maintaining. High drainage properties provide the absorption of moisture into the soil after heavy rains and melting of snow. However, excessive moistening of the debris may cause landslides and development of landslide strains of the rock complex [16].

Conversely, low filtration of the indurated horizon contributes to the formation of surface water run-off, erosion, formation of internal soil vadose water, water logging and unproductive moisture evaporation to the atmosphere.

OBJECTS AND PROBLEMS

The main research of patterns and development were carried out in the 60's and 80's. This research covers a wide range of factors that has an impact on the occurrence of waste dumps loss instability [4-6, 10, 13, 15, 16]. However, this research cannot be considered complete because it doesn't cover the full range of factors influencing this process. According to the authors [1, 13, 14, 16] rocks have different hydrogenous properties, depending on the different content of certain mechanical elements fractions that must be considered when carrying out the research of the causes and effects of deformation on the rock complexes.

Basically, rock hydration affects the angle of the rock slope. Basing on practical observations Baron L.I [2] found that the angle of rock slope increases up to a certain limit with the process of moistening of the material making up this slope, but with further increase in moisture content, the angle of the slope decreases. The similar conclusion is confirmed by the data of the UkrNIUgleobogaschenie Institute [16].

Thus, to get an idea about the influence of water permeability of rock and soil-ground of the waste dump it is necessary to examine the patterns of change of the water permeability in the different parts of the waste dump.

The aim of the research is to study the water permeability of rocks and soil-ground of the waste

dump under investigation, as well as the possible dependence of the water permeability on the bulk density and the structural composition of the rock.

For the research there was chosen the waste dump No. 1 of the townsite Sutogan mine, Lutuginskiy district, Lugansk region. According to the statistical data analysis of the coal mines waste dumps in Lugansk region, where the cases of deformation have been recorded, this waste dump is typical for Donbass.

The townsite Sutogan mine develops coal seams l_1 , l_6 , k_{3B} with seam thickness of 1.1-2.2 m, degree of dip - 5° (mining depth - 610 m), the mine produces coal of G-rank (gas coal). Today the waste dump is a truncated cone, 35-45 meters height. Operation of this waste dump was finished in the 70s. The reclamation of the waste dump under investigation was carried out during the 80s. Plants covering the waste dump slopes were artificially planted, except those that have been brought with a layer of fertile soil during the mine technical stage of reclamation. Currently the slopes and the flat top are mainly covered with acacia (*Robinia pseudoacacia*). Grass cover covering the waste dumps is not uniform and it is represented by typical steppe plants.

Rock mass is the argillaceous-carbonaceous mass of complex structural and mechanical composition. The bulk of the waste dump consists of sedimentary rocks fragments: mudstone, siltstone, silty and carbonaceous mudstone, clay and carbonaceous siltstones, sandstones, carbonaceous material, fragments of limestone and tonstein. Carbonaceous mudstones from the soil and rock layers of the roof contain the inclusions of iron sulfides (pyrite and marcasite), siderite nodules, grains of calcite and other minerals [8].

When rain falls on a dry surface, water permeability at the initial time play a decisive role in the process of absorption. Absorption continues until the interspace of soil is filled with water while the filtering - after filling it up and formation of a continuous liquid flow. However, in nature these two processes cannot be separated, so the concept of water permeability includes both processes. When rainfall intensity exceeds the intensity of absorption, water run-off takes place on the surface and the slopes are destructed by water erosion [17].

In addition, resulting from heavy precipitation, the risk of thermal landslides on the

burning waste dumps increases significantly. This is due to the fact that swelling under the influence of precipitation clay rocks fill the cavities between the fragments of sandstone, siltstone, mudstone, cementing them in a very solid crust which can withstand the pressure of vapor and gases resulting from the carbonaceous rocks combustion inside the waste dump [19].

To determine the water permeability the variable-head tubes method was used (according to N.A.Kachinskiy) [11]. The metal tubes, 8 cm in diameter, and 13 cm height, sharpened at the bottom, were set at a distance of 10-15 cm from each other on the pre-cleaned with a shovel and lined pad 50×50 . After that the water was poured into it with a special fuse that protects the surface of the soil in the tube from the breach. The filling and the weeping time was recorded as well as the water temperature and environment temperature. In the course of analysis the average drainage properties were determined after 1, 10, 30 and 60 minutes of studying, as it is known that water permeability vary in time and achieve the culminating point at the stage of water absorption, and the lowest point- at the stage of absorption stabilization.

