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Content

Studying Structure and Stress Fields in "Grinding Ball" Casting

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Abstract: The article describes the analysis of the failure causes for the grinding balls. The article shows the microstructure of the grinding balls. The chemical composition of the alloy with the introduction of alloying elements was selected. An experiment to adjust the composition of the alloy to improve the physico-mechanical properties of the grinding balls was carried out. Analysis of alloying elements found that an increase in manganese and nickel has a positive effect on toughness. Additionally, titanium was introduced to reduce the strength of the alloy structure and increase its plasticity. The experimental alloy was subjected to heat treatment (normalization at 900 ºC). The number of grinding balls with wear surface more than 5% increased slightly. The resulting alloys have a homogeneous structure and less disorientation of the carbide phase with respect to the matrix. Stress studies in the sample structure were carried out. The experiment was conducted to determine the level of stresses in alloy samples. The experiment found that there were no casting defects in the body of the casting bodies. This allows you to increase the resistance to impact loads and the strength of the grinding balls.

Keywords: grinding ball; ledeburite; perlite; cementite; carbide; impact strength

1. Intorduction

Grinding balls are a necessary element of equipment for grinding and crushing ores. In the Kazakhstan market there are mainly presented cast grinding balls made of wear-resistant high-chromium cast irons of types IHC-28 (Fig.1), since their cost is much lower than that of rolled steel balls. The analysis of the causes of grinding balls failure [1 - 3] shows that the main reason is not wear of the ball surface but the chipped surface or the complete fracture of the ball.

Fig.1. - The piercing of balls ø100 mm (about 75% of the spherical surface) in an lattice mill ball is 3.2 × 3.1, n = 18 rpm

In operation grinding balls have two main loads: abrasive and impact [4]. Therefore, to ensure long-term operation of the balls, they are to possess high hardness, strength, wear resistance and sufficiently good impact strength to resist impact loads.

It should be noted that the balls made of high-chromium cast irons possess high strength properties but their impact toughness is low. This is due to the fact that the structure of high-chromium cast irons is represented by ledeburite and complex carbides of iron and chromium of the Me_3C type (Fig. 2).

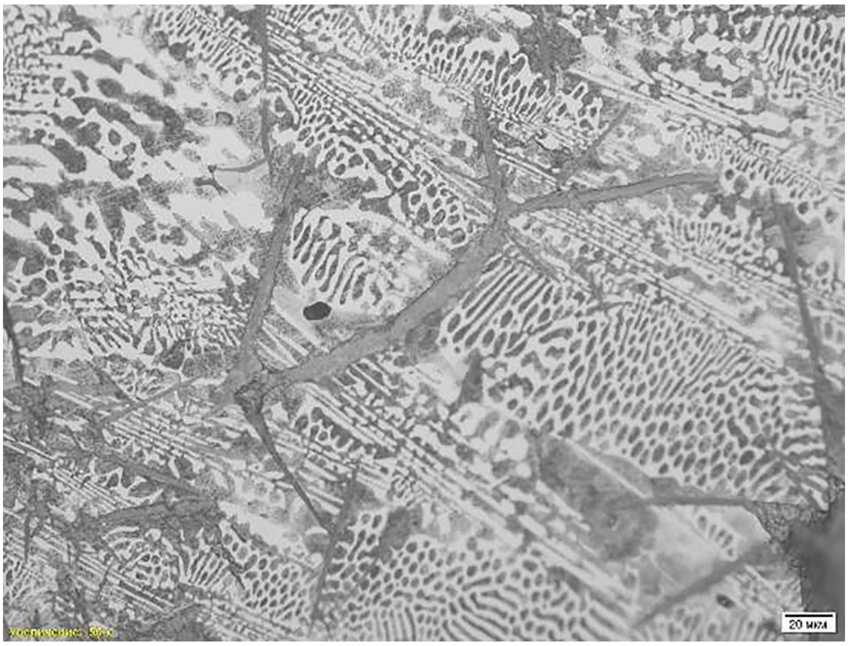

Fig.2. - IHC-28 cast iron structure, ×500

The structure is represented by rather coarse components, cementite lamellae are wide and long. Structural components possess high hardness, especially carbide, while their toughness is low. Ledeburite that contains perlite also does not possess toughness, since its matrix - doped α-solution possesses high hardness. According to equation [5]:

$$\Delta\sigma_{т} = \Sigma_{i=1}^{n} K_i^f C_i^f \ , \tag{1}$$

where K_i^f is the coefficient of ferrite hardening;

C_i^f is the concentration of the i-th doping component diluted in ferrite.

The increasing the value of ferrite hardening due to doping will be 12390 MPa/1%.

The calculation was made on the basis of the fact that the percentage of chromium conversion to ferrite is 30, the rest of chromium is spent for forming carbides [5 - 7]. The lump size of cementite can also cause an increased stress field in the structure, which is conditioned by high disorientation of the cementite needles and ledeburite colonies boundaries [8 - 10].

