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MATERIAL AND MECHANICAL ENGINEERING TECHNOLOGY

Content

Optimal Directions of Digitalization Development

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Abstract: The proposed work is devoted to the issues of the active use of modern information technologies at metallurgical enterprises. The evolutionary process of the development of information technologies is considered, including the passage of several stages from the use of computers to individual metallurgical units to the introduction of automated process control systems and the use of corporate information systems. The practical significance of the work lies in the need for the active use of information technologies at metallurgical enterprises, as the it-solutions formed based on the transparency and manageability of the company, as well as increase the efficiency and competitiveness of the business. Basic IT solutions should be implemented in the field of planning, operational management, accounting, analysis and adjustment of plans. Thus, on the entire management cycle of metallurgical production.

Keywords: information technology, metallurgical enterprises, infrastructure, automation, IT solutions.

1. Introduction

Computer technologies in foundry are currently applied in one form or another at almost every industrial enterprise in Kazakhstan. Improperly designed casting technology leads to marriage, repeated correction of model equipment, excessive metal melting and, as a result, to a long development period for new products and higher cost of final products. The use of computer technology avoids many of the problems inherent in the traditional production cycle and, above all, significantly reduce the development and development time for the production of new cast parts.

When using computer technology, it is usually required to solve the following tasks:

- develop a drawing of the casting according to the drawing of the cast part, including in the form of a 3D model;
- to carry out modeling of the processes of filling the mold cavity and solidification of the casting with a melt for a specific casting method with technology optimization;
- design a mold or model equipment for the selected or specified casting method;
- calculate liquidus, solidus and other critical temperatures of multicomponent alloys; analyze nonequilibrium crystallization; to build polythermal and isothermal sections for multicomponent systems; calculate the phase composition.
- make a mold and model using rapid prototyping technologies (RP-technologies), work out the technology for traditional methods of manufacturing castings;
- to develop and manufacture casting equipment for the manufacture of molds and cores according to XTS-technologies;
- check the geometric dimensions and surfaces of castings (or parts) by optical digitization; including reverse engineering.

Each of these tasks is solved using computer programs and modern software-controlled installations.

CAD (CAD system) - Computer-aided design systems (more precise decoding - Design automation system) are widely used in many areas of mechanical engineering related to metalworking (Figure 1).

In general, CAD is a set of tools for solving the problems of technical preparation of production in various industries. The complex combines systems for engineering and technological design, modules for preparing control programs for CNC machines and engineering calculations. In the foundry, some CAD systems (SolrdWorks, NX, COMPASS T-Flex, and some others) are widely used.

The success of its manufacture largely depends on the correct calculation and design of the gate-feeding system in the casting. Therefore, the development of the mold is now impossible without the use of computer simulation programs for foundry processes.

Thus, using the forecasting system with the help of casting process simulation, incorporated in the casting process modeling programs, it is possible to improve the technology of casting production without spending significant financial resources on test castings.

Successful modeling of foundry processes is impossible without knowledge of the thermo physical and technological properties of casting materials and molds (Fig. 1).

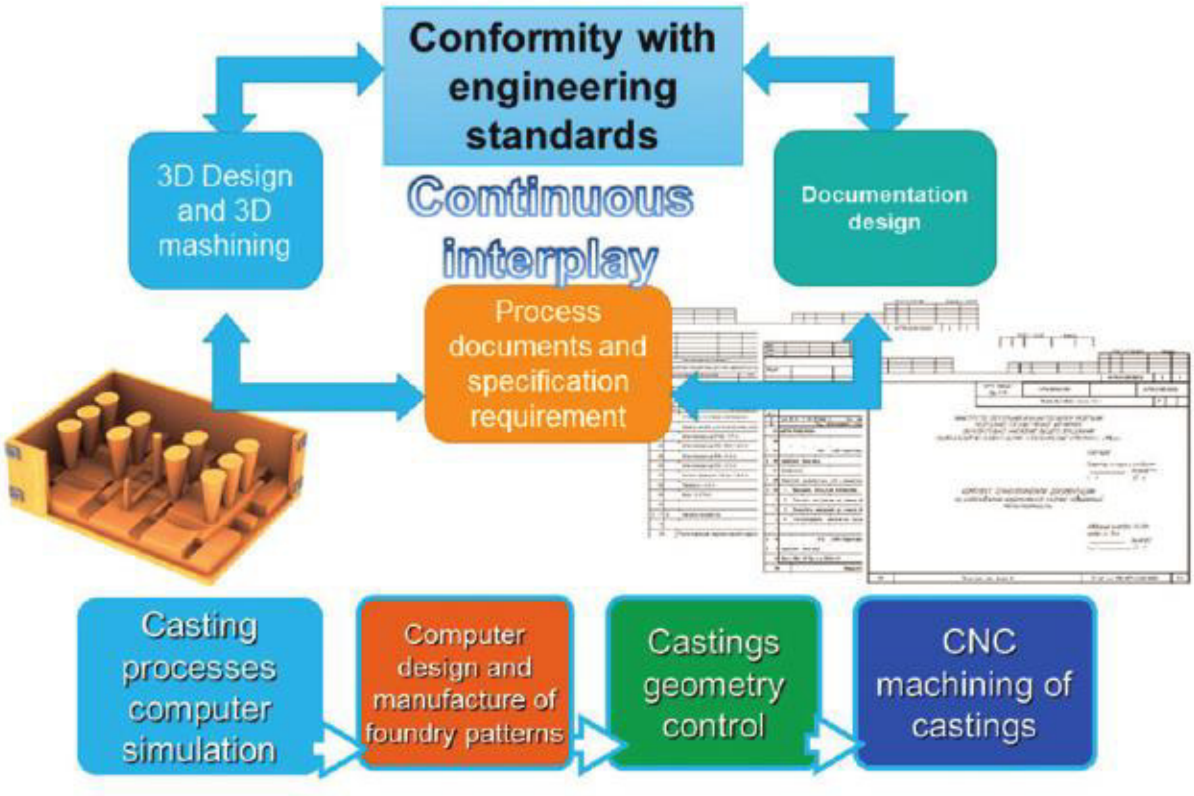

Fig.1. – The principles of foundry technology

However, in addition to the thermo physical properties of materials, in order to obtain adequate simulation results, it is necessary to determine a number of boundary conditions. One of the most important is the heat transfer coefficient between casting and mold. The value of the heat transfer coefficient is not constant and depends on many parameters. In this regard, the calculation of this parameter is very complicated, and it is usually determined experimentally.

Often, there is a lack of reliable experimental data on the thermo physical properties of the alloy and the mold material. Therefore, they often resort to computer modeling of these properties. To simulate the properties of alloys, the method of calculating phase diagrams is widely used. This method is called CALPHAD.

Using these programs, the Thermo-Calc program is used, which can significantly reduce time and material costs by optimizing experimental work because of thermodynamic prediction of the behavior of multicomponent systems.

It is important to note that the typical task of using such programs is the development of new cast alloys and the optimization of the composition of existing ones. Moreover, this is possible even if the reliability of the phase state diagrams for the alloy components does not exist (Fig. 2).

Modern technological development comes in all spheres of life - from the manufacturing sector to education. The industrial revolution of the 21st century, or Industry 4.0, makes us take a completely new look at the seemingly fundamental foundations. For the “classic” commodity mining companies, this is a fundamental challenge. Not overcoming, means losing their place in the world.

In the management of a metallurgical enterprise, important components are the analysis and planning of its activities. At the same time, the analysis process is combined with forecasting the progress of various business processes. They can be controlled, i.e. managed by the subject, or uncontrolled, on which he is not able to exert a sufficiently noticeable influence.

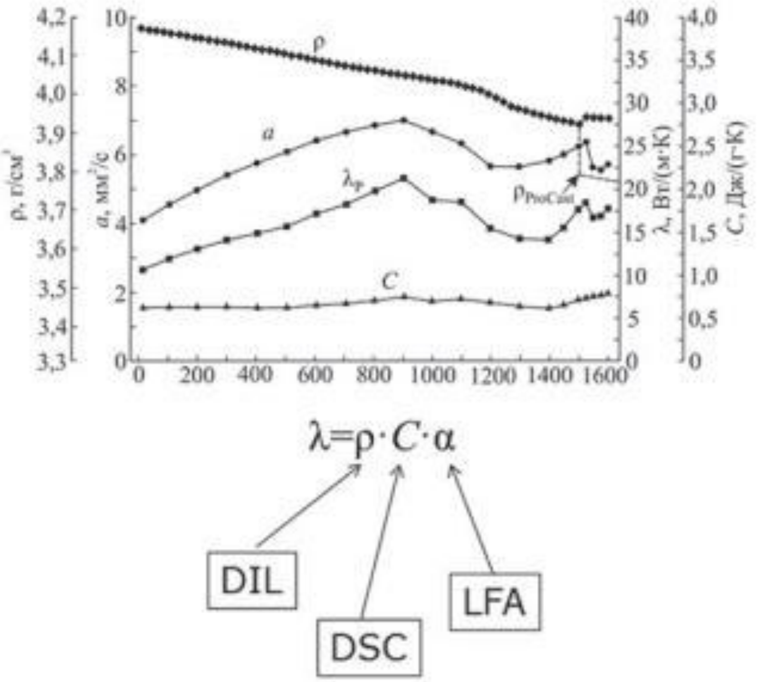

Fig. 2. – Thermophysical properties

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2. Purpose of the study

Kazakhmys Holding Ltd is the main natural resources mining and processing company, and the main copper producer in Kazakhstan. It consists of fourteen mines, 4 mining and processing plants, 2 copper smelters and 2 coal mines, which are located in 4 geographical points of Kazakhstan. Currently, the company is implementing a number of IT projects aimed at automating and digitalizing its production processes. Now the company has implemented IT projects based on Microsoft Dynamics 365 ERP to reduce costs, increase profit, increase asset productivity, automate business processes, and to increase the manageability and efficiency of the company, as well as the exclusion of manual processing of information. In the future, it is planned to equip all the products with RFID tags and introduce cloud data storage, which will consolidate the collection of information on the operation of equipment and maintenance, which will ultimately increase the reliability of work processes.

The classification of information technology depends on the classification criterion. A criterion can be an indicator or a set of features that affect the choice of a particular information technology. An example of such a criterion is the user interface (a set of techniques for interacting with a computer) implemented by the operating system.

IT is divided into two large groups: technologies with selective and full interactivity. IT with selective interactivity owns all technologies that provide information storage in a structured way. This includes banks and databases and knowledge, video text, teletext, the Internet, etc. These technologies operate in a selective interactive mode and significantly facilitate access to a huge amount of structured information. In this case, the user is only allowed to work with existing data without entering new ones [1].

3. Materials and methods of research

Nowadays the IT infrastructure of metallurgical enterprises boasts the same technology as, say, the production of air transport. At the same time, the level of automation grows and develops everywhere so that computers are no longer just technology for individual specialists, but an important component of the entire production process.

Optimal directions for the development of digitalization of IT communication:
- fault tolerant data transmission systems;
- establishment of technological IT standards;
- data mining and exploration surge;
- design of large data systems;
- BI and visualization;
- data storage and integration.

Digital transformation is becoming a global trend in the competitiveness of modern industries and the main driver of economic and industrial development. In the industrial market, the digitalization process is gaining more and more concrete outlines.

As a result, industrial enterprises have new tools to increase efficiency, reduce costs and achieve sustainable development goals. In the long term, financing digital technology segment will continue to grow, new solutions will appear on the market, including those using the capabilities of artificial intelligence.

After all, on the IT market, you can now choose any software for any type of activity, modify it a little, and go on to business victories. Metallurgy uses the Internet primarily as a way of communication. Digitalization will affect most of all several areas: monitoring (important data is quickly delivered to the head office for further processing); management quality (due to the fast communication channel, the head office can correctly allocate resources based on the specific situation). "In addition, the list contains an effective response in case of emergency: the safety of employees is the main priority of any enterprise. With the help of the possibility of online monitoring from the dispatch center, responsible persons can quickly contact people on the spot and vice versa, to build the most competent algorithm for solving any situation."

Access and input of information for managers and employees is carried out at a stationary workplace, as well as using mobile devices [2].

4. Research results

One of the main tools for this is information technology and integrated technological solutions for production.

As a result, today management of metallurgical enterprises pays special attention to the optimization of processes, the integration of quality control at various stages of production and the identification and elimination of losses in production processes. Investment into modernization of production, equipment upgrades and automation (Fig. 3).

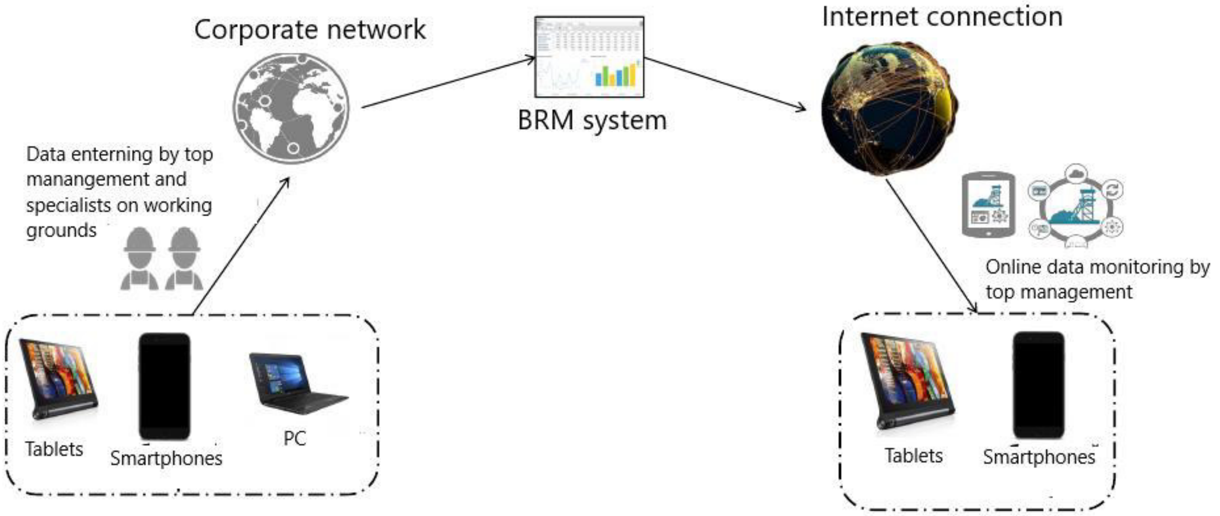

Fig. 3. – Data entering into the system

Moreover, the purchase of new cars instead of old ones, chaotically, will not bring any result. What is important is a system, a modernization strategy, which in the long run can provide higher production efficiency.

According to experts, metallurgy is one of the industry leaders in terms of the implementation of information technology. This development of IT in metallurgy is associated with investment activity in the industry, which stimulated the increase of financial transparency of the business for investors, manageability and cost optimization for management.

Most of the planned functions are already automated; various modules of CAD / CAM systems are actively used in the preparation and design of production processes [3]. Also, information technology is a source of data for statistical analysis, because it is a large amount of information for processing and making production and management decisions.

Of course, automation and various IT solutions should be accompanied by the development and implementation of a single work schedule. This allows you to maintain the unification of products, specifications and technologies, the integrity of information, the completeness and relevance of all information. Almost all departments and business processes depend on the proper management of a unified information base: planning, inventory management, production management, budget planning, costing, etc.

IT solutions for efficient production at most large metallurgical enterprises introduced ERP-systems (enterprise resource planning) [4].

The management of metallurgical companies came to understand the feasibility of working in a single integrated information system that combines the business units of holdings. Initially, many factories left old IT systems consisting of components from various integrators created in different periods. But in recent years, business processes have changed rapidly, and the tasks of the time have transformed. For example, enterprises are concerned with such an urgent problem as the effective management of costs and the value chain.

Over the past period, the company has implemented several important technical solutions to facilitate monitoring of the production process. These include the commissioning of ore-controlling stations (hereinafter - OCS).

Eight stations based on the X-ray fluorescence energy dispersive device RLP-21 manufactured in Kazakhstan are installed at three concentration plants and the Nurkazgan underground mine. Now, with their help, online monitoring of the current metal content in the ore and regulation of ore shipment is ensured online. After installation and commissioning of the OCS with the participation of DASUP specialists, pilot tests were carried out that did not reveal deviations.

In comparison with the previous technology of surface carriage testing of ore, including manual sampling, preparation and chemical analysis of samples, quality control of ore based on OCS provides a number of advantages. The efficiency of monitoring and accounting of ore raw materials has been increased, the time-consuming process of sampling, delivery and sample preparation to the place of chemical analysis has been eliminated, continuous analysis of the ore flow allows to obtain reliable results of a qualitative analysis of the content of elements in ore. In addition, the reaction time was minimized for prompt decision-making when changing the quality composition of ore raw materials [5].

The OCS operator has the opportunity to retrospectively review previous station readings. The software allows to automatically diagnosing the operation of the station with the status of the main devices displayed on the monitor.

To display the readings of the OCS instrument to users of the corporation and to consolidate with quantitative data the weighted accounting system of incoming ore, a software product “Monitoring ore content” was developed and implemented.

At the mining and processing enterprises of the company, the software package “Monitoring of the reading of the scales” was developed and implemented. This made it possible to automate the calculation and registration of ore movement through the conveyor scales of the Nurkazgan mine, the Nurkazgan and Karagailinsky concentration plants. Automated jobs have been created for weighing operators, and the influence of the human factor on the weighing result is minimal. The complex allows you to provide web-reports on the work of the scales to specialists of the corporation. For this, a single database of data storage using multilevel access systems has been formed [4].

Another important production project was implemented in the company based on the RAPID SCADA software package 6 [5]. Using the complex at the Karagailinsky enrichment factory, work was carried out to implement a data collection system from local control systems installed within the framework of the Modernization of Karagailinsky enrichment factory project. Now the operators of the main building of the factory have the ability to monitor the technological performance of mills, flotation machines of copper and zinc-pyrite flotation, as well as lime dosing units continuously in real time.

Using RAPID SCADA, a mimic diagram of the main technological equipment was introduced at the Zhezkazgan enrichment factory (Fig. 4). That is, the entire production process is visualized on the monitor screen. This allows you to optimize process control based on quality measurements, integrating control systems and circuits of individual plants, monitor the condition of factory equipment, including through real-time surveillance cameras, archive data and create reporting forms in the form of graphs. Thanks to this, the transfer of information to the Zhezkazgan enrichment factory departments has also been simplified, which allows faster decisions.

In addition, with the help of RAPID SCADA, images from CCTV cameras were displayed to monitor the situation in the areas in real time. Functionally video cameras are distributed in three directions [6]:

- control over the action of technological personnel;
- control regarding safety measures;
- control over the conduct of technological processes and the safety of inventory items.