Permeability of water are stated in mm w.g. (millimeter of water column) passing through a unit of area.

N.A.Kachinskiy scale was used to assess the water permeability of the soil-ground [11].

According to N.A.Kachinskiy [11] if the water column is 5mm high and the temperature is $+10^\circ\text{C}$, soil leaks over 1,000 mm per hour and water permeability are considered to be failed, from 1000 to 500 – too high, from 500 to 100 – excellent, from 100 to 70 – good, from 70 to 30 – satisfactory and less than 30 mm – unsatisfactory.

The data obtained in the course of study were divided into intervals and processed using statistical analysis methods [3]. The results obtained during the analysis are summarized in table 1.

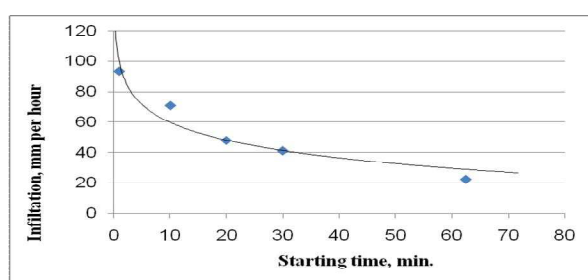
As the Table 1 shows, the maximum value of permeability was recorded in the first minute of observation, in the following minutes the rapid decline and further stabilization were recorded. The tightness of the connection between filtration time and the rate of permeability is confirmed by the determination coefficient value.

Table 1. Permeability of water test results

Area	Permeability of water mm per hour per unit time								Equation of dependence	Determination coefficient
	1	10	20	30	60	average				
						10	30	60		
Landslide body of the northern slope	468,8	273,0	217,1	156,0	86,6	386,3	275,6	233,4	Y = -92,2ln(x)+476,2	0,993
Landslide break line of the northern slope	93,6	71,1	48,2	41,3	22,6	61,0	45,2	25,0	Y=-16,9ln(x)+98,632	0,961
Landslide test area of the northern slope	340,6	119,9	83,6	59,9	27,0	323,9	132,9	116,2	Y=-20,1ln(x)+116,62	0,936
Landslide body of the southern slope	527,9	310,6	232,4	169,0	89,3	378,9	309,9	265,8	Y=-106,3ln(x)+537,8	0,993
Landslide test area of the southern slope	482,3	298,0	221,6	165,1	81,4	362,0	286,4	249,4	Y=-96,2ln(x)+495,82	0,986

Table 2. The results of statistical processing of the permeability of water results

Statistical ratios	Place of sampling				
	Landslide body of the southern slope	Landslide test area of the southern slope	Landslide body of the northern slope	Landslide break line of the northern slope	Landslide test area of the northern slope
Arithmetic average, mm per hour	378,87	362,01	386,26	61,00	323,98
Standard deviation	53,85	41,84	17,80	6,14	37,30
Variation coefficient, %	14,21	11,56	4,61	10,07	11,51
Absolute error	12,69	9,86	4,20	1,45	6,59
Relative error, %	3,35	2,72	1,09	2,37	2,04
Confidence interval	378,87±26,78	362,01±20,81	386,26± 8,85	61,00± 3,06	323,98± 13,45

**Fig. 1.** The dependence of the infiltration rate on the filtration time

The highest permeability values were recorded for the landslide zone part of the landslide body of the southern slope, the drainage properties of this area can be described as the best, and in the first minute – as too high. The minimum value of permeability is recorded for the landslide break

line area of the northern slope, it corresponds to 60 mm per hour and can be described as satisfactory.

The data uniformity was checked and statistical ratios for data sampling on each area were calculated for further analysis and data evaluation. Table 2 shows the basic statistical ratios, calculated for the water permeability values of the waste dump under study.

As the table 2 shows, the variation coefficient for the data sample does not exceed 13%, indicating high uniformity of the results obtained.

The analysis method using the Student's t-test was selected to check the data uniformity [18]. During the test all the probable erroneous elements and the elements which don't belong to the general population, have been extracted. Also, the guess and main hypothesis on accordance of the data

received to the normal distribution law have been put forward and tested [7]. It was found that the distribution of data in the test samples is close to normal.