2. Experiments

The purpose of this study is adjusting the composition of wear-resistant cast iron in order to increase toughness while maintaining high hardness and wear resistance. Wear-resistant cast iron of the IHC-28 grade was chosen as the base alloy as the most popular for the production of grinding balls. The analysis of the alloying elements effect on the structure and α→ γ transformation showed that increasing the content of manganese and nickel leads to stabilization of the γ-solution, and nickel also has a positive effect on toughness. Reducing the chromium content in the alloy leads to decreasing the amount of chromium carbides, which, in fact, provide high hardness.

However, decreasing the proportion of chromium carbides can be compensated by the formation of carbides of the MeC type. In contrast to cementite type carbides, MeC carbides are smaller and spheroidal in shape, which results in lower structure stress and its greater plasticity. To this end Ti is additionally introduced to the alloy as a strong carbide former.

Under the effect of these factors there is formed a structure that corresponds to the Charpy principle [11]: a relatively tough and strong matrix with solid inclusions of the carbide phase. Such a structure is able to provide a complex of properties: hardness and wear resistance with sufficient viscosity [12].

In the experimental studies carried out an alloy of the following chemical composition was melted (Table 1).

Table 1 - Chemical composition of the experimental alloy

Element, %	C	Cr	Mn	Ti	Ni	Si
Experimental alloy 1	2.4	15	3.0	0.6	3.0	2.0
IHC 28	2.7	28	0.8	-	1.5	0.8

The alloy was poured into sand-clay molds [13] in the “Grinding Ball” castings with the diameter of 80 mm. Some of the balls were heat treated and normalized at 900 °C. The obtained balls were marked and loaded into the mill for testing, together with the balls made of IHC-28. The balls were used for coarse grinding of manganese ore from the Bogach deposit. After grinding within 14 hours, the experimental balls and the balls of the usual batch were withdrawn for inspection in the amount of 50 pieces for each batch. The balls were visually inspected for defects (Fig.3): cracks, chips, beats, splittings significant wear of the surface (more than 5% of the diameter).

Fig.3. - Cracks on the ball surface, leading to splitting and peeling of the surface

3. Results

Test statistics are shown in Table 2.

Table 2 - Statistics of experimental balls inspection after testing (pcs. for a batch consisting of 50 balls)

No.	Specimen	Beats number, pcs	Chips number, pcs	Wear of the surface more than 5%, pcs
1	IHC-28 (reference)	2	21	9
2	Experimental alloy	8	16	11
3	Experimental alloy after heat treatment	6	13	13

It can be seen from the data in Table 2 that the balls made of the experimental alloy were less exposed to beats and chips, however, the number of the balls with surface wear more than 5% increased slightly.

Changing the nature of the damage to the grinding balls is caused, first of all, by changing the structure of the alloy due to changing its composition.

Fig. 4 shows the microstructure of experimental alloy 2.

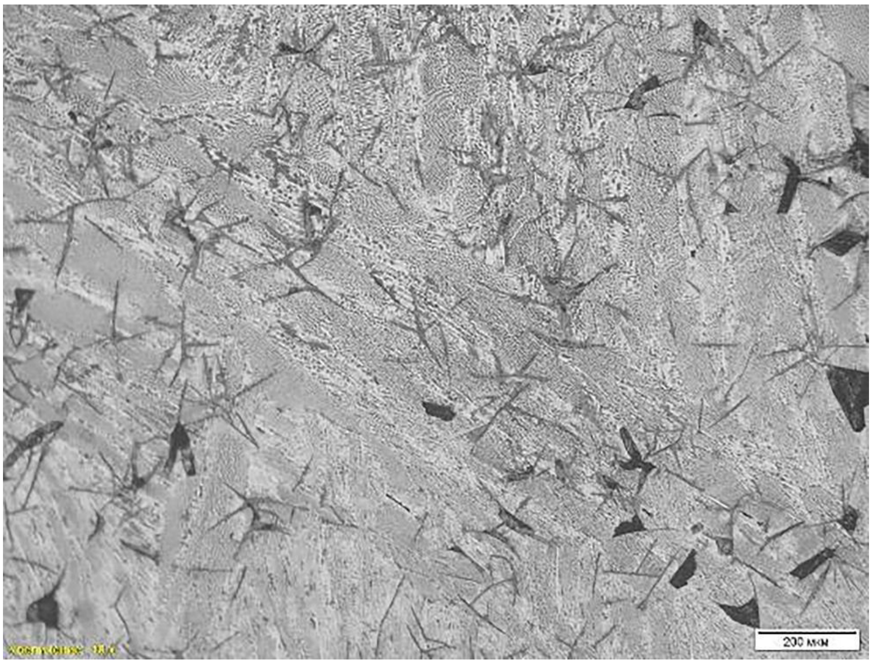

Fig.4. - Microstructure of alloy No. 2, ×500

Comparing the structures of specimens No. 2 and No. 1 (ICH-28) shows a coarser character of the IHC-28 alloy structure. In the experimental specimen ledeburite colonies are smaller, as well as cementite needles, the number of cementite needles is reduced, but a new phase appears: spheroidal carbides of the MeC type.