The following is an example of a dashboard for monitoring qualitative and quantitative indicators, which is a business management tool, i.e. dashboard of business indicators.

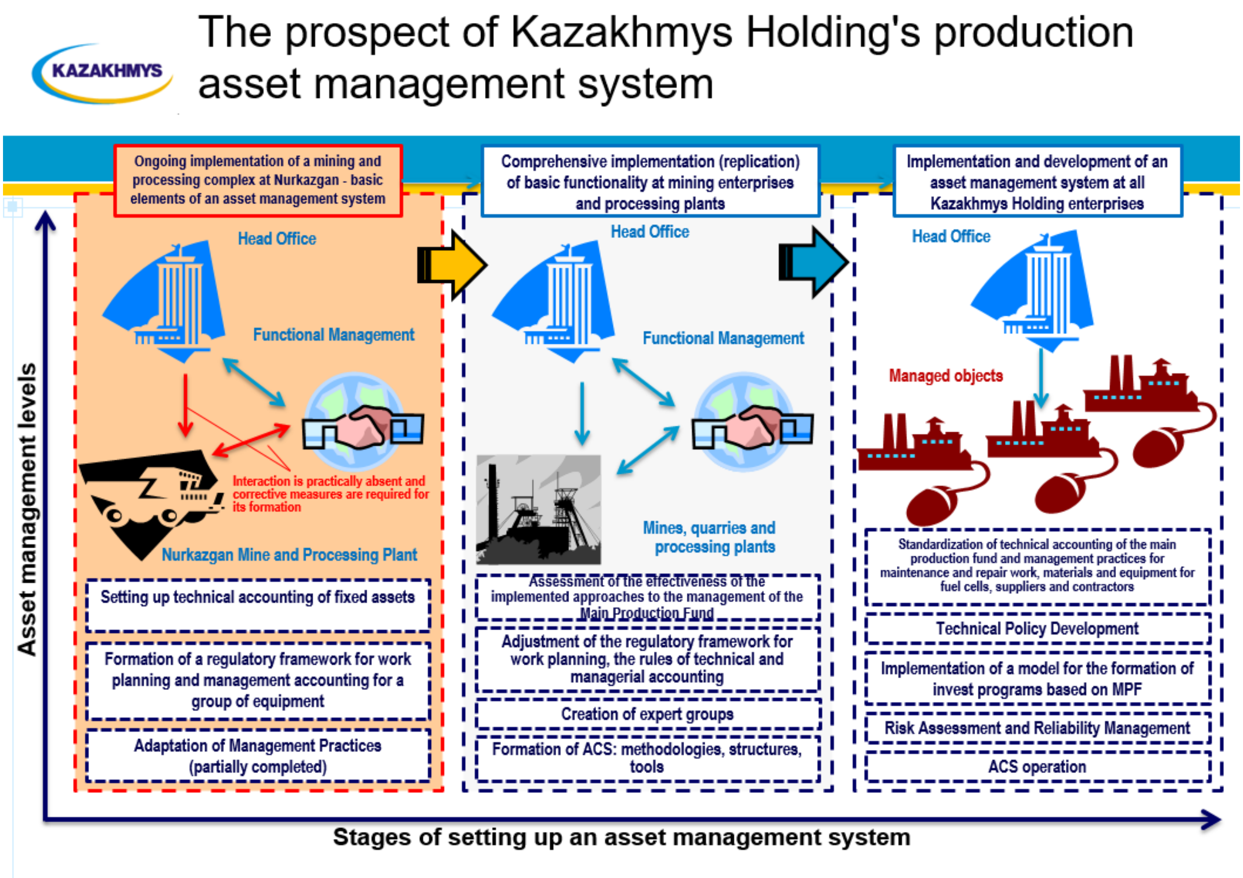

Fig.4 – Development of production asset management Kazakhmys Holding

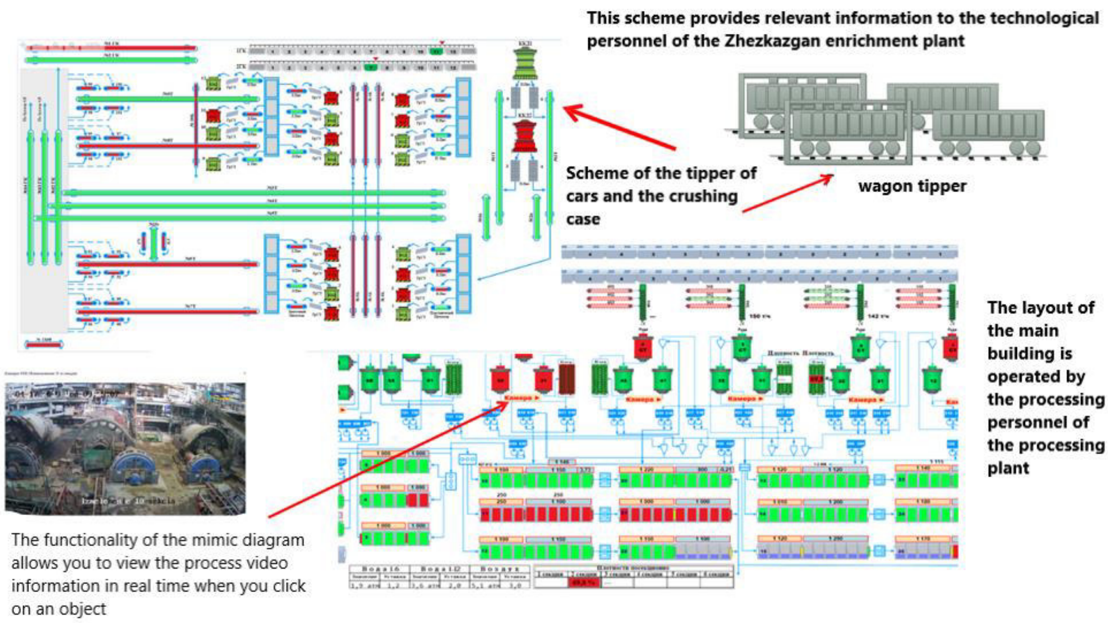

Fig. 5 - Mimic diagram of the main technological equipment at the Zhezkazgan enrichment factory

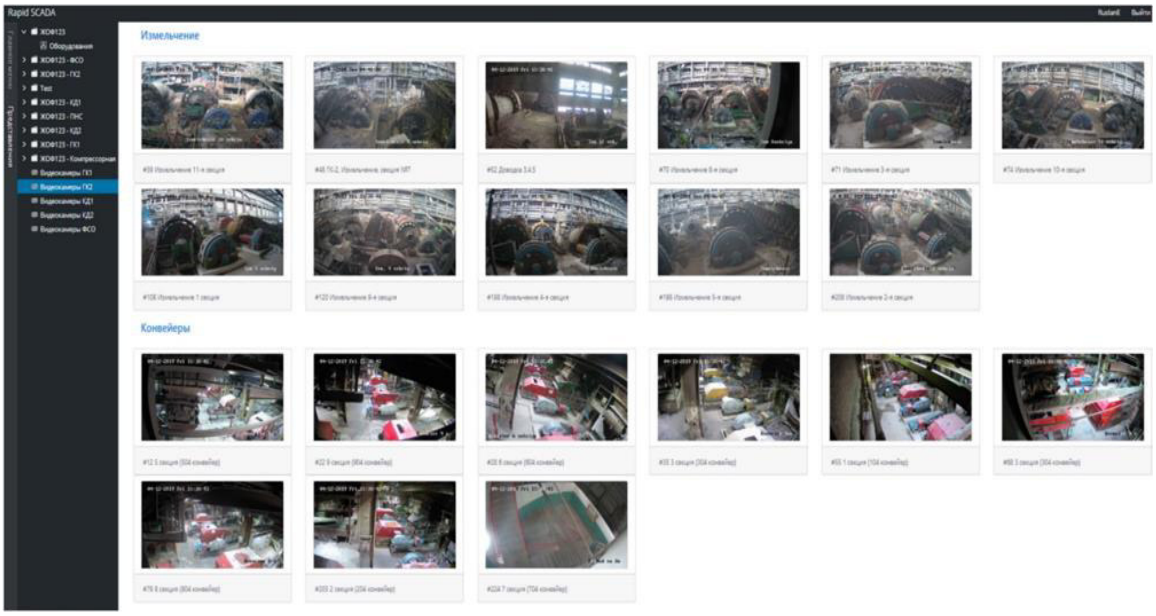

Fig. 6 - Display images from CCTV cameras in real time

4. Conclusion

In conclusion, the introduction of a set of automation systems for technological re-equipment, including elements of the fourth industrial revolution, will allow the Holding to move to a new level of competitiveness by increasing labor productivity, ensuring the safety of workers, developing new business models based on the introduction of digital technologies.

Usually, metallurgical enterprises, include the production of all stages, from the extraction of raw materials to senior conversions. Also, metallurgical holdings may include companies from other industries, which further complicates the management of business performance. Thus, metallurgists are faced with the task of planning resources within the entire holding and improving management of the entire supply chain (supply chain management).

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Modeling the Working Process of Attached Equipment for Impact Fracturing of Oversized Rocks

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Abstract. Based on the studies, the authors give the system analysis that, when designing and developing attached equipment for fracturing oversized rocks, it is necessary to consider, on the one hand, dimensions of the oversize and strength properties of the material, on the other hand, characteristics of the base machine that impose certain limitations on the parameters of the attached equipment. The system analysis is based on the subsystems "basic machine - percussion mechanism" and "tool – oversized rock". The properties of each of the subsystems are characterized by the parameters of the objects included in this subsystem. In this regard, the authors propose a description of the mathematical model of the subsystem "base machine - percussion mechanism". A single-bucket hydraulic excavator was adopted as the base machine. It is characterized by autonomy, relative mobility and a high degree of freedom of working equipment.

Keywords: attached equipment, hydraulic hammer, excavator, modeling

1. Introduction

The experience in the development of rocks shows that even with the use of progressive methods of drilling and blasting, it is not possible to exclude completely the yield of a large fraction (oversize). The yield of oversized materials from the blasted mass, depending on the geological conditions, can vary from 2-3 to 15-20 percent.

At present, the most common method is the mechanical method of fracturing oversized rocks using hydraulic and hydro-pneumatic hammers. Hydraulic hammers in the form of convertible attachments for single-bucket excavators have a fairly wide scope and are used not only for fracturing oversized rocks but also for reinforced concrete and concrete structures, opening asphalt concrete pavements, and development of frozen ground.

However, the existing designs of hydraulic hammers are high-frequency, with low impact energy and high frequency. This leads to local destruction of the rock in the immediate vicinity of the tool, and with prolonged application of a high-frequency load, the tool gradually immersing in the material forms most often a depression, and does not lead to the destruction of oversized rock.

2. Results and discussion

The studies have established [1, 2, 3] that for fracturing oversized materials there is needed increased energy of a single impact, and it is more efficient to increase energy by increasing the mass compared to the velocity of the impact element. In addition, when designing and developing attached equipment for fracturing oversized rocks, it is necessary to take into account, on the one hand, dimensions of the oversize and strength properties of the material, and, on the other hand, characteristics of the base machine, which impose certain restrictions on the parameters of the attached equipment. The studies carried out earlier relate to private issues, therefore, the work aimed at the comprehensive solution of this problem should be recognized as relevant. It is supposed to be solved using the systematic approach to complex multi-parameter problems using mathematical modeling. This approach involves presentation of the object of study in the form of a system interacting with the external environment. The system is superimposed with internal communications and restrictions on structural, technological and other requirements. In accordance with the objectives of the study, the input and output parameters are formed.

The system analysis allows determining for given input effects the parameters and structure of the object at which performance indicators reach their extreme values. Moreover, direct experimentation on full-scale samples requires significant material costs and time, and technical capabilities of the experimental sample often limit the scope of research.

Modeling as a method of scientific research has, on the one hand, acceptable reliability of the results, and on the other hand, significant reduction in costs compared with experiments on field samples.

Therefore, the use of modeling tools in studying a lot of parametric objects is quite justified.

Modeling involves studying the object of study using a model that matches the original and replaces it at individual stages of the study. Mathematical models do not have the same physical nature with the object and do not have a geometric similarity with it. A necessary condition is the presence of a system of equations describing the behavior of the object and model under study.

It is advisable to use mathematical models in the case when the dependences of individual parameters of the object on external factors are known.

The widespread use of modern computing technologies makes mathematical modeling a convenient tool for studying complex multi-parameter systems.

Physical models have the same physical nature as the object of study and differ in scale of parameters from it. At this, the physical similarity and identity of the laws of motion of the model and the object under study are necessary. Physical models are used in the absence of a mathematical description of the object of study.

Using a physical model involves an experiment, which is an important stage in scientific research. Using the experiment, working hypotheses and assumptions are checked, new ideas of the object under study are formed, specific dependencies and values are established [4, 5].

An active experiment makes it possible to set the values of factors in advance according to a certain plan, and the researcher can actively intervene in the course of the experiment. Moreover, the design of the experiment significantly reduces the complexity and time of its implementation, allows achieving a given level of significance with the minimum possible number of experiments or with a given number of experiments, the maximum possible level of significance of the result [6].

A machine for fracturing oversized rocks is a complex dynamic system with a branched structure, numerous connections and various restrictions. The system is under the effect of active forces (impact component), external disturbances (resistance on the tool) and control actions by the operator. In the general case, these effects are random in nature and can be observed in various combinations.

A universal methodology for studying similar objects is provided by the system analysis [10, 25]. In Fig. 1 the machine is presented in the form of a system “base machine - percussion mechanism - tool - oversize".

The system is based on the subsystems “base machine - percussion mechanism” and “tool - oversize”. The properties of each of the subsystems are characterized by the parameters of the objects included in this subsystem.

In this paper let’s consider a mathematical model of the subsystem “base machine - percussion mechanism”. It is advisable to adopt a single-bucket hydraulic excavator as the base machine, for which the autonomy, relative mobility and a high degree of freedom of working equipment are characteristic. In addition, when replacing the percussion mechanism with a bucket, the excavator is capable of shipping the finished product.

When developing attached equipment as convertible attachments for a single-bucket construction excavator, it is necessary to take into account characteristics of the base machine, which impose certain restrictions on its parameters [7].

Firstly, the restriction on the total mass of attached equipment. On the one hand, the additionally attached mass of equipment should not violate the excavator stability during relocation. At this, the following design position is considered: the excavator is located on a flat surface, inclined towards the working equipment at an angle β to the horizontal, the boom and the arm have a maximum reach, the impact mass is in the lowest position (Fig. 1).

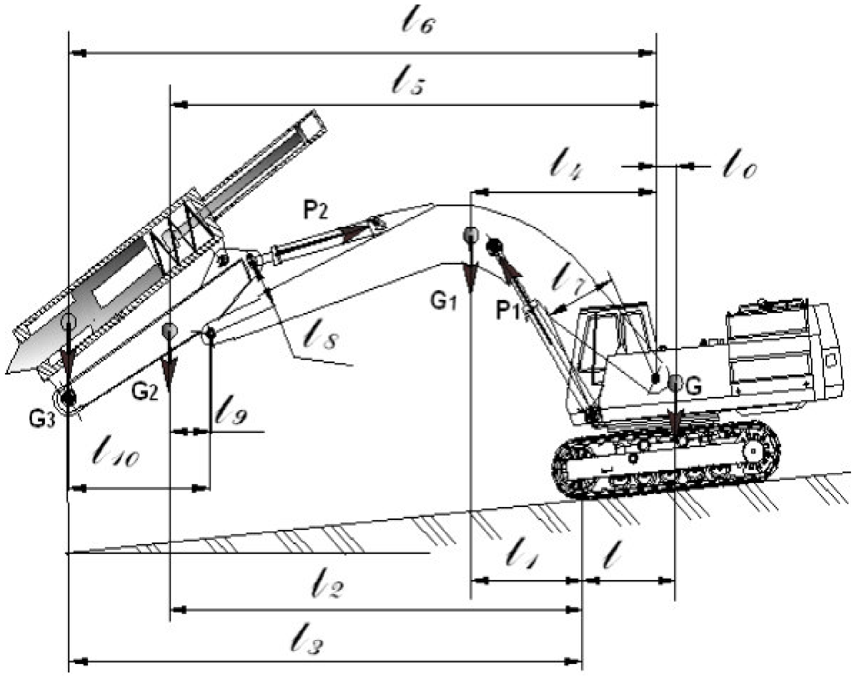


Fig. 1. – The excavator analytical model in the transportation position

From the condition of equilibrium the total mass of the attached equipment

$$m_3 \leq \frac{ml - m_1 l_1 - m_2 l_2}{l_3 k_1}, \quad (1)$$

where m, m_1, m_2, m_3 are the masses of the base machine, the boom, the arm and the attached equipment, respectively, kg;

l, l_1, l_2, l_3 are distances from the tipping rib to the center of gravity of the base machine, the boom, the arm and the attached equipment, respectively, m;

κ_1 is the static stability factor.

On the other hand, the additional mass of attached equipment should be taken into account when checking the force calculation of the boom and arm hydraulic cylinders in the specified design position:

$$m_3 \le \frac{P_1 l_7 - g m_1 l_4 - g m_2 l_5}{g l_6} \tag{2}$$

$$m_3 \le \frac{P_2 l_8 - g m_2 l_9}{g l_{10}}, \tag{3}$$

where P_1 and P_2 are forces on the boom and arm hydraulic cylinder rods, respectively, N;

l_4, l_5 and l_6 are distances from the boom mount pivot to the center of gravity of the boom, arm and – attached equipment, respectively, m;

l_7 and l_8 are arm of forces P_1 and P_2, respectively, m;

l_9 and l_{10} are distances from the arm mount pivot to the center of gravity of the arm and the attached equipment, respectively, m;

g is acceleration of gravity, m/s^2.

The maximum allowable total weight of the attached equipment is the smallest of those calculated.

Secondly, the limitation on the spring stiffness that determines stability of the excavator in the operating mode during acceleration of the impact mass. The design position is as follows: the boom has the maximum reach, the arm is in the vertical position, the excavator rests on the rear tipping rib and the attachment rack (Fig. 2).