Low filtering of the indurated horizon contributes to the formation of the runoff, erosion, formation of internal soil vadose water, waterlogging and unproductive moisture evaporation to the atmosphere. When rain falls on a dry surface water permeability at the initial time play a decisive role in the process of absorption. This process depends on the soil skeleton density, which is characterized by bulk density values.

Regression dependence equation was established with the help of Microsoft Excel [12]. The results of the correlation-regression analysis are shown in table 3.

Thus, as part of the study the degree of connection between the permeability of water and the bulk density was analyzed, and the existence of the strong connection was established, confirming the increase of permeability in the light ground and reduce of permeability in the compacted ground.

It is known that certain fractions have different effects on the soil and rocks properties. This is due to the different mineralogical and mechanical composition of the fractions, their physical and physico-chemical properties [9, 11, 20].

Macroaggregates about 0.25-10 mm, with high porosity (> 45%), mechanical and water stability are of the great agronomical value. In the course of the analysis the coefficient of structure (K) was determined, which means the content of aggregates of 0.25 - 10 mm (%). Thus, the larger the value of K, the better the soil structure. In order to establish the connection between drainage properties and physical-mechanical properties of soil, the correlation and regression analysis was conducted between the permeability value and structural and mechanical composition, for which was selected the soil pedality coefficient of structure of the soil.

Regression dependence equation was established with the help of Microsoft Excel [12]. The results of the correlation-regression analysis are shown in table 4.

Thus, the investigation analyzed the degree of connection between the coefficient of permeability and the coefficient of soil structure. The data obtained during correlation-regression analysis indicate the presence of correlation relationships between the studied parameters, but the analysis showed no evidence of sufficient correlation between these indicators, which gives the idea of the presence of a more complex and multiple connection between physical and mechanical properties.

Table 3. The results of the correlation-regression analysis

Exposure	Correlation ratio, η	Dependence equation
Landslide body of the southern slope	0,88	$Y = 80,563 x^{-0,710}$
Landslide test area of the southern slope	0,93	$Y = 45,395 x^{-0,608}$
Landslide body of the northern slope	0,55	$Y = 36,364 x^{-0,572}$
Landslide break line of the northern slope	0,89	$Y = 3,9843 x^{-0,218}$
Landslide test area of the northern slope	0,92	$Y = 89,39 x^{-0,749}$

Table 4. The results of the correlation-regression analysis

Exposure	Correlation ratio, R	Dependence equation
Landslide body of the southern slope	0,99	$Y = 2E-05x^3 - 0,0223x^2 + 7,5115x - 774,25$
Landslide test area of the southern slope	0,99	$Y = -2E-06x^3 + 0,0024x^2 - 0,9163x + 185,52$
Landslide body of the northern slope	0,97	$Y = 0,0004x^3 - 0,4071 x^2 + 155,15 x + 19630$
Landslide break line of the northern slope	0,99	$Y = -0,0034x^3 + 0,5843x^2 - 33,08 x + 678,99$
Landslide test area of the northern slope	0,99	$Y = 2E-06x^3 + 0,0025 x^2 + 0,8991x - 42,804$

CONCLUSIONS

Analysis of the waste dumps strain problem is of great current interest, as due to the low level of environmental activities funding, the harmful effects of waste dumps are not reduced.

The results of the study allow us to estimate the time history of water filtration at the time, which is important in estimating the impact of precipitation on water properties of the waste dump soil-ground. The waste dump slopes test area is more exposed to water erosion, as confirmed by the results of water permeability measurements.

To reduce the harmful effects of precipitation, which manifests itself in the form of erosion, as well as excessive moistening of rocks in some spots, it is necessary to control the water run-off from the top of the waste dump or to control its permeability of water by means of landscaping.

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ИССЛЕДОВАНИЕ ВОДНОГО РЕЖИМА
ПОРОДНОГО ОТВАЛА №1 ШАХТЫ
пос. СУТОГАН

Лилия Зубова, Юлия Макаришина

Аннотация. В статье приведены результаты полевых исследований водопроницаемости почвогрунта типичного для Донбасса породного отвала, на котором возникли и развиваются деформации. Произведен анализ репрезентативности полученных данных о водопроницаемости породы породного отвала с использованием общепринятых методов статистического анализа. Для дальнейшего изучения закономерностей изменения водно-физических свойств грунта породного отвала проведен анализ корреляционной связи с физико-механическими характеристиками породы и почвогрунта породного отвала.

Ключевые слова: породный отвал, водопроницаемость, гранулометрический состав, объемная плотность.

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