In order to eliminate the effect of casting defects on the rejected material statistics, there were studied stresses in the structure of specimens No. 1 and No. 2. The level of stresses was determined using a fluxgate magnetometer with a scanning device of the 1-8M type using magnetometric diagnostics.

4. Discussion

The presence of casting defects, inhomogeneity, coarse grains, segregation of impurities or non-metallic inclusions leads to changing the shape and level of the stress fields [14]. Common signs of stress concentration zones are:

- alternating distribution of the magnetic field in all the channels simultaneously;
- multiple changing the sign of the fringing field *H* in all the channels simultaneously at the distance that is smaller than two wall thicknesses;
- sharp heteropolar distribution of the H_p field across the channels or a sharp surge in one of the channels;
- uneven (possibly without a sign change) distribution of the field H_p with the maximum gradient *dH/dx* *.

Magnetic records of the studied specimens are shown in Fig. 5, 6.

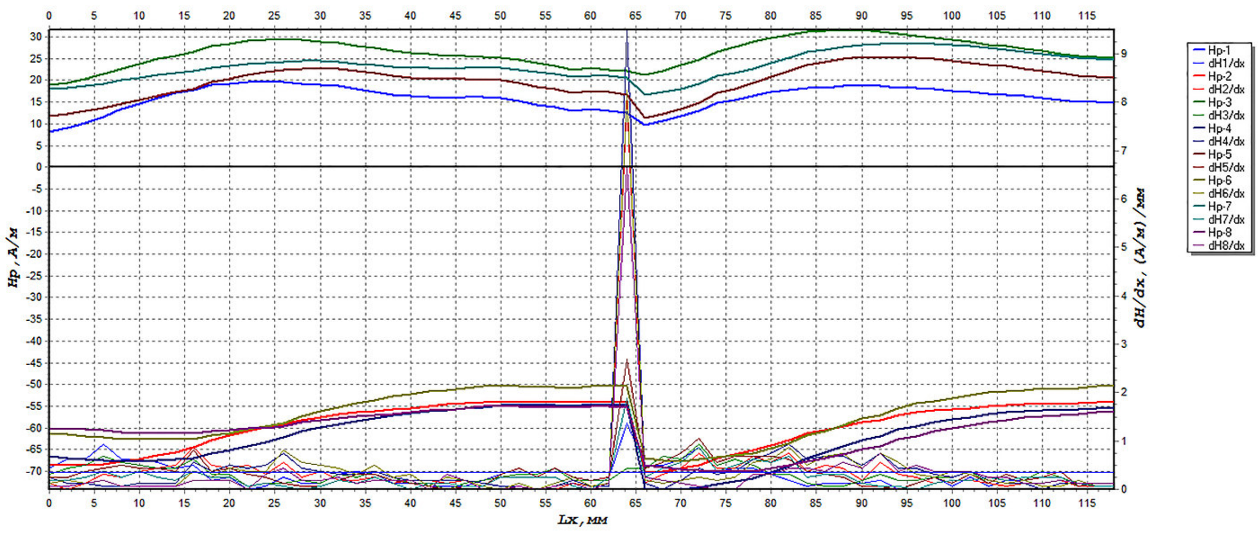

Fig. 5. - Magnetic record of specimen No. 2 (experimental alloy)

The magnetic field distribution H_p of the specimen is in general uniform, there are small negative anomalies with an amplitude of up to 65 A/m, which indicates the absence of casting defects in the casting body.

The maximum indicator of the magnetic field intensity H_p is within 32 A/m, the intensity of the field change along the length *dH/dx* is within 9.5 (A/m)/mm. A sharp peak in the center of the measured range is caused by changing the position of the specimen.

Figure 6 shows the magnetic record of specimen No. 1 (IHC-28).