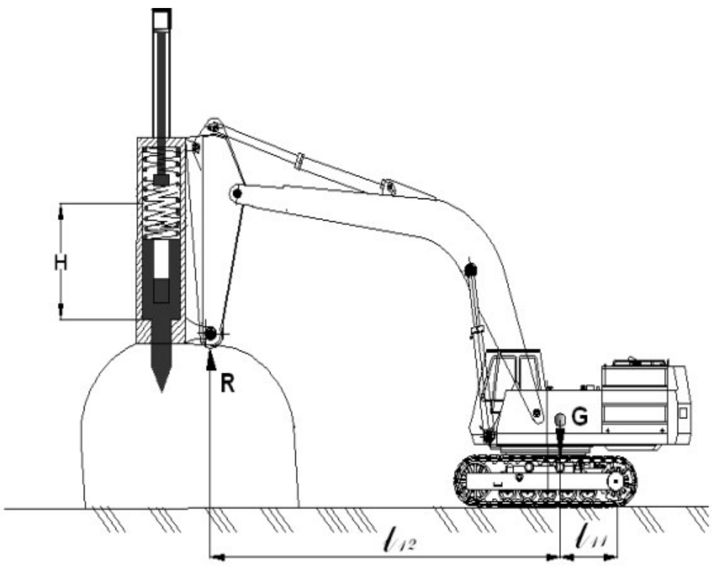


Fig. 2. – The excavator analytical model in the working position

The reaction on the attached equipment rack:

$$R = \frac{l_{11}}{l_{12}} G, \tag{4}$$

where l_{11}, l_{12} are distances from the base machine center of gravity to the tipping rib and the rack of the attached equipment, respectively, ;

G – the excavator weigh, N.

The spring stiffness from the condition of dynamic stability is:

$$C \le \frac{R}{H k_2}, \tag{5}$$

where H is the impact element height, m;

k_2 is the dynamic stability factor.

Thirdly, the restriction on the height of the impact element. The specified restriction is conditional in nature and in the adopted kinematic diagram of the attached equipment depends on the stroke of the lift hydraulic cylinder. To increase the impact energy, it is necessary to strive for the maximum possible lift height of the impact element. In addition, when determining the main parameters of attached equipment for fracturing rocks and durable building materials, it is necessary to take into account the restrictions imposed by the characteristics of the power plant and hydraulic drive of the base machine [6].

The existing hydraulic hammer designs have a significant drawback: relatively small energy of a single impact that cannot be increased by the kinematic connection between the impact element and the drive at the time of the impact. Promising is the design of attached equipment [7], which is the basis of the subsystem “base machine - percussion mechanism”.

Figure 3 shows the analytical model of the subsystem “base machine - percussion mechanism”.

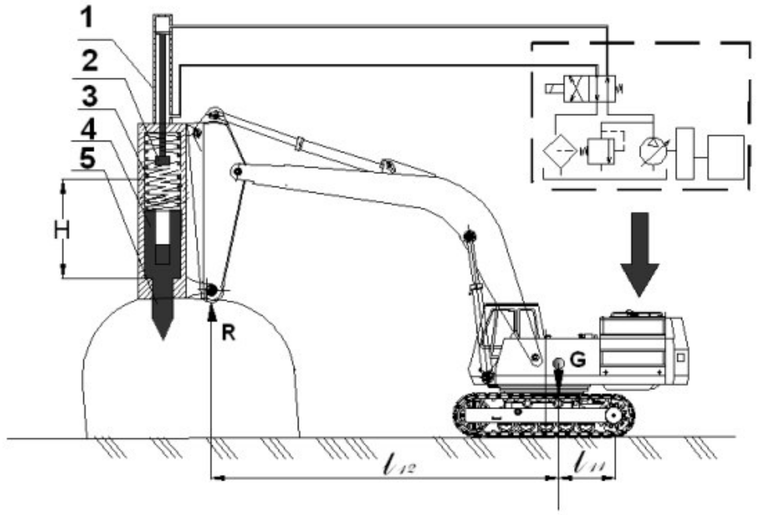


Fig. 3. – The subsystem “base machine – percussion mechanism” analytical model

The attached equipment consists of lift cylinder 1 with gripper 2, impact element 4 and spring 3. The attached equipment is driven from the hydraulic system of the base machine. In the initial position, impact element 4 rests on the surface being fractured. The rod of lift cylinder 1 with gripper 2 is extended. When the working fluid is supplied to the rod cavity of hydraulic cylinder 1, gripper 2 closes and, together with impact element 4, starts to move upward, overcoming the force of spring 3. When reaching the extreme upper position, the flow of the working fluid into the rod cavity stops, gripper 2 opens, and impact element 4 under the action of its own weight and the reaction of spring 3, accelerates and strikes the fractured surface. At the same time, the working fluid is supplied to the piston cavity of hydraulic cylinder 1, and the rod with gripper 2 moves down to meet impact element 4. The working fluid is again supplied to the rod cavity of hydraulic cylinder 1, and then the process is repeated. The working process of the attached equipment is essentially non-linear, therefore, when analyzing the working process, it is advisable to distinguish two phases: the impact element wind and its acceleration.

Wind. At this stage, the energy reserve for impacting is formed. The impact element with the hydraulic drive of the base machine moves to the upper position. Here are the equations of motion:

$$pF = CH + Mg \tag{6}$$

$$M_k = qp; \omega 1 = \frac{\omega}{i}$$

$$\frac{M_k}{i} = if(\omega < 188{,}5 - 0{,}532\omega + 768{,}718 - 23{,}643\omega + 5125) \tag{7}$$

$$V = \frac{\omega 1 q}{F}; t = \frac{H}{V} \tag{8}$$

where p is pressure in the pressure main, Pa;

F is the cross section area of the rod cavity of the hydraulic cylinder, m^2;

C is the spring stiffness, N/m;

H is the cylinder rod movement, m;

M is the impact element mass, kg;

Mк is the torque of the hydro-pump shaft, Nm;

q is the cubic capacity of the base machine hydro-pump, m^3;

i is the reduction ratio of the matching reducer;

ω is the angular velocity of the engine crankshaft, r/s;

$\omega 1$ is the angular velocity of the hydro-pumpa, r/s;

V is the impact element lift velocity, m/s.

Equation (7) determines the angular velocity of the crankshaft of a diesel engine depending on the external load, equation (6) generates the pressure main pressure, and equation (8) determines the movement of the impact element.

When compiling the mathematical model, the following assumptions were made:

- the working fluid has constant parameters;
- the work of regulatory and safety equipment is considered ideal;
- uneven pump flow, leakage of the working fluid and internal resistance to movement of moving parts are not taken into account.

The input of the subsystem is the structural parameters of the attached equipment: the mass and lift height of the impact element, the spring stiffness, the cross-sectional area of the rod cavity of the lift cylinder. The output is the angular velocity of the crankshaft of the base machine engine, the pressure main pressure, the speed and time of the impact element lift.

Acceleration. It implements the stock of stored energy during the wind in the form of the generalized indicator "impact energy". The kinematic connection with the drive is broken, the impact element under the action of gravity and reaction of the spring moves to the lower position. The equations of motion are as follows:

$$M_a = CH + Mg; T = \frac{CH^2}{2} + MgH; \tag{9}$$

$$V = \sqrt{\frac{2T}{M}}; t = \sqrt{\frac{2H}{a}} \tag{10}$$

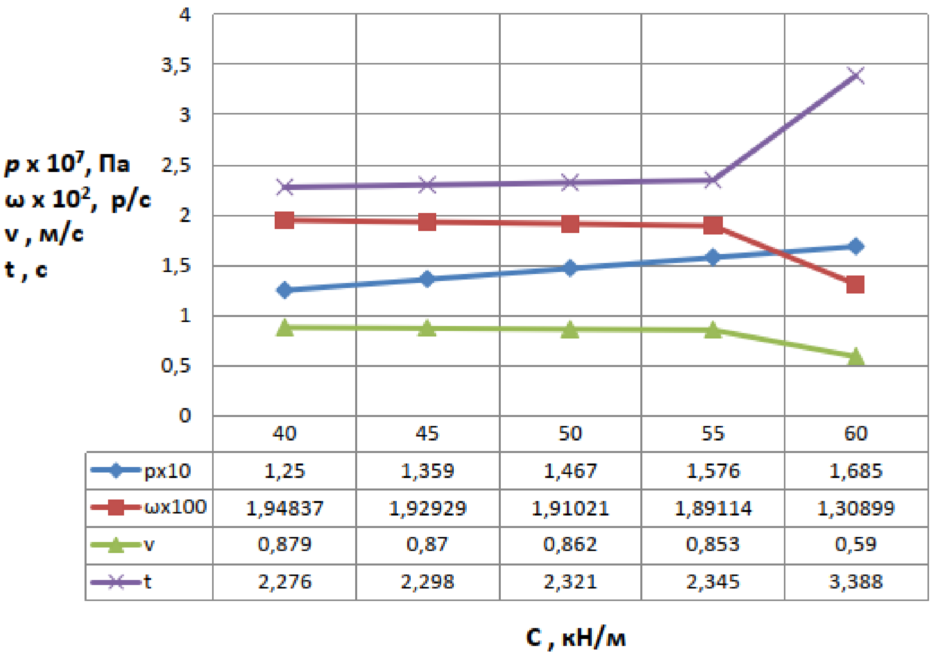
where a is the impact element acceleration, m/s^2;

V is the impact element velocity at the moment of impact, m/s;

T is the impact energy, J.

The main parameters are the time of acceleration, the impact element velocity at the moment of impact and the impact energy.

Thus, the above theoretical premises were implemented in the MathCad environment and are presented in Fig. 4, where the dependence of the main parameters of the impact element wind on the spring stiffness is shown. With increasing stiffness up to 50 kN/m, pressure in the pressure main and the load on the engine of the base machine increase. As a result, the angular velocity of the crankshaft and the flow of the hydraulic pump are slightly reduced, and the lift velocity of the impact element does. At the same time, the impact element lift time increases but slightly.

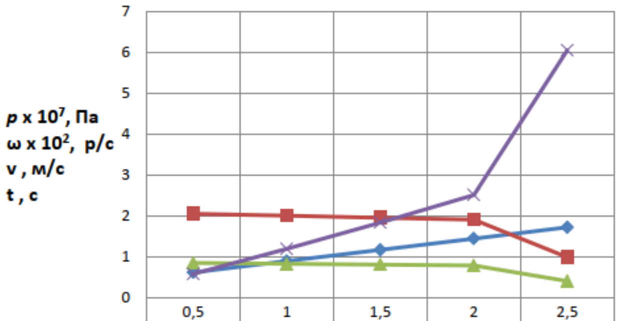


	40	45	50	55	60
px10	1,25	1,359	1,467	1,576	1,685
ωx100	1,94837	1,92929	1,91021	1,89114	1,30899
v	0,879	0,87	0,862	0,853	0,59
t	2,276	2,298	2,321	2,345	3,388

Fig. 4 – The main parameters of the impact element wing process dependence on the spring stiffness: M=3500 kg; H=2 m; S=0.0092 m^2

Further increasing the stiffness leads to engine overload, and the latter transits to the corrective branch of the external speed characteristic. The rate of changing these parameters (except for pressure in the pressure main) changes due to the angular velocity of the crankshaft drop.

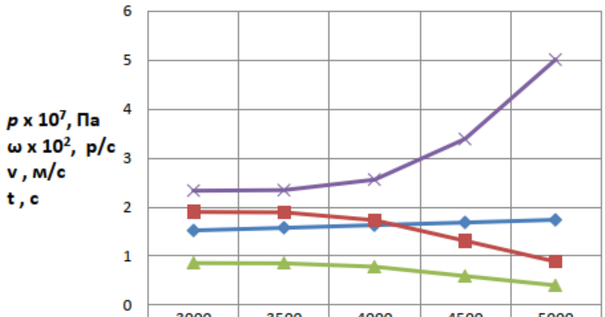
With increasing the lift height (Fig. 5) and the impact element mass (Fig. 6), the picture does not change qualitatively, because the action of these factors also leads to increasing pressure in the pressure main and the engine load of the base machine.



H, м	0,5	1	1,5	2	2,5
px10	0,625	0,9	1,175	1,45	1,725
ωx100	2,05806	2,00979	1,96153	1,91326	0,99531
v	0,854	0,834	0,814	0,794	0,413
t	0,586	1,199	1,843	2,519	6,053

H, м

Fig. 5 - The main parameters of the impact element wing process dependence on the lift height: C=55 kJ; M=3500 kg; S=0.01 m^2

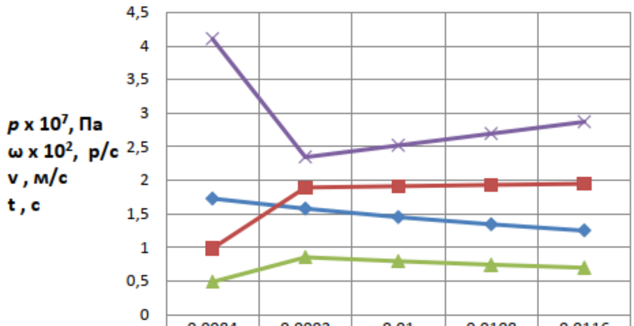


M, кг	3000	3500	4000	4500	5000
px10	1,522	1,576	1,63	1,685	1,739
ωx100	1,90067	1,89114	1,73288	1,30899	0,8851
v	0,857	0,853	0,782	0,59	0,399
t	2,333	2,345	2,559	3,388	5,01

M, кг

Fig. 6.- The main parameters of the impact element wing process dependence on its mass: C=55 kJ; H=2 m; S=0.0092 m^2

Fig. 7 shows the dependence of the main parameters of the impact element wind on the cross-sectional area of the rod cavity of the lift hydraulic cylinder. With the minimum cross-sectional area (0.0084 m^2), high pressure occurs, which leads to overloading the engine of the base machine and transition to the correction branch of the external speed characteristic. In this case, the angular velocity of the crankshaft, the hydraulic pump supply and the lifting speed of the impact element are minimal. With increasing the cross-sectional area (0.0092 m^2), pressure in the pressure main decreases, the load on the engine of the base machine decreases too, as a result of which the angular velocity of the crankshaft increases, slightly increasing the flow of the hydraulic pump. Slight increasing the supply rate cannot compensate for the loss in the velocity of the impact element by increasing the cross-sectional area of the rod cavity, and the latter begins decreasing. The lift time increases in proportion to the cross-sectional area of the rod cavity.



	0,0084	0,0092	0,01	0,0108	0,0116
px10	1,726	1,576	1,45	1,343	1,25
ωx100	0,98602	1,89114	1,91326	1,93212	1,94837
v	0,487	0,853	0,794	0,742	0,697
t	4,106	2,345	2,519	2,694	2,87

S, м²

Fig. 7 – The main parameters of the impact element wing process dependence on the lift cylinder rod cavity cross section: M=3500 kg; H=2 m; C=55 kJ

3. Conclusions

Thus, all the output parameters (except for pressure) have a "breakpoint" on the graphs that corresponds to the operation of the engine in the maximum power mode. Therefore, the rational attached equipment parameters should be considered those which values at the wind stage bring the engine of the base machine to the maximum power mode. At the acceleration stage, the kinematic connection with the drive is broken, the impact element under the action of gravity and the reaction of the spring is moved down. The output parameters of the stage are as follows: the acceleration time (t), the speed (V) and the impact element acceleration (a) at the moment of impact, the impact energy (T).

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Analysis of Effectiveness of Vibrating Screens' Work

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Abstract. Due to constant contact with large volumes of highly abrasive masses, sieves of screens undergo intensive wear. Therefore, sieves of screens are the most wearing parts. The authors of the article conducted a patent analysis of screens. It is noted that the effectiveness of screens depends on sieves tension, the uniform supply of coal to a screen and the distribution of coal over the entire width of screening surface. The article also analyzes the design features of sieves of screens, screens material, and the reasons for the failure of screens work.

Key words: screen, sieve, sieves tension, sieves sticking, vibrating screen, crusher

1. Introduction

Processing processes at a processing plant depend on the particular type of mineral, but as a rule, the general processes will be crushing, screening, grinding, sorting.

The technological scheme of production, the quantity and dimensions of necessary equipment of processing plants depend on the required capacity, minerals composition, their physical properties, beneficiation ability and final requirements for the obtained beneficiation products.

The process of minerals processing at beneficiation plants, as a rule, is divided into several stages: preparation (crushing, screening, grinding, sorting, firing), main beneficiation (gravity enrichment, magnetic separation, flotation) and auxiliary processes (dehydration, thickening, drying and water clarification).

Screening is the process of separating bulk materials by size on screening surfaces, i.e., sieves.

Screening operations, like other methods of sorting by size, are mainly used to solve the following problems:

-for the separation from the stream of crushed (disintegrated) rock mass of raw materials fraction of a certain size, which is required for subsequent technological operations or for the return of a large fraction to recrushing (the so-called closed crushing cycle)

-for the separation of marketable products of given grain size classes. For example, to obtain narrow fractions of the size of crushed stone or abrasive materials.

-for the separation of raw materials into parallel flows and the subsequent processing of material of various sizes by different technologies.

The screening process is implemented using special machines, screens.

Despite the fact that there are many well-known structures of vibrating screens, in modern mining practice two main types of vibrating screens are widely used, which differ in the type of vibrations.

The first, the so-called inertial type of screens is equipped with one vibration drive, which transfers to the screen orbital vibrations in a vertical plane. To transport material through, the box of a sieve is installed at an angle of 7-17 degrees to the horizon.

The second type of screens, the so-called self-balancing or self-synchronizing, is equipped with two vibration drives operating in antiphase and creating rectilinear vibrations of the box. This type of screens provides classification and simultaneous transportation of material to the sieve and therefore can be installed either horizontally or at a small angle to the horizon. Self-balancing screens provide somewhat greater accuracy (effectiveness) of separation by size and require a lower structural height for installation than inertial screens, but they consume 10-20% more electricity.

2. Types of screen structures

Based on a patent analysis, the authors of the article identified existing types and methods of screening, presented in table 1. [1]

Beneficiation production is characterized by significant energy intensity. Thus, in the above table, we can highlight some of the main disadvantages in the structure of screens. These are dimensions of equipment, the structure of the sieve, poor grinding of bulk material, vibration parameters.

Domestic engineers offer various solutions to the shortcomings in the structure of screens. Below are specific examples of solutions to the tasks.

Patent No. 25647, Authors: Korobova O.A., Likunov A.V., Elemes D.E., Vavilov A.V., Guryanov G.A. The technical result from the use of the claimed invention consists in increasing the intensity of mixing the material on the sieve of the screen, and as a result, increasing the capacity of screening while maintaining the quality of sorting bulk material. [2]

Patent No. 24081, Authors: Guryanov G. A., Smurygin A.V.

The technical result consists in the fact that the sieve has the ability to move relative to the box, including with the help of the drive, and oscillates with a constant amplitude and frequency. A vibrating screen is proposed, comprising a box, spring shock absorbers, a sieve located inside the box, a circular vibrator, the shaft of which rests on bearings mounted in housings on the box, unbalances mounted on the ends of the shaft of the circular vibrator, engine's pulley. The sieve contains locking devices and is mounted movably on the box using eccentric shafts, at the end of one of the eccentric shafts an additional pulley is installed, which is connected by a flexible connection with the engine's pulley. Due to this, the quality and effectiveness of screening is increased [3].