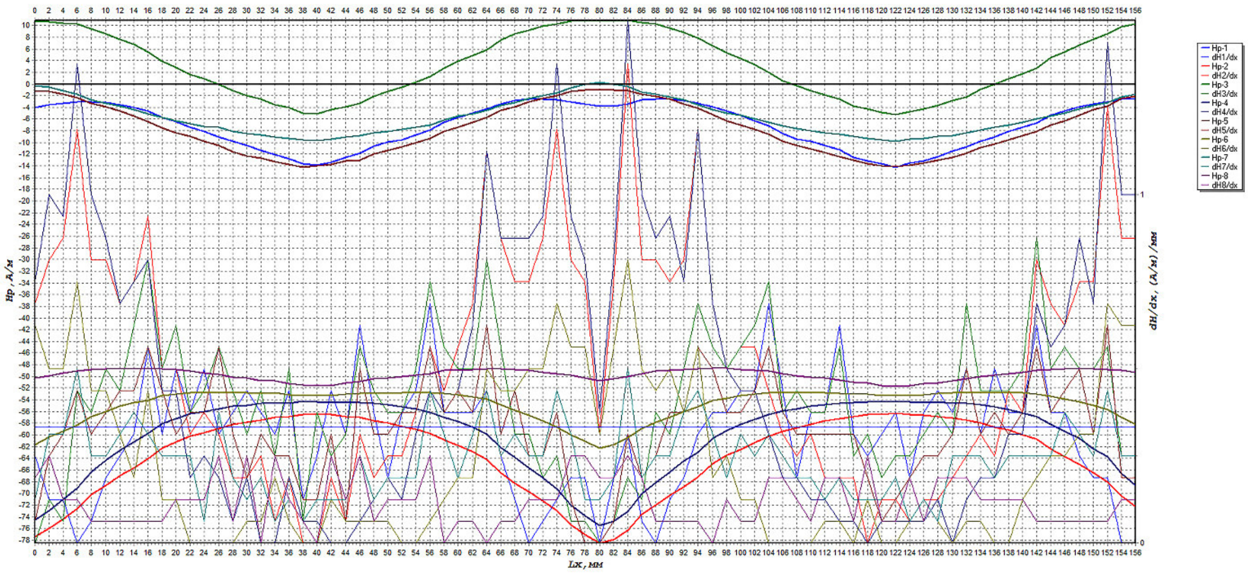

Fig. 6 - Magnetic record of specimen No. 1 (IHC-28)

The magnetic field of the specimen distribution over almost the entire length H_p is discontinuous, which indicates the structure inhomogeneity. The absence of clearly high peaks indicates the absence of casting defects such as porosity and gas shells, since their presence causes abnormally high amplitude peaks.

The indicator of the magnetic field strength H_p in the range up to 10 A/m, the intensity of the field changes along the length *dH/dx* is in the range of 1.5 (A/m)/mm.

Comparing the magnetic records of specimens 1 and 2 show a flatter nature of the intensity fields distribution in the experimental alloy. The presence of peaks and jumps in speciment No. 1 is due to the cementite needles boundaries incoherence with the matrix, which leads to low toughness of the structure. The absence of casting defects suggests that the beat of the balls made of the IHC-28 alloy is caused by low impact toughness and is not associated with macrodefects.

5. Conclusions

(1) To increase the operating life of the grinding balls, it is necessary to increase the impact strength along with the surface hardness and strength. A part used in the industry of Kazakhstan, balls contain chromium, which does not give the required impact strength, which leads to their premature destruction.

(2) The experimental alloy, while maintaining high strength and wear-resistant properties, possesses higher impact strength.

(3) High impact strength is caused by a more uniform structure and lower disorientation of the carbide phase with respect to the matrix. This reduces the stress level of the structure, which provides increased resistance to impact loads.

(4) Studies of internal stresses in the grinding balls made of the experimental alloy showed the absence of casting defects.

6. Acknowledgment

These studies were carried out as a part of implementing the program-targeted funding by the Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan BR05236295 "Designing, developing and introducing technologies for producing and processing wear-resistant materials of a new generation to obtain parts of metallurgical units".

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Development of a Unified Innovative Production System for LLP "Maker"

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Abstract: The purpose of the publication is to substantiate a new system that focuses on the research and development methods in production organization. The new system is an interconnection of innovation processes. Currently, the priority of the technological development is innovation and lean production. Functional model of Automated system of scientific research is described. Goals during the implementing of innovative projects are given in the article.

Key words: innovative technologies, research work, experimental design work, scientific and technological training, organizational (organizational and technological) preparation, digitalization, system design, innovative economy.

1. Introduction

Innovative technologies are a combination of new knowledge, methods and technologies used in an enterprise in order to increase its productivity. In the modern world, the issue of competition, the search for new customers, and entry into the international market is an acute issue. The market requires high quality and product durability. Therefore, the engineering company LLP "Maker" set the goal - to implement the State program of industrial and innovative development of the Republic of Kazakhstan for 2015 - 2019 by modernizing and updating equipment, creating new jobs, as part of the Unified Program "Business Road Map - 2020".

The situation was complicated by the use of outdated standards, instructions focused on paper workflow. To achieve the objectives, as part of the Industry 4.0 digitalization program company made a total modernization by purchasing new high-tech equipment [1].

The use of technologies and techniques that previously existed did not allow making a qualitatively new leap in the development and creation of the product, as well as ensuring its innovativeness and complexity.

2. Investigation

To achieve the proper functioning of the production preparation system, the emphasis should be on the system design of innovative production preparation, which represents the detailed, structuring, modeling and optimization of the organization of innovative activities (Fig. 1):

1. Scientific research works (scientific research related to search, practical and theoretical research).
2. Research and development work (R&D) (work aimed at acquiring new skills and knowledge and applying new products and technologies when releasing);
3. Scientific and technological preparation of production (a set of organizational, design and technological measures for the formation and introduction of a new product into production).
4. Organizational and technological preparation for the production of new products

It is important that these standards and methods were developed in the second half of the twentieth century. They are outdated and not aimed at active innovation, to increase the effectiveness of research (research work) in the context of innovative design [3].

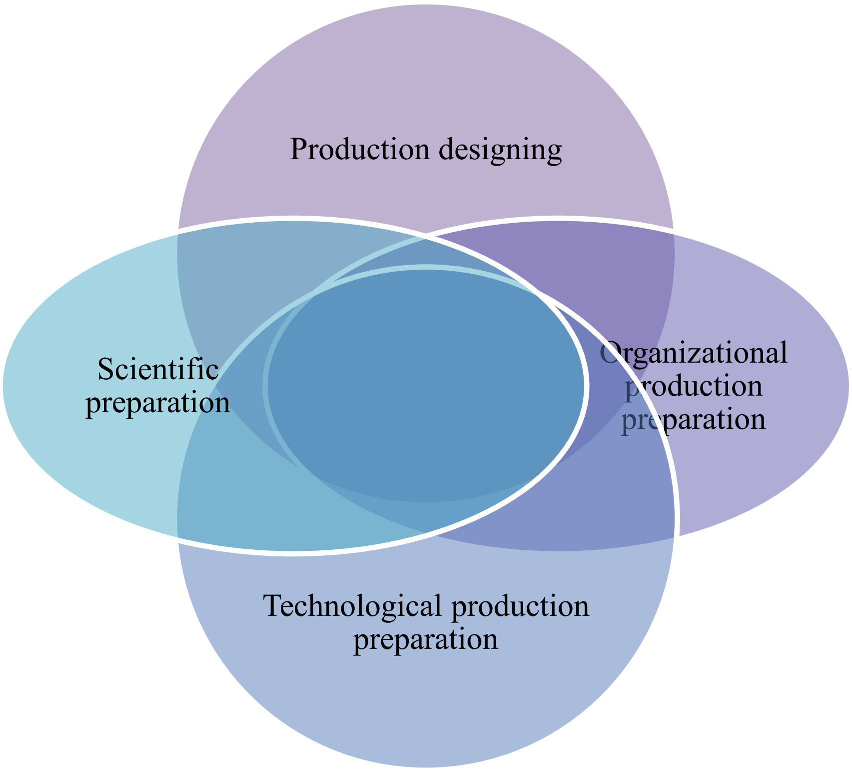
The recommendations of the completed R&D should ensure the production of competitive products with the proper level of quality, and should also provide all the requirements of high and critical technologies.

The management of innovation in the commercialization of innovations has the following main stages in the product life cycle [4]:

- new technology development;
- new product designing;
- new product testing;
- mew product market research;
- new product promotion.

The fundamental complement to the organization of research and development at the present time is a comprehensive computerization based on the use of new technologies. This allows you to use a combination of research and innovation.

Engineering development of science-based innovative design, the creation of new generations of competitive products is possible with the help of information technology, based on the use of an automated system of scientific research.



Pic 1. - The relationship analysis diagram (of work on innovative production preparation)

Automated system of scientific research was created for the technological support of work. It is based on functional models (Fig. 2, 3, 4).