Patent No. 23421, Authors: Elemes D.E., Surashov N.T. [4]

The technical result from the use of the claimed invention is to significantly increase the capacity of the process of sifting bulk materials, applying additional mixing of the material.

Table 1 - Types of screens structures and disadvantages in the design of screening

№	Name	Innovation patent number. Published	Authors	The essence of the invention	Structure flaws
1	Vibrating screen	25647 16.04.2012	Korobova O.A., Likunov A.V., Elemes D.E., Vavilov A.V., Guryanov G.A.	Known vibrating screen, including a box with a screening surface, connected by elastic elements with a movable frame mounted on the foundation by means of shock absorbers, and a vibrodrive mounted on the frame.	The disadvantage of this invention is the high metal and energy consumption, a double frame of the structure, two vibro drives.
2	Vibrating screen	24081 15.06.2011	Guryanov G.A., Smurygin A.V.	Known vibrating screen, including a box with a sieve located therein, under which longitudinal bars are installed.	The disadvantage of this invention is the poor loosening of bulk material. At the same time, the longitudinal bars installed from below reduce the useful (light) area of the sieve. These factors reduce screening capacity.
3	Spiral vibrating screen	23421 15.12.2010	Elemes D.E., Surashov N.T.	A vibrating screen comprising a box with a convex down sieve placed in its bottom mounted on an eccentric vibration exciter, and a vibration exciter's drive configured to control the rotational speed.	The disadvantage of this invention is that with a significant complication of the structure of the the effectiveness of the screening process practically does not increase, since the additional effect on the bulk material is carried out from below, placing the entire layer of bulk material on the sieve,i.e., monolayers of bulk material do not mix with each other, there is no active loosening of bulk material.
4	Vibrating impulse screen	408 15.12.2008	Malyavin M.V., Shevchenko A.O.	Known inertial screen that contains two unbalanced vibrators that are kinematically and electrically not connected to each other and rotate in opposite directions.	The disadvantage of this invention is that with a significant complication of the structure of the sieve the effectiveness of the screening process practically does not increase, since the additional effect on the bulk material is carried out from below, placing the entire layer of bulk material on the sieve,i.e., monolayers of bulk material do not mix with each other, there is no active loosening of bulk material.
5	Spiral screen	23420 15.12.2010	Elemes D.E., Surashov N.T.	Inertial-type vibrating screen containing a box with spring shock absorbers, inside which sieves are located	The disadvantage of the known screen is the low quality of screening due to deviation of vibration parameters, i.e., the amplitude and frequency of the box oscillations from their nominal value during start and runout, as well as when changing material properties, such as humidity, and increasing the mass of the material on the sieve
6	Crusher-Screen	3399 10.06.1996	Zagorulko V.A., Lee V.L., Myshkin V.V., Konovalov A.P., Levin V.Ya.	A spiral vibrating screen including a loading device, a spiral drum in the form of a coil spring, made of separate sections with different pitch of turns and installed with the possibility of rotation in the supports, a drum rotation drive and bypass trays.	The disadvantage of this screen is low productivity, compared with structures of flat vibrating screens currently used

Patent No. 408, Authors: Malyavin M.V., Shevchenko A.O.

The base for the creation of the proposed vibratory pulse screen is the objective of improving the vibrating screen to increase the effectiveness of classification of bulk materials of high humidity by making it possible to set such vibration accelerations on working surfaces that would be sufficient to break the surface films and the adhesion forces between the grains of wet bulk materials. The use of electric pulse inductors as exciters enables to give vibrations supplied to the sieve of the screen a pronounced pulsed character with a pulse length of 1-5 m / s, and to give each point of the surface of the sieve accelerations sufficient to destroy surface films and the adhesion forces of grains of wet bulk material. The rigid fastening of the sieve's frame to the screen's frame and the springless structure of the electric pulse inductors used in it enable preventing the occurrence of a damping effect, which can significantly limit the possibility of making points of surfaces of sieve to accelerate sufficiently for effective classification. [5]

Patent No. 23420, Authors Elemes D.E., Surashov N.T.

The technical result from the use of the claimed invention is to significantly increase the productivity of the process of sifting bulk materials, using the complex excitation of the material. [6]

Patent No. 3399, Authors: Zagorulko V.A., Lee V.L., Myshkin V.V., Konovalov A.P., Levin V.Ya.

To ensure selective crushing and reduction of overall dimensions in a crusher-screen containing a drum mounted on rollers with a screening surface, lifting elements. The loading hopper the drum, mounted obliquely, and its screening surface is formed by longitudinal and transverse ribs, rigidly connected to each other, and located at an equal distance from each other. The lifting elements are made in the form of rows of protrusions on the inner surface of ribs and are located with a gap equal to the distance between ribs, and the working surface of protrusions is inclined to the screening surface of the drum. In addition, the crusher is equipped with cleaning elements installed externally above the upper part of the drum between the transverse ribs. [7]

3. Structures and types of sieves

Performances of the screening process largely depends on the structure of the screening surface, namely on the size of the surface, the size and shape of holes. When choosing a sieve, it is necessary to focus on such parameters as durability; light weight; cell sizes (gaps); operating conditions; cost.

The right choice of screening surface allows increasing the processing efficiency of the source material. Certain structural features with different hole sizes, material and method of attachment enables to establish the production process in accordance with the technological scheme of product processing. Table 2 shows the most common types and structures of sieves [8]

Table 2 - Structures and types of sieves

№	Type of sieve	Structural features
1	Sieve made of Hardox steel	This type of sieves for screens are used in cases where there is a need for increased wear resistance while reducing the weight of an equipment. Such sieves are made of Swedish metal Hardox brand steel, which is a kind of standard of high-quality wear-resistant steels. Such sieves are made of flat rolled metall of different thicknesses (from 3.2 mm to 15 cm) and sizes (width from 1 m 35 cm to 3 m 35 cm), depending on the size of frames into which they will be inserted. Hardox steel sheets also have a very smooth surface that is resistant to scratches, cracks and dents. Due to this surface property, sieves from this material are easily cleaned and less clay and dirt adhere to them. Hardox sieves are resistant to vibration and shock, can be used at both low and high temperatures. They are used amid increased abrasiveness of materials to be sieved, for example, in the mining or gold mining industry.
2	Wire sieve	Wire sieves made of steel wire are quite popular because of their low cost, relative strength, little weight, and can be easily repaired. The thickness of the wire varies, and the wire itself can be made of stainless steel, high carbon or carbon steel, depending on the operating conditions. For example, if it is needed to screen wet materials, where there is a high risk of corrosion, stainless sieves are preferable. The most common cell shapes in wire sieves are slotted, square, rectangular. The size range is from 1.25 mm to 10 cm. The wire, which is used most often, has a diameter of from 0.8 to 10 mm. This type of sieve has found its application in sorting into fractions of quarry material, soil and ores.
3	Rubber sieve	The sieves made of rubber are almost comparable to polyurethane sieves in terms of basic characteristics, but have a lower cost per m2 of a sieve. The service life of the sieve, pretty much depends on the properties of the screened material, the operating conditions of the screen, the correct choice of the screening surface. A professional approach to the selection of the type of sieves for the screen allows to significantly save the financial and material component of an enterprise.
4	Polymer sieve	Despite the fact that modern polymers have a rather long reserve of working capacity, they are still significantly worse in their durability to metal sieves. Basically, they are made of polyurethane or rubber and used in flushing screening. Polymers are not subject to corrosion, but are unstable to abrasion wear. Due to the use of water, the abrasiveness of the material is reduced, which, accordingly, reduces the degree of wear of polymer sieves. These screens are the cheapest and lightest, so they are often used in mobile screens.

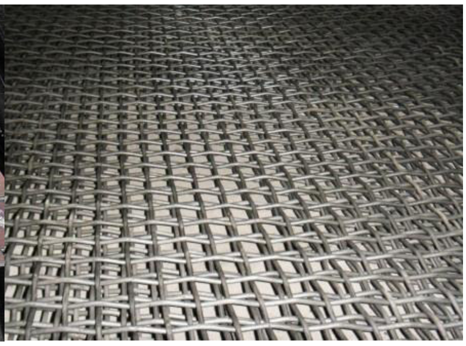

Fig. 1 - Sieve made of Hardox steel

Fig. 2 - Wire sieve

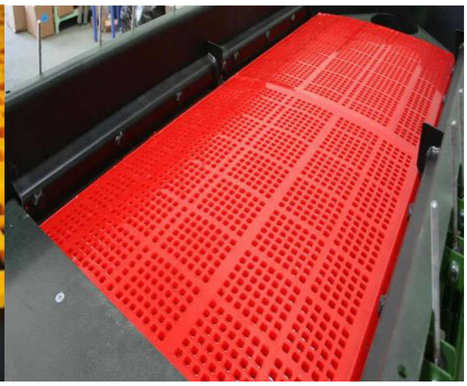

Fig. 3 - Rubber sieve

Fig. 4 - Polymer sieve

Sieves are the most wearing parts. The wear of sieves leads to the loss of varietal material, as well as the loss of time for replacing worn sieves. Apart from sieves, fast wearable parts of screens also include spring supports, screen's boxes and vibrator's bearings. In previous analyzes, a number of reasons for the failure of a sieve were identified:

1. The sticking of sieves' holes;
2. Unequal distribution of material over a sieve, and as a result, a thick layer of material on the surface of the sieve and its breakthrough;
3. The weakening of the tension of sieve's wire;
4. The increased content of fines in the oversize product due to the low quality of the initial power (particle size distribution, humidity, particle shape);
5. Mechanical malfunction of a screen or its settings.

The main reason of the sticking of screens' sieves is not the quality of the sieve itself, but in the principles of the functioning of the screen itself. The sieve must be fixed very rigidly, all the load must pass to the screen's springs and vibrator. If this rule is observed, then the reason lies in the spring of the screen. Cylindrical twisted compression springs are used on screens. The main characteristic of these springs is the reduction in length during load, when compression springs are not subjected to loads, its branches do not touch each other. Screen springs are installed on its box and are under constant load. During operation, they transform the compression strain into the torsional strain of the spring steel of which it is made. If the spring of the screen subsides by 10-20 mm, this negatively affects the decrease in oscillations during screening, although it is not noticeable "by eye". The subsidence of the screen's spring is the main cause of the sticking of the sieve. During maintenance of the sorting sections, the condition of springs is often not monitored, which impacts the entire production process. It is recommended to change the screen's springs once in every 1-2 years.

There is a problem of mechanical sorting by size (classification) of bulk materials on grates and sieves (screening), especially with increased humidity of bulk materials. So, for example, screening of some types of coal at a moisture of 6 to 14 is significantly difficult, since moisture in such a material is present mainly in the form of surface films. Small classes of bulk material have the greatest external humidity due to their largest specific surface area. External moisture in the form of surface films is the cause of the sticking of small grains of material between themselves, their adhesion to large grains of higher classes and the smearing of sieves' cells. To solve these problems, the most common at present is the use of various structures of vibrating screens and sieves, in which the creation of various modes of vibration on the working bodies is ensured.

The screening quality, capacity and the service life of the screening surface are largely determined by the structure of its fastening in the screen box. The sieve has the ability to move relative to the box, including using the drive, and oscillates with constant amplitude and frequency, the required sieving quality is ensured. The reduction in power to the drive is due to the fact that only a sieve, and not a massive box, is driven into the oscillatory motion. [9]

4. Conclusion

Increasing the capacity of the screening process can be carried out by increasing the intensity of mixing of material on the screen's sieve, and maintaining the quality of sorting bulk material; the movement of the sieve relative to the box, using the drive, and making oscillations with constant amplitude and frequency; increasing the capacity of the process of sifting bulk materials, using additional mixing of material; improving the vibrating screen to enhance the classification efficiency of bulk materials of high humidity by making it possible to give the working surfaces such vibration accelerations that would be sufficient to break the surface films and the adhesion forces between grains of wet bulk materials; increasing the capacity of the process of sifting bulk materials, using complex excitation of material

The low service life of sieves leads to huge financial costs for enterprises producing construction materials, both in purchasing new sieves to replace worn sieves, maintenance of screens, as well as minor repairs. The wear of the sieve leads to a deterioration in the quality of sorted material. In addition, there is an irretrievable loss of sieves' material.

The wear of the sieves under the action of sorted material is a consequence of the contact-dynamic effect of sorted material. The wear under the action of sorted material leads to an increase in the cross section of a cell, thinning of sieve's plate and its subsequent destruction with the formation of large holes.

When examining worn sieves, it was found that sieves wear out unevenly across the width of a plate. The greatest wear is at the places of loading of material, due to the large shock loads caused by falling material, as well as a large amount of abrasive passing through sieve's mesh. Often this area occupies a third of the width of the screen and a tenth of the length of the screen. Under the influence of oscillation movements, the sorted material is distributed along the width of the sieve of the screen and leads to the less intensive wear of the entire plate. Despite this, the sieve's plate wears out more in the middle than at the edges. This is due to the unequal distribution of sorted material along the width of the sieve (more abrasive passes in the center than at the edges). As the sorted material moves toward the end of the sieve's plate, wear increases. This is because the movement of sorted material is accelerated. I.e., the speed of movement of sorted material at the end of the sieve's plate is higher than at the beginning. Moreover, the mass of sorted material does not impact the increase in wear, since the main screening occurs on about 1/3 of the surface of the sieve's plate.

Due to constant contact with large volumes of highly abrasive masses, screen's sieves undergo intensive wear. Therefore, screen's sieves are the most wearing parts. The low service life of sieves leads to high economic costs. This is due to purchasing new ones and downtime when replacing worn sieves. In addition, the wear of sieves leads to the deterioration in the quality of sorted material.

The metal screens used in the industry provide somewhat greater hour capacity of screens, since they have a larger "live" section. However, operating experience has shown that the service life of metal sifting surfaces is very short and ranges from 24 to 400 hours. At the same time, the wear resistance of rubber sieves, depending on the size and nature of sorted material, is 2-15 times greater. Therefore, rubber sieves are more promising from the point of view of increasing the service life and efficient use of screens.

In many screen strutures, rubber sieves are pre-tensioned during installation. During operation, they are under the influence of additional varying tensile strains from the mass of sorted material. As is known, the presence of tensile deformations increases the wear rate. Therefore, the reduction of tensile strains or the creation of compressive strains can be considered as a method of increasing the wear resistance of screens' sieves. However, at present, there is little information on the relationship between the wear rate of rubbers and physical and mechanical properties that change under the action of compressive or tensile strains. In addition, sieves of screens are also under the impact of vibration along with the screen's box, but there is no data on the effect of vibration on the wear resistance of rubber parts of machines.

Therefore, the question arises of studying a set of tasks that form ideas about the wear of rubber screening surfaces of screens under the action of sorted material under conditions of wear in the mass of loose abrasive taking into account vibration. Further expansion of the range of used rubbers for screens' sieves requires comprehensive theoretical and experimental studies of the assessment of the wear of rubbers in the conditions of their use.

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Studying and Developing Digital Models of Face Conveyor Elements for Underground Workings of Coal and Ore Mines

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Abstract. The article discusses the design of a face turning belt conveyor and the features of the technology of its use, as well as methods of calculating the load of units and parts in the turn zone. Using simulation modeling, there has been designed an element of the conveyor belt, a tension and drive drum with a belt, and built stress distribution in the belt in the loaded state taking into account the possible uneven load on the belt. With the use of these technologies, the coal mining process using a turning conveyor belt is improved, since transportation of the mineral is continuous and synchronized with the cutter-loader.

Keywords: face conveyor, simulation modeling, transportation, loading, turning conveyor

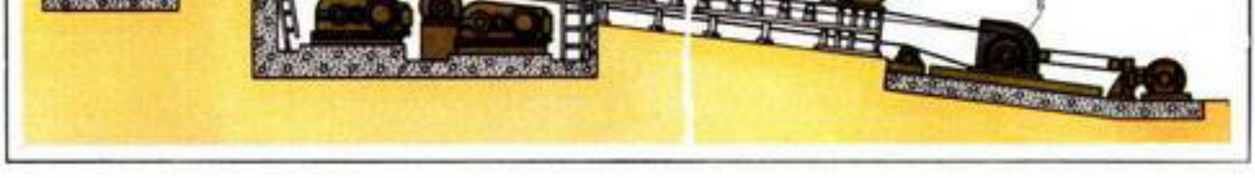
1. Introduction

A belt conveyor is a continuous transporting device with a combined load-carrying and traction body in the form of a closed (infinite) flexible tape. The tape is driven by friction between it and the drive drum; it leans along the entire length on stationary roller bearings. In mines and quarries belt conveyors are used for transporting minerals and rocks from sinking, overburden and mining faces along horizontal and inclined mine workings inside mining enterprises, hoisting them to the surface and then moving them to the processing plant or loading point of external transport, and rocks to the dump. Belt conveyors are also used to deliver minerals from a mining enterprise directly to the consumer (for example, coal to a heat and power center or ore to a metallurgical plant). In mines specially adapted belt conveyors are sometimes used to move people along inclined workings [1].

Quarry belt conveyors (by design) are divided into face, dump, transfer and stationary main ones. In addition, they are an integral part of some quarry aggregates consisting of rotary and chain excavators, dump forwarders, transport dump bridges, and loading cranes. The sections of the face and dump conveyor belts are mounted on a rail-sleeper grid (they allow bending the line with lateral movement as the face moves). A loading trolley with a receiving funnel and a feeder moves along the rails of the face conveyor belt, and a two-drum unloading cart moves on the dump conveyor belt. The rail, in addition, is used to be captured by the tractor mover during lateral movement of the conveyor. The conveyor belt is mounted on carts and moves along the track in the longitudinal direction. The line of stationary belt conveyors is assembled on the ground, concrete path or beds, and the drive and the tension device are mounted on the foundation. In ore quarries, when hard rock is loaded with a single-bucket excavator and secondary crushing (by a mobile crusher) in the face, stationary and mobile type conveyors are used for in-mine transportation and hoisting (in-line technology), and when crushing in a stationary crusher, there are used stationary type conveyor belts for hoisting (cyclic-continuous technology).

2. Results and discussion

The main structural elements of belt conveyors are as follows (Fig. 1): a conveyor belt, a drive, a line with roller bearings, a loading and tensioning device.