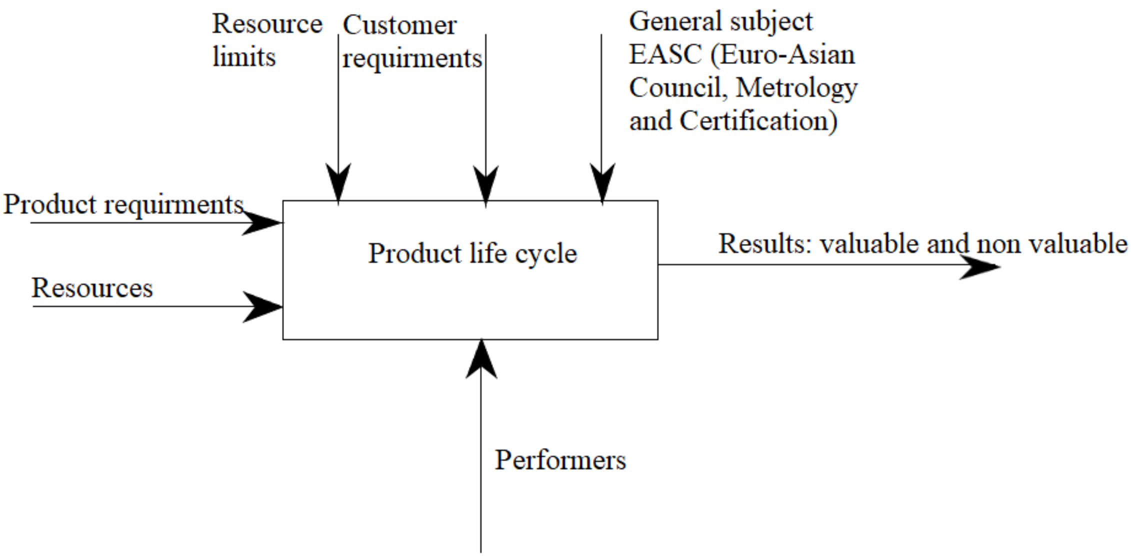


Fig. 2 – High level of product life

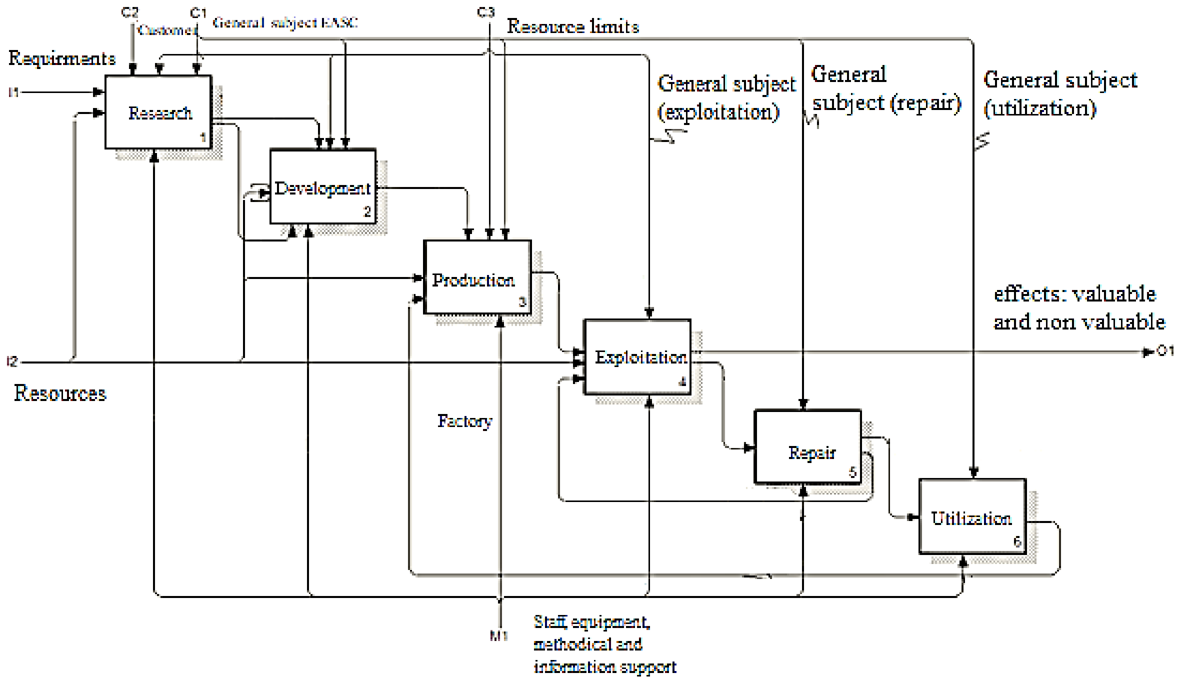


Fig. 3 - Functional model of product life

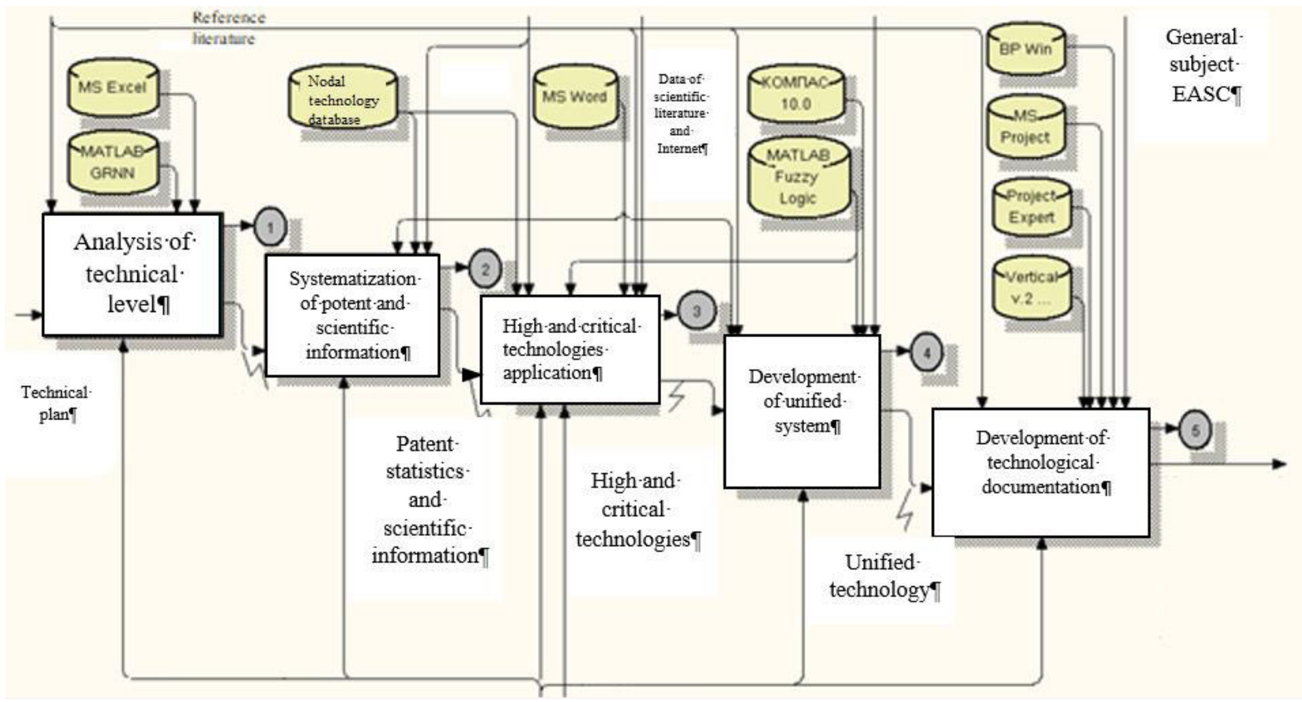


Fig. 4 – Functional model of Automated system of scientific research

The functional model of new products (Fig. 4) contains 5 blocks of tasks, as well as 10 automated software products designed to automate tasks. This model is the basis for the technological support of work on the creation and design of new products.

The "Analysis of the technical level" block defines the basic parameters of the technical level of the product. The "Systematization of Patent Information" block includes technical proposals, conclusions, and justifications. The block "Selection of high and critical technologies and the formation of a single technology" defines lists of both individual developments and the entire spectrum. The "Formation of a single technology" block defines the composition of a single technology. The block "Development of sets of project and directive technological documentation" includes research for the preparation of technological documentation of innovative projects, the construction of calendar schedules, the development of business plans.

Using the developed model of an automated system of scientific research of high and critical technologies, it is possible to change the structure of research and development in innovative design conditions.

Research work is an applied, strategic, fundamental activity related to scientific research, conducting experiments and research to gain new knowledge, testing of hypotheses, establishing of patterns, scientific generalization and justification.

Development work implies a set of work that is used in the creation and modernization of products, the development of design and technological documentation, as well as in the manufacture and testing of prototypes. During design and technological modeling, feasibility in innovative training, a matrix project management system is used using the structure of computer-aided design and a training system for high and critical technologies in engineering production.

The system of scientific and technological preparation of production is a combination of design, technological and organizational activities that ensure the readiness of the enterprise to produce high-quality products that meet modern requirements for the quality of engineering products. Technological requirements imply the presence at the enterprise of a set of technical documentation, innovative projects that ensure the implementation of technological innovations, new means of technological equipment (equipment, control, automation, equipment) that were put into effect during the implementation of projects.

The life of the enterprise in improved, new working conditions requires modifying the methods for managing the technical preparation of production, creating a flexible innovation management system, a new organizational mechanism focused on developing competitive products, restructuring the organization of technological processes that encourage the creation and implementation of end-to-end management of the innovation process from the idea before its implementation.

The replacement of technological pre-production systems with the latest innovative pre-production systems must comply with the technological, strategic and innovative marketing requirements. The implementation of work packages for scientific and technological preparation of production is divided into prospective or non-factory, the term of which, as a rule, is more than a year, and / or if these works are performed by special groups of innovative infrastructure. In terms of perspective scientific and technological preparation of production, these groups carry out: selection of innovative technology, development of a unified new technology, technological support for the competitiveness of a new product, development of a new product design for manufacturability, long-term forecasting technology, etc.

In production, technological preparation of production is carried out according to the scheme of operational preparation of production, using: standards and methods of a unified system of technological preparation of production, a unified system of technological documentation, regulatory documents of industrial systems of technological preparation of production, specialized systems of technological preparation of production, automated systems of technological preparation of production [5].

The main components of the operational technological training of machine-building enterprises are:

- organization and management of technological preparation of production, technological analysis of product design, production, development of technological processes, development of technical re-equipment of production;
- development of control programs for CNC machines; development of technological standards; design of special equipment;
- installation and debugging of the technological complex.

Innovative projects, which are the basis for the modernization of technological preparation of production, should contain: technical and economic justification of innovative projects, documents confirming the novelty and programs for the implementation of innovative production projects [5].

During the implementing of innovative projects, the following goals are need to be solved:

- the study of each element of the conceptual apparatus necessary in the study of the problem of innovative development of technical preparation of production;
- the role and place of technical development in the innovative development;
- specification of innovation classification;
- systematization of the state and current trends in the development of technical training management systems;
- the relationship of innovation and stocks;
- classification of reserves and methodological provisions for assessing the innovative development of production preparation;
- methodology for assessing the effectiveness of capital investment in innovative development;
- building a profitable economic and mathematical model that will allow the company to maximize profits in the process of innovative development of technical preparation of production;
- justification of the need for risk management in innovative design.