1 – пdrive drum, 2 - drive, 3 – conveyor belt, 4 – roller bearings, 5 – loading device, 6 – tension drum

Fig. 1 – Basic elements of the belt conveyor design

The main advantage of using a belt conveyor is that with its help it is possible to transport goods over a very long distance. In some cases, the length of the carrying body can reach 3-5 kilometers. No other conveyor can be so long. This is caused by a large weight, a complex design and, most importantly, a high cost of equipment. There is no problem with the belt conveyor. Another indisputable advantage is high performance. Sometimes the speed can reach 6-10 m/s, with the belt width of 2.4-3.0 meters. In this case, the productivity can exceed 20-30 thousand tons per hour. In addition, the belt conveyor belongs to the universal conveyor lines. This is due to the fact that it can move a variety of loads. Another important advantage is the ability to move goods in the inclined position. With increasing the angle and the length of the conveyor, its speed decreases [2]. Increasing the coal underground mining, especially in the 90-s of the last century led to significant increasing the scale of open development. But the reasons of inefficiency of coal development in mines caused a stormy discussion about the underground development inefficiency.

The main design feature of a belt conveyor is determining the width of the belt, its greatest tension and engine power according to the required conveyor performance, length and the conveyor mounting angle. The performance of a belt conveyor depends mainly on the width of the belt and its speed.

Turning conveyors (Fig. 2) are necessary for transporting materials in curved workings, this reduces the need for additional transfer points, as well as the length, and hence the cost of their sinking and supporting.

In this work we will consider the design of such conveyors and the features of the technology of their use, as well as methods of calculating the load of units and parts in the turn zone, designing the element of the conveyor belt, the tension and drive drum with the belt, and building the graph of stress distribution in the tape in the loaded state. Using this conveyor, the process of coal mining is significantly increased, since the mineral transportation is continuous and synchronized with the cutter-loader [3, 4].

Fig. 2 – General view of the turning belt conveyor

The broken coal form the cutter-loader comes to the turning conveyor train. From the turning conveyor train coal comes to the belt conveyor. The length of the turning conveyor train (according to the real data) can reach oil 175m. The maximum radius of the conveyor turn by 90^o is equal to 7 meters. The technical productivity of the train is up to 27 m^3/min. The resource guarantee of the uninterrupted work is 1 million tons of coal. The conveyor can work with the inclination angles up to 30^0.

The development of turning conveyors in any zone of their lines allows automating the processes of seam mining of deposits using the chamber method, which is becoming increasingly popular due to the exhaustion of reserves occurring in complicated geological conditions.

Today, there are systems of computer aided design (CAD systems), which main task is reducing the cost and terms of design and production due to replacing real processes of prototyping, scale modeling, testing, etc. with their virtual analogs. The process of technical re-equipment of the leading industrial enterprises, the leading research institutes, etc., which has no alternative at present due to heavy competition in the world and domestic markets, requires updating the material provision on the basis of computer aided design systems. The growth of the CAD working places at the enterprises, in spite of present difficulties, shows the fact of the global demand in the labor market for specialists possessing such technologies of engineering analysis using ANSYS CAE-systems [5].

Is it possible in mining, taking into account the future structural changes in the volumes and assortment of the minerals mines to overcome the forthcoming crisis and what is the role of developing mobile delivery equipment based on the belt conveyor in it? The work is being done taking into account the possibility of turning the belt by 90 degrees. At present at KSTU a lot of problems of using of the scraper conveyor have already been solved, but there are a lot of problems in designing a belt conveyor. In the practice of the CIS countries these problems have been fragmentarily, in the USA there is a company manufacturing such systems. Unfortunately, the problems of designing are not presented in technical literature, and rare photos of conveyors do not permit to judge the principal solutions and methodologies, reducing the problems to suppositions. Therefore. There has been an attempt to study this important scientific-technical problem. One of the important issues if designing elements of the 3D turning belt conveyor with a tension and driving drum with the belt. There should be built stress distribution in the belt in the loaded state. To do this, there is simulated a section of the closed belt with drums and designed the element of the belt conveyor, a tension and driving drum with belt. This will allow building stress distribution in the belt in the loaded state [6].

The design technique using the CAE-extension of the ANSYS system implies solving the following tasks:

- implementing the analysis of structural schemes, including the particularity of the turn;
- features of implementing the turn up to 90 degrees;
- in the design sense and taking into account the possibility of finding the basic solution based on the belt conveyor;
- formulation of the basic simulation processes;
- 3D model of the elements of the conveyor.

For this, a closed tape section with drums is being built. There are solved the problems of the belt simulating taking into account the possibility of loading the tension station through the drums and the transported load [7].

Let's build a belt conveyor belt (Fig. 3).

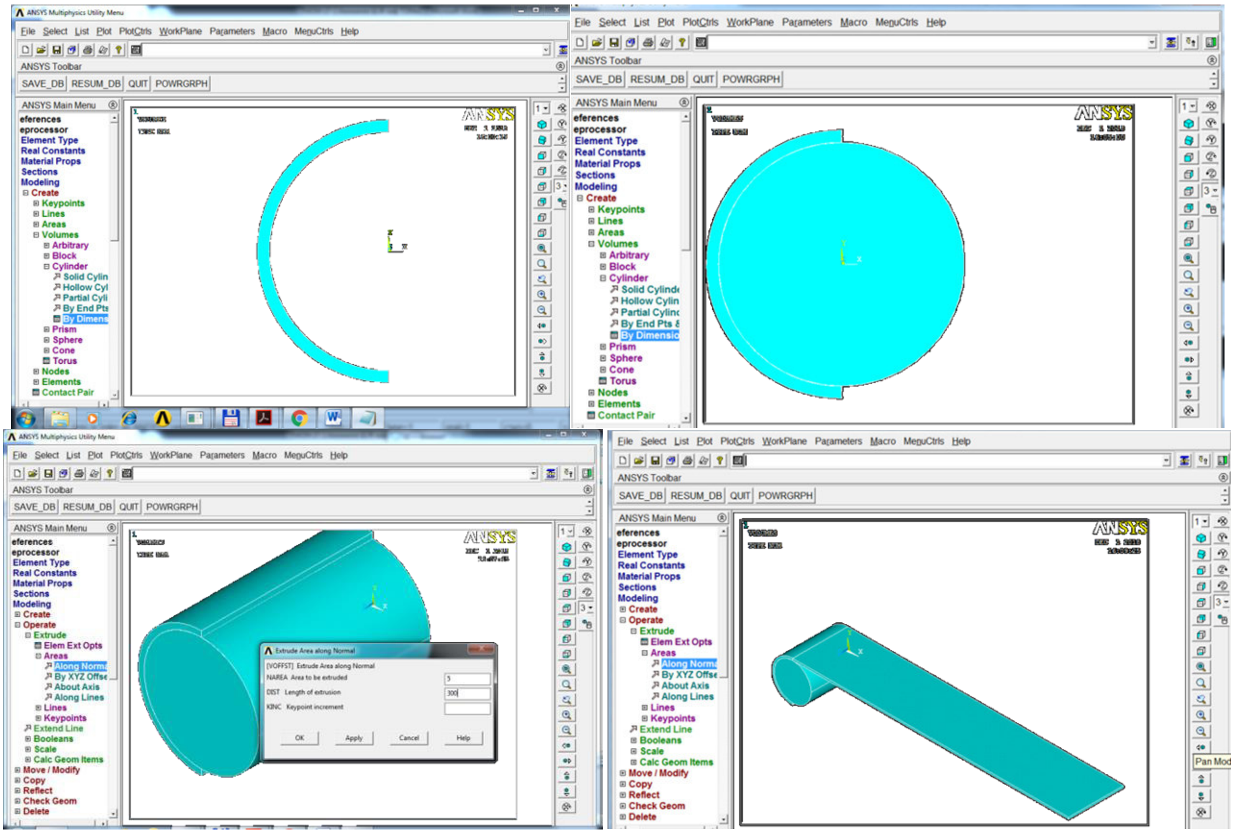


Fig. 3 – Fragments of simulating a closed belt with drums taking into account its loading with a tension station through the drums and transported load

Let's divide the working part of the belt into sections so that in the process of solving there can ve obtained a more detailed and accurate result (Fig. 4).

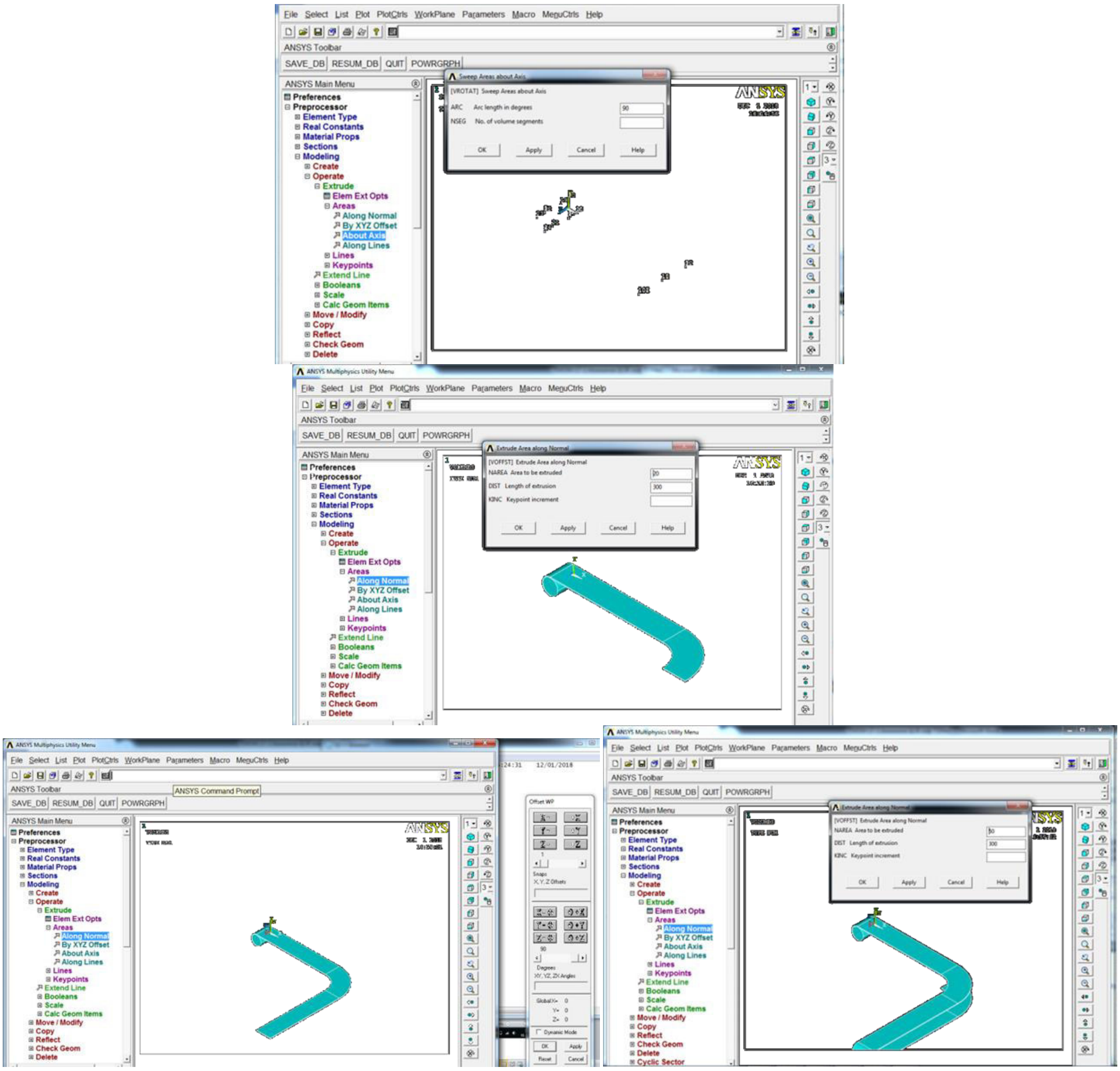


Fig. 4 – Fragments of simulating the belt dividing into small sections

Then let's build a model of the working surface turn by 90 degrees (Fig. 5).

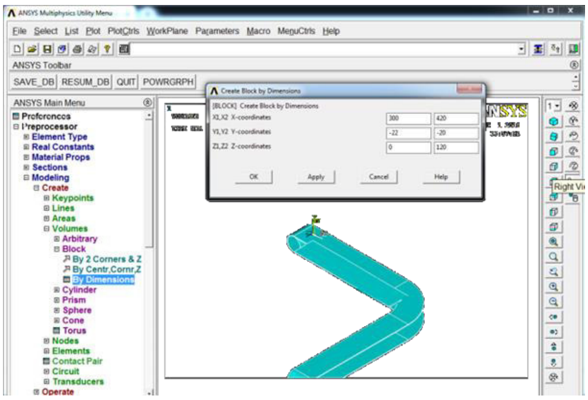


Fig. 5. – A fragment of simulating the working surface turn by 90^0

Then let's build a rectangle of simulating the force (Fig. 6).

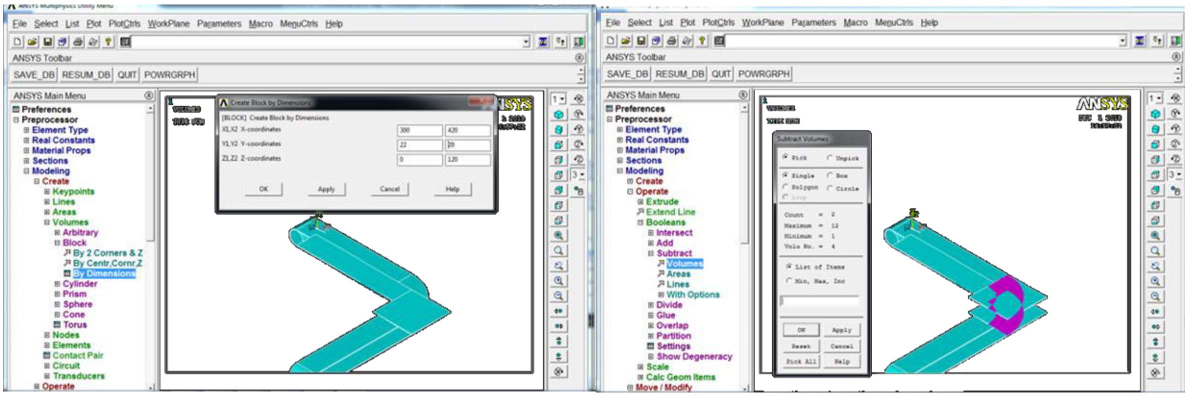


Fig. 6 – A fragment of simulating the force load when turning

Then, using the finite element Solid 92, introducing the elasticity modulus and the Poisson coefficient and the Vmeshall command, we divide all the regions into unit elements in the form of a grid [7].

Then we fix the drum on both sides on all the axes, supply the load to the belt, select the 109 region with indicating the load 5000 N (Fig. 7).

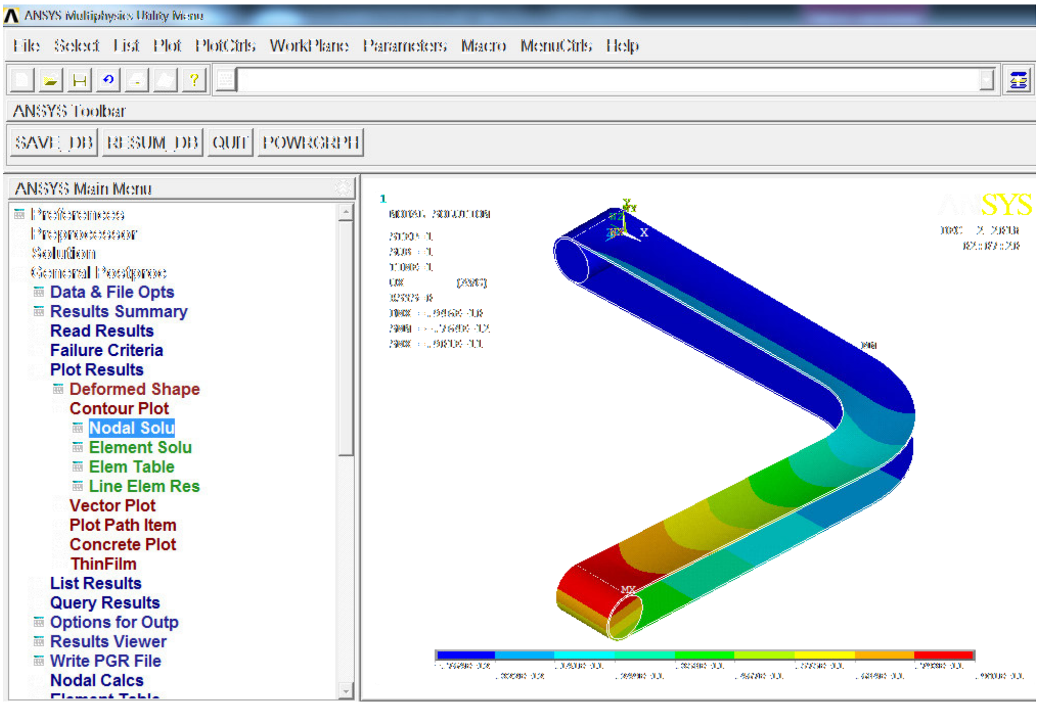


Fig. 7 - A fragment of simulating loading when turning

Below there are given fragments (Fig. 8) from the screen of stress distribution in the contact zones and on the belt surface with comments to the graphs and pictures by the Ansys software. There are indicated coordinates of the initial and final points of the graphs.

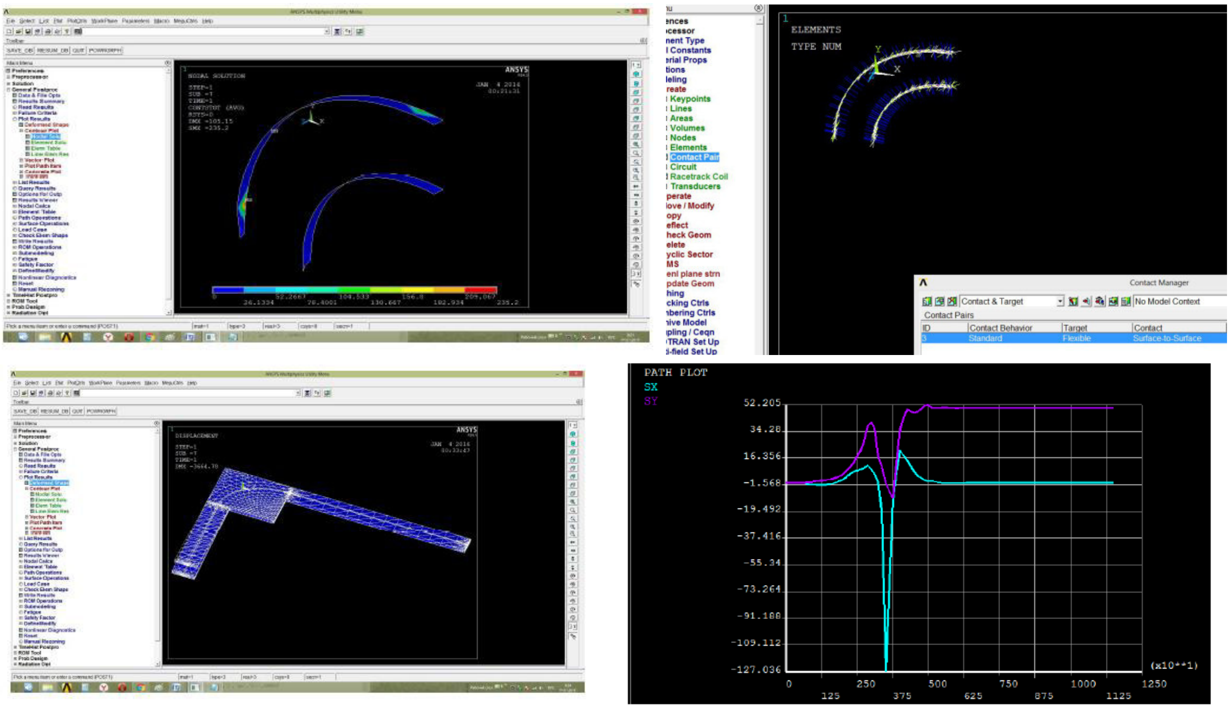


Fig. 8 – A fragment of simulating stress distribution in the contact zones and on the belt surface

3. Conclusions

Thus, the practical relevance of the work consists in that the methods proposed are characteristic of the conveyor working processes which gives an engineer the possibility to design units and mechanisms taking into account their real loading. Using simulation modeling there appears the possibility to indicate the way of reducing loads and increasing the efficiency of transporting machines.

To mine and load coal there have been proposed technologies that are close to the technologies of the chamber mining with the use of a turning belt conveyor. Such conveyors are used in the USA by the JOY company when mining minerals with chamber technologies which permits to increase sharply the mining efficiency. There have been obtained and approbated the elements of simulating a belt conveyor with drive drums and a section of the belt based on 3D technologies and finite-element simulation.

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Automation of Oversizes Destroying Process at Rock Supply Line for Primary Crushing

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Annotation: In this article were set next conclusion by Authors, that during study and analysis of the creation of technical specification and requirements for the new equipment, there are a lot of abilities to include here requirements for automation control process without human participation and high level of people qualification. As expirience shows, there are a hidden problems with needing of systematicaly education of personal to operate equipment by the moving people from one working place to another. It is rising a risks of wrong operation of equipment and make shorter of equipment lifetime. For example, during Covid-19 pandemic or Industry 4.0 revolution, time to time human participation need to be maximum excluded at non-stopping production lines to avoid a stop processes, when a people take part as key participant in different cycles of line. Also, automation process helps to solve a problem with reducing of positions of harmful processes for human. During the making a study, including analysis of production lines at mining companies, we offer a new process with the latest technology tendency in hydraulic systems, data processing and automation systems.

Keywords: automation, hydraulic breaker, manipulator, oversize

1. Introduction

As most people know, in the beginning mining and rock processing consist of this steps:

1) drilling and blasting of rock open mining or underground;
2) transportation of rock for the primary crushing by the railway transport, heavy wheel transport or conveyor;
3) primary milling of rock to medium size particles, usually at jaw crushers;
4) transportation to next step of milling by the conveyor;
5) milling to small sizes particles (end milling) at hammer crusher, cone crusher or roll crusher;
6) transportation to the storage, kiln firing or flotation;

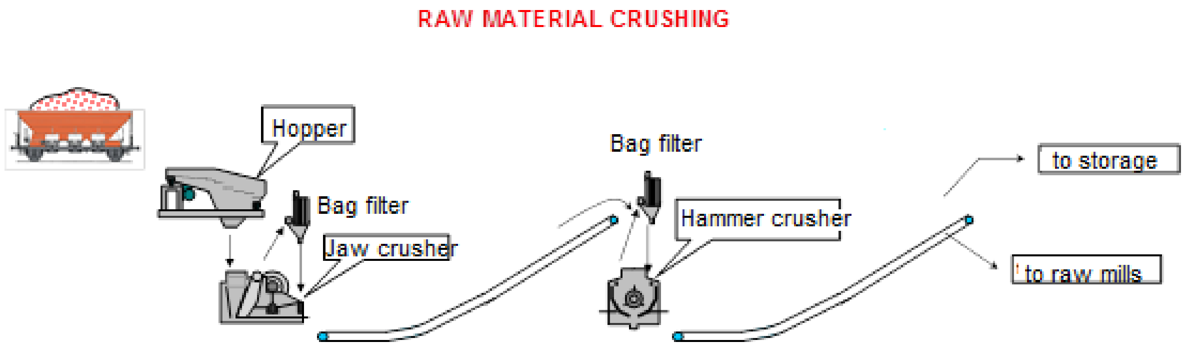

Fig. 1 – Cement factory raw material process line.

2. Results and discussion

So in our job we use a rock process between second and third shown steps, it means after the transportation to jaw crusher but before the rock crushing to medium size particles.

At this stage, most known problem is an oversize rock material.

After the drilling and blasting of rock not possible to control a size or operate accurately to have always identical sizes. By the selecting of primary crusher we need to have maximum effective equipment as at technical specification side as at economic side. In this case, there is always a risk to have oversize rock material. To avoid a reducing of effectivity of crusher we need to use optimal power crusher.

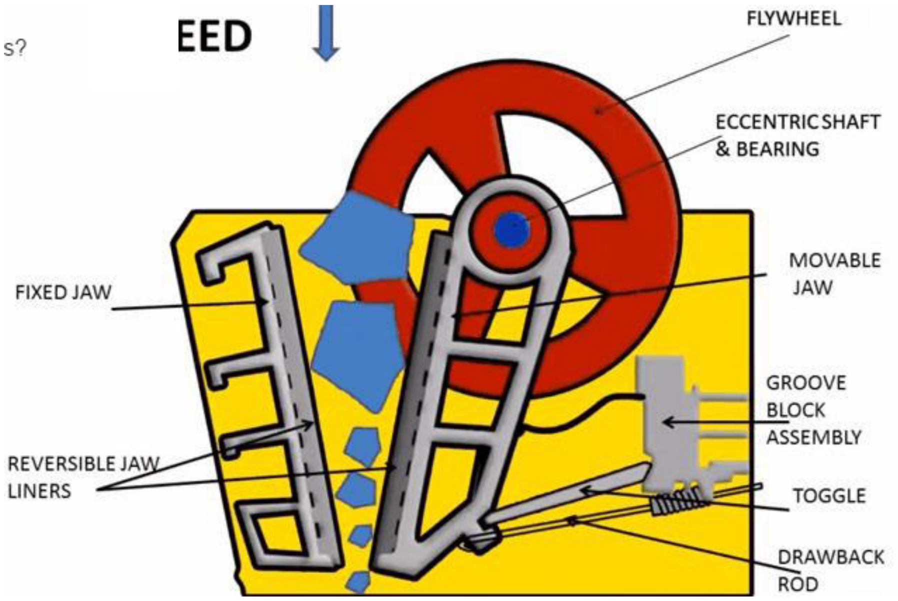

Fig. 2 – Loading of row material to the jaw crusher

Therefore, the part of row material can't be processed by the crusher because of jamming at hopper or at crusher inlet, it calls oversize. Its size is bigger than overall available dimensions of crusher inlet.

So during the process of rock material there are often a task to crush of oversize material after drilling and blasting job. Jamming of it not allow to continue process line, extracting and transportation of it make a lot of additional power (Fig. 3).

Fig 3. – Oversize at jaw crusher inlet

Our function is making oversize crushing process to be automatic.

We can offer to solve it by next stages:

1) Oversize detection by the detection sensor;
2) Stopping of transportation line process to crusher;
3) Making a measuring of overall sizes of oversize and its position in crusher inlet or in hopper by the measuring sensors;
4) Data processing with special software;
5) Calculation of the optimal oversize's point to crush it most effectively;
6) Calculation of the operation hand linear dimensions to put a tool to this point;
7) Operation by the hand manipulator with tool and starting the crushing;
8) Stop and remain back to start place;
9) Making a measuring again by the measuring sensors and start of transport line process.

For the detection of oversize row material in online-mode by the detection sensors we offer to choose a light barrier technology (Fig. 4)

Fig.4 – Light barrier technology

This technology using 2 type of sensors: laser emitter and receiver. Emitter and receiver locate opposite to each other for several meters, during its length it is connected by a lot of rays every several centimeters. This rays of light line make a flat surface till 3 meter width. After some of rays will be disconnected, sensor send to controller a signal with parameters for the data processing.

This solution allows to make a software to detect objects inside the detection pole.

In our job we offer to locate sensors behind of side wall of crusher inlet directly in throat of crusher, across of material moving direction line. Of course, sensors need to be protected by steel housing because of application. Sensors will allow to get immediately a data about row material moving and to have fast feedback from it.

Suppose, that after we take a continuous changed signals during every second, not means of oversize jamming, and only breaking of signal during half of minute or more (programmed value) with the non-changed length of ray allow to conclude for some oversize was jammed. This information is enough to send a signal to next step of process – stop the transportation line and start an analysis of oversize dimensions, form and position.

Stopping the line need to make more accurate and correct data process about oversize and must provide safety for the equipment crushing process.

Next step of process - measuring of overall sizes of oversize and position in crusher inlet or in hopper by the measuring sensors.

At this stage we need get more information about oversize, because light barrier technology working in another level and does not allow to measure oversize surface dimensions, position in the throat of crusher. To solve it available new one technology, based on the scanning of surface, based on 3D-scanner technology (Fig.5).

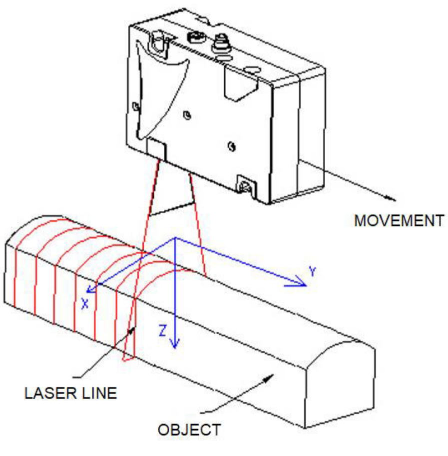

Fig 5 – 3D laser scanner technology

This technology helps us to get more information we needed by the scanning of surface of oversize. The end solution of 3D-scan technology has several options, as linear moving laser head step by step, as installed fixed laser head with the rotation, depended of economic size of project of customer and their own preferences. In our mind, linear moving laser head is most accurate technology in this type of application, but it could be more complicated during realizing.

Data from 3D scanner is sending to data center to operator, to electrical cabinet. Received data let to make 3D-model of oversize upper surface with the linear dimensions.

Because of making a scan of bottom half surface is too complicated in this stage, for the processing of data to calculate more-less accurate a center of mass, the data about upper oversize surface is enough for us. By the making a software for calculation we need to suppose and accept, that oversize bottom half has a flat surface and its deepness ends till surface of our light barrier or little lower. Calculated center of mass is optimal point for the force applying of crushing process.

For crushing of oversize we need to put our instrument with more-less accurately to center of mass of oversize surface to crush it equally for several pieces and avoid appearing of additional smaller oversize after crushing of main piece of roll material. But nevertheless, if this case sometime possible and will be, we just make all the process cycle again.

New software let make calculation of coordinates for the tool.

For the oversize crushing we offer to use rock breaker boom system technology with the installed hydraulic hammer at the end (Fig. 6).

By the rock breaker boom system possible to set tool of hydraulic hammer to oversize and crush it by the high power hitting. Operation of hydraulic hammer makes by the several hydraulic cylinders.

Fig. 6 – Rock breaker boom system

Usually this appearing technology not allow to operate of hydraulic hammer automatically and always need to have operator handling to operate the process. Therefore we offer to modernize this technology with the last solution by putting to hydraulic cylinders a position control sensor technology (picture 7).

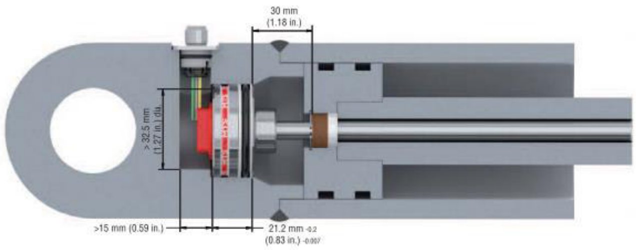

Fig.7 – Position control sensor

This technology uses for the accurate detection of hydraulic rod position.

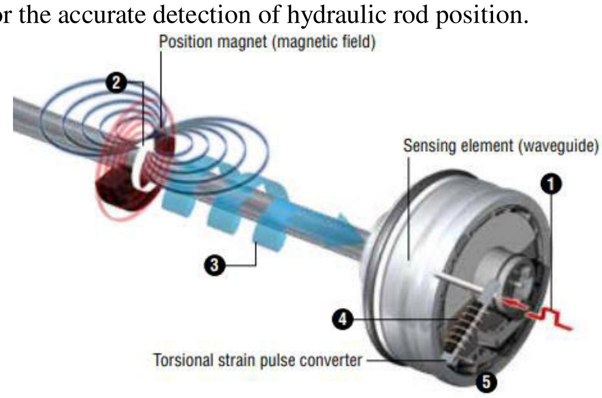

Fig. 8 – Working principal

This technology allow not just detection of coordinate of hydraulic rod position, but also with the using of latest digital technology in hydraulic system, electro-proportional control valves and digital amplifiers let to control and operate very accurate by the speed of moving of hydraulic rod and set exact coordinate of hydraulic rod by the working process with 0.01mm tolerance or better (picture 9).

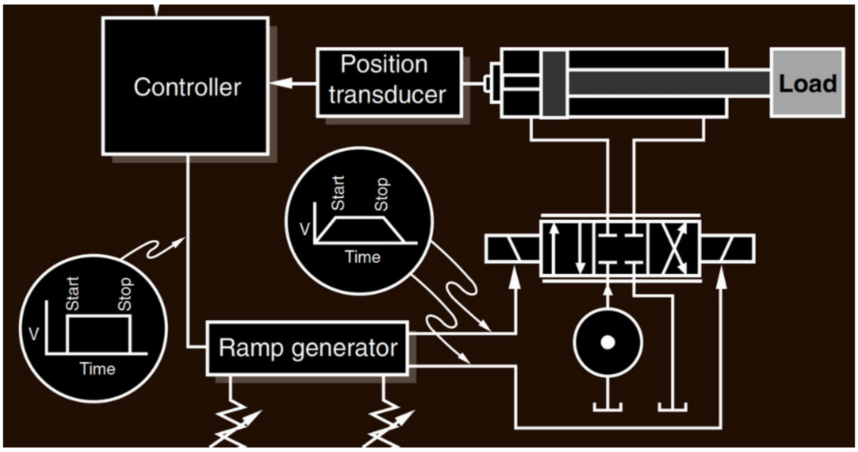

Fig. 9 – Electro-proportional control process of operate of hydraulic rod speed technology

So, after the putting tool of rock breaker boom with hydraulic hammer to crush oversize we need to remain tool back to own regular place to avoid the damage for boom system after the starting of transportation line again.

After the finishing of process we need to make control analysis with 3D-scanner sensor again. It helps us confirm, that our problem was solved, oversize was crushed, remain parts was processed by jaw crusher. In case of remain parts also make a problem with jamming, we need to start all the cycle again.

For the ability of hand operation of rock breaker boom system with hydraulic hammer there is available to set there a camera with high resolution from several sides of view. Camera allow to operate remotely by the operator all needed job for the installing of tool and crush of oversize. All data possible to send through by Ethernet/Internet to any place of the world to central office, let to control and operate by one person with several the same equipment to rise effective.

3. Conclusion

Automation of process at each stage of production line or minning process, especially this case we had considered in our work, allow to move progress ahead and help to make a human as a main key element of chain in the creating process, for make and operate new technologies, sometime maintenance and repair processes. By the way all "dirty" job human made before possible to give to robots to except a hard work and direct free abilities and resources to intellectual job with every year of higher effective and productivity, profit of each family. Today this is a most actual target for all science in the world.

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Improvement of the Organization of Maintenance And Repair of Dump-Cars

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Abstract. The authors of the article found that, depending on the level of carrying capacity and the costs of maintenance and P, the entire fleet of dump trucks can be divided into two groups, differing in costs by 10% or more. It is shown that the established dependence of the probability of a truck dump failure on the ratio of the transportation distance to the weighted average slope of the route allows us to predict the magnitude of these failures. It was revealed that the level of trouble-free operation of mining dump trucks is determined mainly by the reliability of the group of the most important dump truck components, which includes a compressor, a water pump, a generator, and an engine starter, as well as a driveline. The effectiveness of the organization in the quarries of mobile diagnostic laboratories and auto repair shops is shown. To monitor the operation of the main units of dump trucks, it is proposed to use an information system and an algorithm for its functioning is developed. As a result of the developed organizational measures introduced at the Bogatyr Komir quarry using the information system, it was possible to reduce maintenance and P costs by 18%.

Keywords: dump truck, repair, maintenance, failures

1 Introduction

Maintenance and repair of mining dump trucks are the necessary organizational and technical measures that are carried out when defects are detected in the dump truck during preventive maintenance or during any breakdowns during operation.

To maintain the truck in constant readiness, it is necessary to periodically carry out its maintenance and repair (MOT and R), which have a decisive influence on the performance of mining vehicles, as well as determine the duration of its downtime.

Due to the maintenance of M and R, downtimes of dump trucks, as shown by literature [1], makeup 20-30% of the calendar time, and the costs of maintenance and R depending on the load capacity of dump trucks reach 29-32% of the total operating costs [2] (Fig. 1). At the same time, the share of the number of workers engaged in the repair of technological vehicles ranges from 17 to 20%.

It is necessary to note the peculiarity of the data recorded in Figure 1, which consists in the fact that depending on the loading capacity of dump trucks, there is a sharp separation of them by the costs of maintenance and R. For dump trucks with a lifting capacity of 32 - 68 tons, the costs of maintenance and R are on average 40%, for dump trucks with a loading capacity of 91 - 204 tons - already only 30%. This state of affairs in the field of operating costs is since for dump trucks with a carrying capacity of more than 91 tons, the costs associated with the repair and replacement of tires increase sharply.

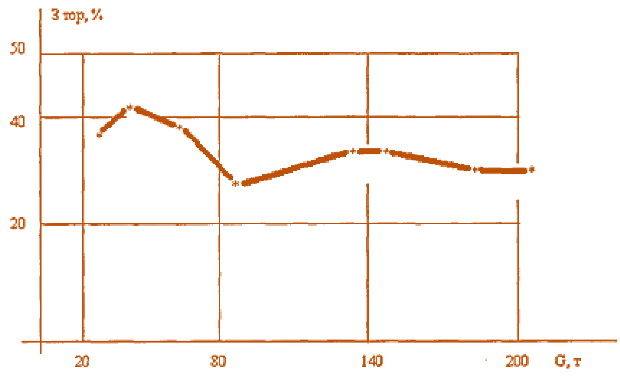


Fig. 1 - Change in operating costs for maintenance and repair of dump trucks, depending on their carrying capacity

The operational experience of diesel engines installed on dump trucks shows that violation of regulatory values at which their normal operation is possible leads, as a rule, to various kinds of engine failures.

At the same time, as shown by the data on the determination of the in-shift reliability of the BelAZ dump truck engines, expressed by the likelihood of an in-shift failure due to various malfunctions associated with the diesel engine that was received at the Sokolovsko-Sarbaisky and Inguletsky mills when transporting ore with a density of about 3.5 t/m^3, this value is largely determined by the transportation distance and the value of the weighted average slope of the ore transportation route [3]. These data are shown in tables 1 and 2.

Table 1 - Data on determining the intrashift reliability of the BelAZ dump truck engines

Dump truck working conditions		The probability of intra-engine failure, fractions of units.
Transportation distance (L), km	Weighted Slope (a), %	
Sokolovsko-Sarbaisky Combine		
1,3	3,20	0,063
2,1	3,20	0,071
2,0	5,30	0,094
2,2	7,10	0,134
Inguletsky Combine		
0,40	2,00	0,051
1,80	1,82	0,066
2,30	4,80	0,098
1,2	2,15	0,067
1,7	6,50	0,113

An analysis of these data shows that there is no stable correlation between the probability of an intra-shift engine failure and the ore transportation distance. However, the general tendency to increase in-shift engine failure is observed with increasing transportation distance. It should be noted the significant role of the weighted average slope of the route, an increase in which corresponds to an increase in the intra-shift engine failure (see table. 2. and Fig. 2).

Table 2 - Values of weighted average slope of the track,%

W_o	0,066	0,051	0,067	0,063	0,071	0,098	0,094	0,113	0,134
a	1,82	2,0	2,15	3,2	3,2	4,8	5,3	6,5	7,1

An analysis of these data shows that the intra-shift engine failure increases sharply (1.4–1.5 times) with an increase in the average weighted slope of the track.

Thus, the presence of such a causal relationship between the value of the average weighted slope of the route and the value of the intra-shift engine failure characterizes both the operation of the vehicle itself and the real conditions in which it operates, and allows us to use this relationship as a justification for the predicted value of the intra-shift engine failure of dump trucks conducting sophisticated statistical research.

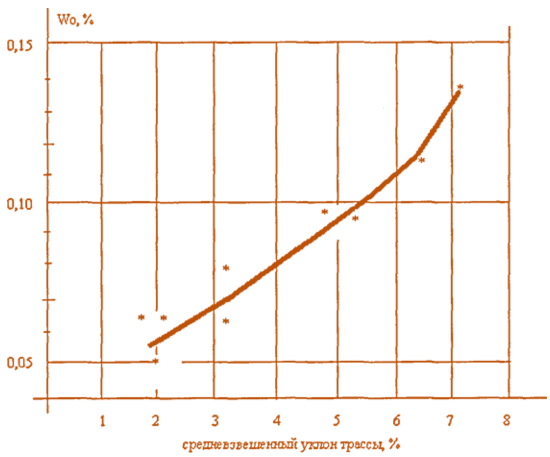


Fig. 2. - The dependence of the magnitude of the intra-shift engine failure of the truck on the value of the average weighted slope of the track

Studies have established [4] that the costs of maintenance and P increase as the service life of the truck is increased, while they are determined by the costs of maintenance and P at the beginning of operation of the truck, as well as the coefficient of the intensity of the costs of maintenance and P as the vehicle mileage increases to its cancellation.

Practice shows that the wear of heavy dump trucks during operation is different at different quarries and depends on both mining (quarry depth, volumetric weight, rock formation, etc.), and on the road and climatic conditions. At the same time, the failure rate for individual components and assemblies of the dump truck sharply differ, which leads to a different frequency of their service. The criterion for determining the frequency of service is considered to be not the hours of operation of the dump truck, but its mileage in kilometers. So, for example, at the Bogatyr Komir quarry, the uptime of the most unreliable dump truck unit (Cardan transmission) is only 900-1000 km, and the most reliable (front brake pads) is 7000-9000 km (Table 3).

Table 3 - The uptime data of the most unreliable dump truck assembly (cardan transmission)

Unit	Average failures per shift	Uptime - mileage, km
Cardan drive	0,089	900-1000
Starter	0,053	1400-1500
Water pump	0,044	1800-1950
Compressor	0,041	1950-2100
Generator	0,024	3250-3400
Fuel system	0,017	4500-4700
Hydromechanical system	0.017	4500-4700
Cylinders air suspension	0.014	5400-5600
Front brake pads	0,011	7200-9000

Indeed, the more complex the dump truck assembly in its design, the higher the average number of failures per shift.

On the other hand, the intra-shift reliability of the dump truck as a whole is largely determined by the transportation distance and the average weighted slope of the ore transportation route. This value was determined for the conditions of the Sokolovsko-Sarbaisky and Inguletsky plants when transporting ore with a density of about 3.5 t / m3 [4]. These data are shown in table 4.

Table 4 - The data on the probability of the intra-shift failure of the truck and the transportation distance

Dump truck working conditions		The probability of an intra-shift failure of a dump truck, fractions of units
Transportation distance (L), km	Weighted average slope (a),%	
Sokolovsko-Sarbaisky Combine		
1,3	3,20	0,0225
2,1	3,20	0,0186
2,0	5,30	0,0243
2,2	7,10	0,0305
Inguletsky Combine		
0,40	2,00	0,0326
1,80	1,82	0,0194
2,30	4,80	0,0229
1,2	2,15	0,0234
1,7	6,50	0,0322

An analysis of these data shows that there is no stable relationship between the probability of the intra-shift failure of the truck and the transportation distance, as well as the weighted average slope of the track, which could be approximated by an analytical relationship.

On the other hand, the intra-shift reliability of the truck as a whole is largely determined by the ratio of the transportation distance (L) and the weighted average slope of the track (a). In this case, the probability of failure in the truck can be described by the formula (1):

$$W = 0{,}017 + 0{,}003 / (L/\alpha) \quad (1)$$

With values of 0.6 <L / α <l (km /%), the probability of an intra-shift failure W tends to an almost constant value equal to 0.02 (Table 5 and Fig. 3).

Table 5 - The probability of intra-shift failure,%

W	0,0194	0,0186	0,034	0,0229	0,0225	0,0243	0,0305	0,0322	0,0326
L/α	1	0,65	0,56	0,48	0,41	0,38	0,31	0,26	0,2

Thus, the presence of a stable causal relationship between the considered parameters characterizing both the operation of the vehicle itself and the real conditions under which it operates allows this dependence to be used as a justification for the predicted value of the intra-shift failure of dump trucks without conducting complex statistical studies.

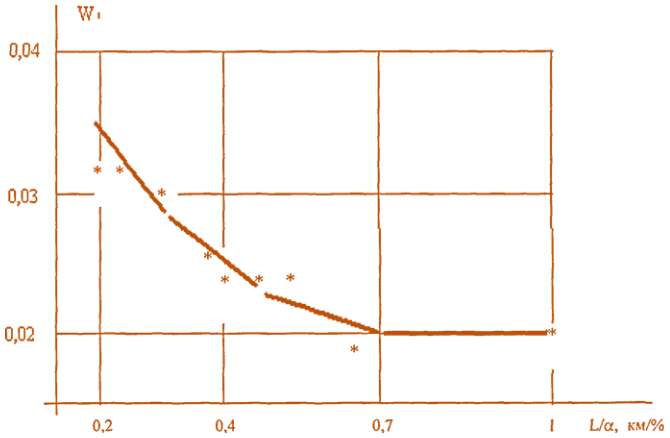


Fig. 3. - The dependence of the magnitude of the intra-shift engine failure of the truck on the value of the average weighted slope of the track

Results and discussion. To improve the operational characteristics of the dump truck at the Bogatyr Komir mine, an improvement was made in the maintenance system and R.

Firstly, during the repair and maintenance of dump trucks, the “Regulation on the maintenance, diagnosis, and repair of BelAZ mining dump trucks with a lifting capacity of 75 tons or more" was used as the main regulatory document [5].

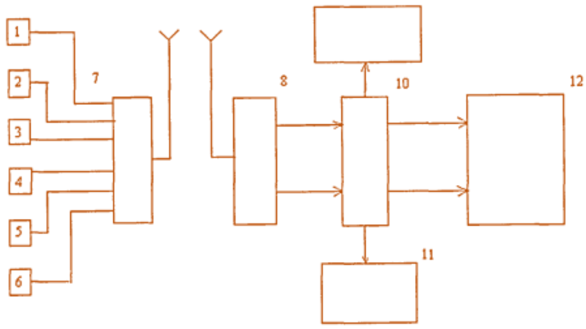
Secondly, the so-called regulated the repair is adopted as the basis of maintenance and repair, and not unscheduled maintenance on demand, when repair is carried out only in case of failure of a unit or assembly, i.e. from the "wheels". This measure was taken to reduce material costs for eliminating this type of damage, as well as to reduce downtime of dump trucks.

Thirdly, the TS and R system is based on diagnostic data, which allows repairing only dump trucks with almost fully used technical resources.

Specifically, the improvement of the TS and R systems was implemented in the following three directions:

- widespread use of diagnostic methods for the technical condition of the truck in real-time;
- organization of a mobile diagnostic laboratory;
- improving the system of accounting, processing, and analysis of data on the operation of mining vehicles and predicting the time of failure.

Currently, TS and R are fundamentally changing due to the widespread use of electronic systems that continuously monitor the life functions of a dump truck. A typical diagnostic system installed on dump trucks operating on the Bogatyr Komir mine consists of sensors based on a microprocessor and designed for harsh operating conditions on heavy dump trucks, monitoring electronic devices, the information from which is transmitted in the form of a database to an automated operational management system characteristics of vehicles, and then directly to the dispatcher in real-time (Fig. 4). Each sensor gives an alarm in the event of an emergency. As shown above, the group of the most important dump truck units includes a compressor, a water pump, a generator and an engine starter, as well as a Cardan drive, therefore, according to the prepared recommendations for the maintenance of dump truck components and assemblies, it is recommended that you first control 11 parameters of the internal combustion engine of which the most significant are engine speed, oil level, and engine pressure, increased pressure in the crankcase, battery voltage, and others.



1 - speed sensor, 2 - oil level sensor, 3 - engine pressure sensor, 4 - crankcase pressure sensor, 5 - battery voltage sensor, 6 - temperature sensor, 7 - microprocessor, 8 - amplifier, 9 - emergency status display, 10 - integrator, 11 - computer, 12 - subroutine

Fig. 4 - Diagnostic system that controls the operation of dump trucks

Recently, the so-called vibroacoustic method has been tested as a diagnostic method, based on measuring the movement, speed, and acceleration of the mechanism, as well as spectral-acoustic analysis [6].

The peculiarity of this method is that it is an indiscriminate method for diagnosing diesel mining dump trucks, which allows you to save the resource of its constituent elements. The essence of the method is based on the fact that in a diesel engine, vibrations are generated by a crank mechanism, a fuel supply system, a valve-distributing mechanism, a combustion process, a diesel start-up system and other units. These vibrational vibrations form the acoustic spectrum of the engine, which, as the diesel engine runs and its elements wear, naturally transforms, and the degree of wear of one or another diesel engine is reflected in the acoustic spectrum parameters. Deciphering the acoustic spectrum allows you to accurately determine the specific type of defect that changes the spectrum, and determine the degree of its influence on the stable operation of the diesel engine.

As a diagnostic tool, VAM vibration analyzers manufactured by Russian manufacturers were used. At the same time, piezoelectric accelerometers were used as sensors receiving the vibration signal.

A mobile diagnostic laboratory is designed to reduce the cost of repairing parts, components and assemblies of a dump truck and has been used for in-car care of dump trucks. The diagnostic laboratory is called by radio in case of malfunctions and damage to dump trucks directly in the field.

The mobile laboratory was located on the UAZ car chassis and is equipped with additional acoustic equipment such as VAM vibration analyzers. The interpretation of the obtained acoustic spectra was carried out on site.

Diagnostics was carried out both during idle operation of the engine and in the variant of test diagnostics, in which test actions are applied to the idle engine, which minimizes the noise of the vibroacoustic signal. Based on the results of the diagnostic laboratory, depending on the type of malfunctions and the complexity of their elimination, a decision is made either on field repair using a mobile repair shop or on the stationary repair.

A mobile repair shop is formed on the basis of a special machine equipped with a hydraulic-controlled crane, an air compressor, oxygen-acetylene welding equipment, etc. The result of the joint work of the mobile diagnostic laboratory and the repair shop was an 18.4% reduction in the downtime of mining dump trucks (Table 6) compared with the same functional operations carried out in stationary conditions of the repair shop.

Table 6 - Downtime data for mining dump trucks

Year of exploitation tions	Annual mileage, thousand km	Downtime for repair, h	Specific downtime for repairs, h / 100 moto-h	
	BelAZ -7512	BelAZ -7512	BelAZ -7512	Normative
2017	24,4	364	20,6	26,2
2018	25,6	432	22,1	26,2
The average	25	398	21,35	26,2

Conclusion. Using the information system that allows you to determine the mileage of the truck in kilometers, as well as sensors that monitor the most important parameters of the engine, the operation of the most important components of the dump truck (engine, driveline, generator, brake pads, etc.) is tracked and displayed in the database in the dispatch center. The current mileage of the dump truck is compared with the standard duration of the failure-free operation of its units, while a control signal is generated when the excess of the current mileage reaches 5%. In this case, the dispatcher warns the repair services about the need for an appropriate type of maintenance or sends a mobile diagnostic laboratory and a car repair shop to monitor the operation of the dump truck unit and, if necessary, repair it directly in the context.

As a result of all organizational measures aimed at minimizing the costs associated with the maintenance of mining dump trucks at the Bogatyr Komir mine and their repair, we obtained the following dynamics of changes in operating costs for maintenance and repair, which shows that for the period 2017-2018. due to the organizational and technical measures taken, it was possible to reduce operating costs by 18% for maintenance and P mining dump trucks.

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The study of the flow characteristics of a hydraulic rotary hammer

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Abstract. The article is devoted to the study of the flow characteristics of a hydraulic rotary hammer. During the study, a calculation was made of fluid flow in each phase of the working cycle. Based on the calculation results, a flow diagram of the fluid flow was compiled.

Key words: hydroperforator, fluid flow rate, striker speed, duty cycle

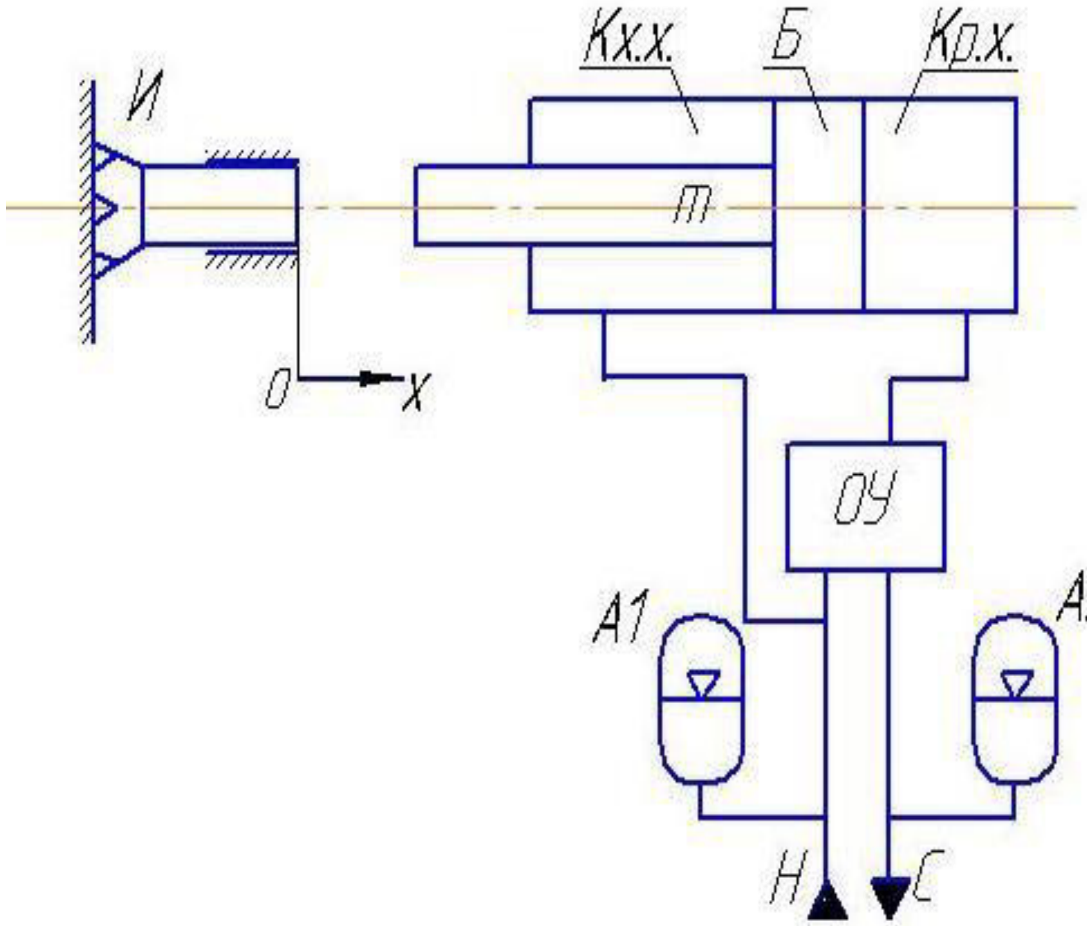
1. Introduction

A Hydraulic rotary hammer is designed for drilling holes and wells in rocks.

Scientists of KSTU developed the GP-206 hydroperforator, which is used on drilling carriages and drilling rigs during underground mining of mineral deposits.

The main tasks in the study of hydraulic shock machines are the study of the duty cycle, i.e. determination of its output parameters: impact energy, impact frequency, working cycle time, moving striker, consumption consumed in phases.

Figure 1 shows the structural diagram of the GP-206 hydroperforator, which consists of the following elements: hammer, tool, dispenser, hydropneumatic accumulators, travel chamber, idle chamber [1].



Б - firing pin; *m* - the mass of the striker; $K_{p.x.}$ – a chamber of a working course; $K_{x.x.}$ – idling chamber; *И* – tool; *ОУ* – governing body; *A1, A2* –hydropneumatic accumulators

Рис. 1 – Структурная схема гидроперфоратора с управляемой камерой рабочего хода

Technical characteristics of the GP-206 hydroperforator:

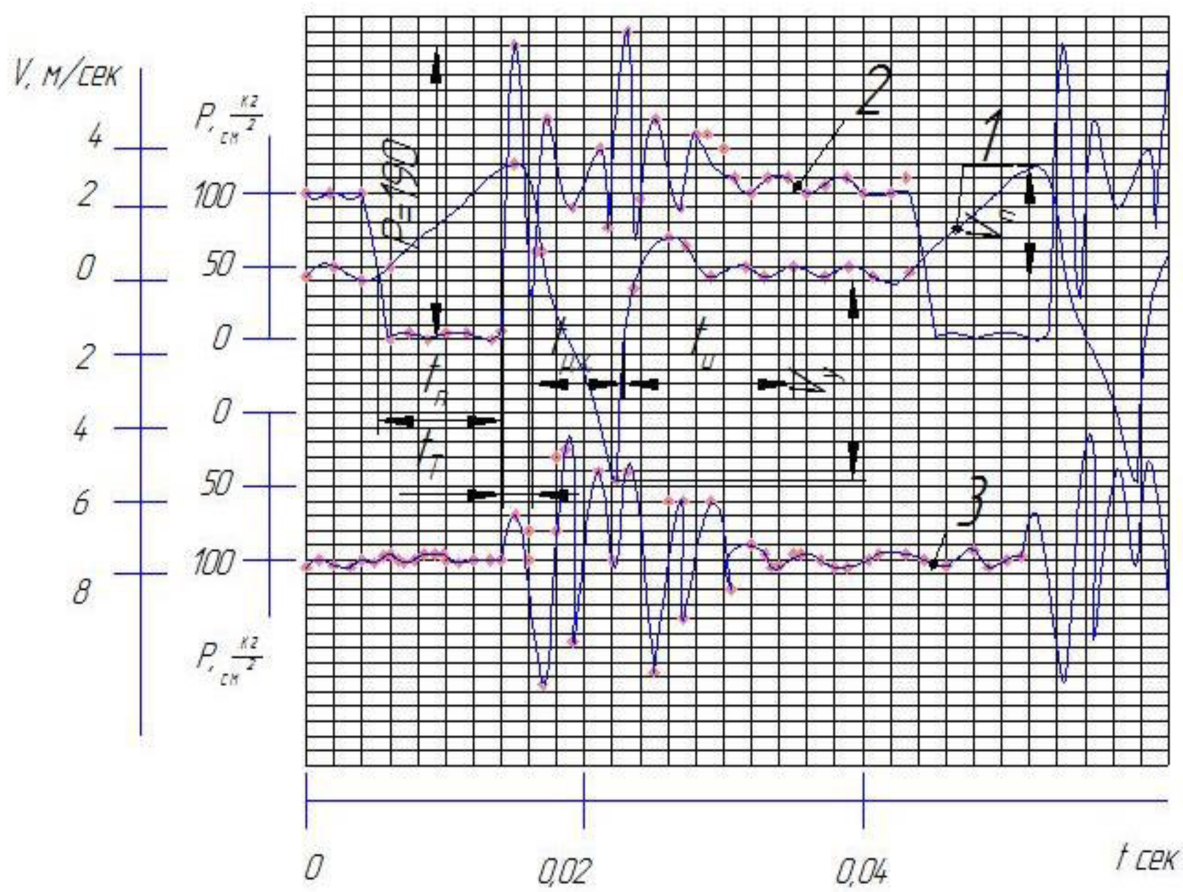
1) Impact energy, 1kJ;
2) Impact frequency, 3000 beats / min;
3) The pressure of the working fluid, 10 MPa.

This hydroperforator has a rotating spool, which drives the hydraulic motor.

The operation of a hydraulic rotary hammer is characterized by a cycle asymmetry: idle (reverse) stroke is completed in a longer period of time than a worker. During the working stroke, the actuator is informed of accelerated motion, due to which it acquires significant energy in relatively small areas of displacement, which is realized at the end of the stroke in the process of shock loading of objects [2].

2. The study of the working cycle of the hydroperforator GP-206

In the process of testing the GP-206 hydroperforator, an oscillogram was obtained (Figure 2), k_n = 1.2 — spool overlap coefficient. The model is designed for the following parameters: impact energy A = 1 kJ, the period of oscillation of the striker T = 2·10-2 s; impact velocity υ_y = 8 m / s and working fluid pressure P = 10 MPa.



T- the cycle time; t_n - phase of the return of the striker; $t_т$ - phase of braking; $t_{p.x.}$ – phase of the stroke; $t_и$ – phase of interaction of the striker with the instrument; 1 - change the speed of the striker; 2 – change in pressure in the working chamber; 3 – pressure change in the idle chamber

Fig. 2 - Waveform of the GP-206 hydroperforator

T is the cycle time; tn-phase of the return of the striker; TT phase of braking; tr.x. - phase of the stroke; "t" _ "and" - phase of interaction of the striker with the instrument. 1- change the speed of the striker; 2 - change in pressure in the working chamber; 3 - pressure change in the idle chamber.

The analysis of the waveform allows you to determine the following parameters [3]:
- the UHC duty cycle is determined by the formula (1):

$$T=t_n+t_т+t_{p.x} + t_и, \quad (1)$$

where t_n is a striker return phase, s;
$t_т$ *is* a braking phase, s;

$t_{р.х}$ is a phase of the stroke, s,
$t_{и}$ is a phase of the interaction of the striker with the instrument, s.

$$T = 0{,}01 + 0{,}002 + 0{,}0064 + 0{,}012 = 0{,}0304 \text{ s.}$$

- the striking frequency of the striker is determined by the formula:

$$n=\frac{1}{T}; \quad (2)$$

$$n=\frac{1}{0{,}0304}=33 \ \frac{об}{с}.$$

- the volume of the rear chamber of the UHF is determined by the formula:

$$q_{ц2}=\frac{1}{2}\cdot Q_{ц2}\cdot t_{в}, \quad (3)$$

where $Q_{ц2}$ is a rear camera consumption, $\frac{m^3}{s}$,
- the rear camera flow rate is found by the formula:

$$Q_{ц2} = S_{р.х}\cdot\vartheta_{р.х.}, \quad (4)$$

where $S_{р.х}$ is a stroke chamber area, m^2;
$\vartheta_{р.х.}$ is speed in the travel chamber, m/s,

$$Q_{ц2} = 0{,}00105 \cdot 3=0{,}00315 \ m^3/s;$$

$$q_{ц2}=\frac{1}{2}\cdot 0{,}00315\cdot 0{,}01=0{,}016\cdot 10^{-3} \ m^3.$$

- determine the flow rate by the formula:

$$Q=\frac{q}{\eta}, \quad (5)$$

where η=0,9 – volumetric efficiency,

$$Q=\frac{0{,}016\cdot 10^{-3}}{0{,}9}=0{,}0178\cdot 10^{-3} \ \frac{m^3}{s}.$$

- determine the impact energy by the formula:

$$A=\frac{\vartheta_y^{\,2}\cdot m}{2}, \quad (6)$$

where ϑ_y – shock velocity, m/s;
m – mass striker, kg,

$$A=\frac{7^2\cdot 11{,}65}{2} = 285{,}5\,J$$

- determine the stroke of the striker according to the formula:

$$h=\frac{\vartheta_y\cdot T}{2\cdot(i+\tau)}; \quad (7)$$

$$h=\frac{7\cdot 0{,}0304}{2\cdot(1{,}6+2{,}9)}=0{,}024 \text{ м},$$

where i and τ are kinematic parameters are determined by the formulas (8), (9),

$$i=\frac{t_n}{t_p}; \quad (8)$$

$$i=\frac{0,01}{0,0064}=1,6.$$

$$\tau=\frac{t_p+t_u}{t_p}; \quad (9)$$

$$\tau=\frac{0,0064+0,012}{0,0064}=2,9.$$

In the return phase, the battery is charging. In the braking phase of the striker, the battery is charged both from the pump and from the UHC, which gives the kinetic energy of the striker through the fluid from the rear chamber. This process continues in the phase of the stroke. Next, the battery is discharged, covering the shortage of pump flow during accelerated movement of the striker.

The optimal characteristics of the working cycle should ensure a minimum of losses during the passage of fluid through the channels connecting the UGD elements. The main energy-transforming design parameters of the volume of machines is their working volumes [4].

The pressure in the working chamber in the phase of return of the striker drops from 10 MPa to 0 MPa in the range over a period of time from 0.004 to 0.014 seconds. This is due to the fact that during the return of the striker, the working fluid goes into the drain pipe. The minimum pressure in this phase reaches 0 MPa.

In the second phase, the braking of the striker occurs, as a result of which there is a sharp pressure jump up to 19 MPa. In the time intervals from 0.014 to 0.016 seconds.

In the third phase, the striking stroke occurs, which is characterized by pressure surges from 5 to 19.5 MPa. This is since the spool switches. The running time is 0.0064 seconds.

In the fourth phase, the striker interacts with the tool; the pressure in this phase jumps from 5 to 20 MPa. The time of this phase is 0.012 seconds. Next, the cycle repeats.

The pressure in the idle chamber in the return phase is kept at a certain level with relatively no jumps. The maximum pressure in this phase reaches 10 MPa.

In the braking phase, a sharp pressure jump up to 19 MPa occurs. In the time intervals from 0.014 to 0.016 seconds.

In the third phase, a working stroke occurs, which is characterized by pressure surges from 6 to 18.5 MPa. The stroke time is 0.0064 seconds.

In the fourth phase, the striker interacts with the tool; the pressure in this phase jumps from 5 to 18 MPa. The time of this phase is 0.012 seconds. Next, the cycle repeats.

Change in the speed of the striker: at the moment of switching control, the braking of the striker is sharply braked, as evidenced by a larger angle of the slope of the speed curve in the braking phase than in the phase of the working stroke. The duration of the braking phase is short and amounts to t = 2·10-3 s. Due to the sharp braking, the striker stroke decreases and in the phase of the stroke, the striker accelerates to a speed Vy = 7 m/s lower than the calculated one (8 m / s), which reduces the energy capabilities of the mechanism. Excessive burst of pressure in the chamber of the stroke does not occur [5].

3. Consumption characteristic of the GP-206 hydro perforator

According to the oscillogram, we compose the flow characteristic of the hydraulic perforator.

The fluid flow rate is the amount of fluid flowing through a living section of a stream per unit time. The fluid flow rate is characterized as a value that is defined as the product of the cross-sectional area of the piston and its speed.

Flow rate = cross-sectional area · travel speed.

$$Q=S\cdot\vartheta. \quad (10)$$

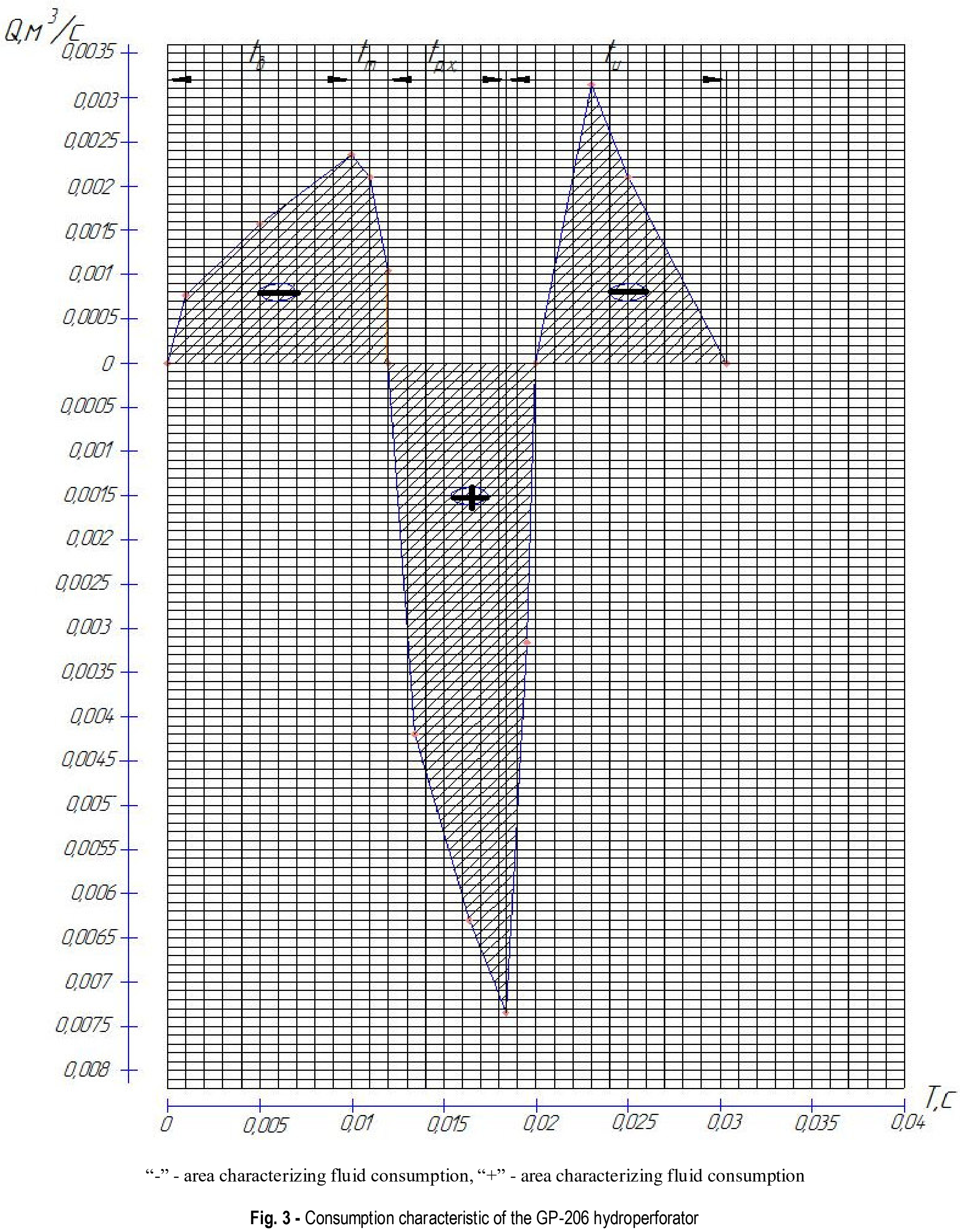
where S s a cross-sectional area, m2;

ϑ is a displacement speed, m / s [6].

Figure 3 shows a flow rate diagram. The area under the lines characterizes the fluid volumes of the hydraulic perforator in the corresponding phase.

During the return, the striker initially moves with acceleration from 0 to 3 m/s, thereby increasing the flow rate from 0 to 0.002355 m^3/s, then in the braking phase, the striker slows down from 2 to 1 m/s, while the flow rate decreases with 0.0021 to 0.00105 m^3/s. This is because as the striker moves, the pressure in the drain hydro line and the drain accumulator increases, i.e. the pressure from the side of the working cavity increases, the hydro accumulator included in the pressure line is also charged. During the transition process, the distributor switches, brakes and stops the striker, battery charging is completed. In these phases, the fluid is consumed, which can be seen in the flow characteristics of the hydraulic perforator.

During the working stroke, liquid from the battery and power source is supplied to the working cavity, as a result of which the firing pin accelerates from 0 to 7 m/s, the flow rate increases to 0.00735 m^3/s and strikes the tool. This phase is characterized by fluid flow. Then there is a further transfer of the kinetic energy of the hammer to the tool and switching of the distributor.



"-" - area characterizing fluid consumption, "+" - area characterizing fluid consumption

Fig. 3 - Consumption characteristic of the GP-206 hydroperforator

1 – striker return phase.

$$Q = S_{x.x.} \cdot \vartheta_б, \quad (11)$$

$S_{x.x.}$ is the idle area, $S_{x.x.} = 0{,}000785$ m^2;
$\vartheta_б$ is the striking speed, $\vartheta_б = 0; 1;2;3$ m/s.

Table 1 – The dependence for the striking return phase

Q (m^3/c)	0	0,000785	0,00157	0,002355
T(s)	0	0,001	0,005	0,01

2 – braking phase.

$$Q=S_{p.x.}\cdot\vartheta_{б}, \tag{12}$$

$S_{p.x.}$ is the idle area, $S_{x.x.}$= 0,00105 m^2;
$\vartheta_б$ is the striking speed, $\vartheta_б$= 2;1 m/s.

Table 2 - The dependence for braking phase

Q (m^3/s)	0,0021	0,00105
T(s)	0,011	0,012

3 - stroke phase.

$$Q=S_{p.x.}\cdot\vartheta_{б}, \tag{13}$$

$S_{p.x.}$- is the idle area, $S_{p.x.}$= 0,00105 m^2;
$\vartheta_б$ – is the striking speed, $\vartheta_б$= 0;4;6;7 m/s.

Table 3 - The dependence for stroke phase

Q (m^3/s)	0	0,0042	0,0063	0,00735
T(s)	0,012	0,013	0,0164	0,0184

4 – phase of the interaction of the hammer with the tool

$$Q=S_{p.x.}\cdot\vartheta_{б}, \tag{14}$$

$S_{p.x.}$ is the idle area, $S_{p.x.}$= 0,00105 s^2;
$\vartheta_б$ – is the striking speed, $\vartheta_б$= 3;0;1,3;2;0 m/s.

Table 4 - The dependence for phase of interaction of the hammer with the tool

Q (m^3s)	0,00315	0	0,00315	0,0021	0
T(s)	0,0195	0,02	0,023	0,025	0,0304

The fluid intake per cycle is determined by the formula (15):

$$W_ж = \frac{А_{уд}}{Р_Н}; \tag{15}$$

where $А_{уд}$I s the impact energy, J;
$Р_Н$ – pump pressure, Pa.

$$W_ж = \frac{1\cdot 10^3}{10\cdot 10^6} = 0{,}1\cdot 10^{-3}м^3.$$

The energy loss is determined by the costs, the values of which in different phases depend on the parameters of the duty cycle, determined by the ratios of the phases time, acting forces and speeds [7].

4. Conclusion

In shock hydraulic motors, the working fluid is an energy carrier, due to which a connection is established between the pump and the hydraulic motor. In addition, the working fluid provides lubrication of the moving parts of the elements of the hydraulic perforator.

This study allowed us to identify how much hydraulic fluid a perforator consumes in one working cycle, with a positive spool overlap. Leaks at this overlap are minimal.

In the return phase of the striker, the fluid flow rate is 0.002355 m^3/s. In the phase of the stroke, 0.00735 m^3/s. In the phase of the interaction of the striker with the tool 0.0021 m^3/s.

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