From the above it follows that at present, the priority in the development of a modern innovative economy is the management of technological shifts, the intensive development of all types of innovative activity, including the innovative preparation of engineering production. The innovative potential of society is currently based on the realization of the intellectual, scientific and technological potentials of society and is determined by the complex mechanisms of productive forces and production relations. When implementing innovative projects, it is necessary to take into account certain features, therefore, therefore, these projects are less amenable to unification and standardization than investment projects. Innovative projects are characterized by riskiness, uncertainty, multivariance (the possibility of various modifications) from the beginning of creation to the introduction of innovative products. When implementing an innovative project, it is necessary to analyze the choice of a base for forecasting and analyzing innovations, the selection of criteria for the success of an innovation, the selection of the best option between quality and customer requirements, etc.

3. Conclusions

After carrying out the studies, the following results were obtained:

1) Functional models of an automated research system and functional model of product life are presented;

2) The main aspects for the design of innovative projects are presented, such as research work, development work, the system of scientific and technical preparation of product;

3) The functions of promising scientific and technical preparation of production are determined;

4) The components of the scheme of operational technological preparation of production are listed;

5) Tasks in the implementation of innovative projects are identified.

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Designing Bench for Belt Conveyor Roller Expansion

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Abstract. The article describes the goals of modernizing mechanical engineering production. The article describes a bench for the belt conveyor rollers expansion. There are designed individual elements of the bench and the bench assembly. For designing, there has been used the computer system NX. There has been empirically determined tensile strength of steel 3, steel 35, steel 45, steel H12M. The engineering analysis of the crimp mandrel and the roller has been carried out with developing a CAD model, idealization of the model, and developing a discrete model.

Keywords: expansion, bench, engineering analysis, mathematical model, crimp mandrel.

1. Introduction

Mechanical engineering of any technically developed state is the most important sector of the economy [1]. Mechanical engineering ensures stability of the energy, metallurgy, agricultural sectors, transport and other important fields of the economy, manufacturing various types of equipment, machines, instruments, and goods for the needs of the country's population [2].

Today in Kazakhstan's engineering there are systemic problems associated with a low threshold of investment attractiveness of this industry, a low level of competitiveness of engineering products in the domestic and foreign markets, and insufficient modernization of engineering production.

The goals of modernization of engineering industries are as follows:

- launching new products and/or products with higher quality and reliability indicators;
- increasing the efficiency of technological equipment;
- reducing the product manufacturing cycle time.

The Karaganda Foundry and Machine-building Plant Maker LLP is one of the largest manufacturers of rollers for belt conveyors. In the framework of the "Performance 2020" program, since 2015 the project "Modernization of the Karaganda Foundry and Machine-building Plant Maker LLP has been implemented. The project was confirmed by the operator of the Program of the Kazakhstan Institute for Industrial Development JSC and received a reimbursement for the development of a comprehensive plan (7.9 million tenges). Within the framework of this program, it is planned to develop a new reinforced bench for rolling conveyor belt rollers. An important element of the bench is a crimp mandrel. In this regard, after developing the bench design, computer simulation was performed to determine the optimal pressure for rollers expansion using this mandrel.

2. Results and Discussion

2.1 Designing a Bench for Roller Expansion

The stand was designed in the NX Unigraphics CAD system in the PLM Teamcenter product lifecycle management system. This software allows designing and adjusting the entire amount of design documentation in a fairly short time.

The bench for rollers expansion (Figure 1) consists of 7 main units: base - position 1; supports - position 2, position 3; back support - position 4; prism - position 5; retaining shafts - position 6; roller - position 7; crimp mandrel - position 8.

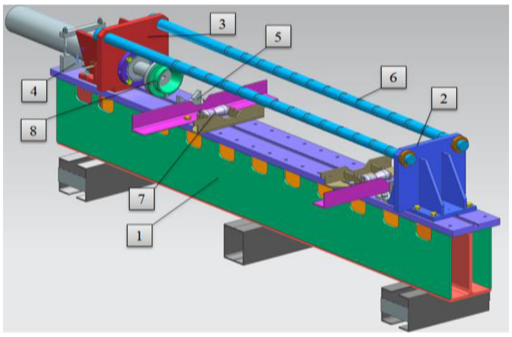


Fig. 1 – General view of the bench

The base of the bench shown in Figure 2 is made of a I-section beam (position 1), the material is steel 3, GOST 380-2005. A plate is welded to the top shelf of the I-beam (position 2), the plate material is steel 3, GOST 380-2005. To reduce bending moments that can occur in the cross section of the bench during operation, reinforcement ribs (position 3) are welded to the wall of the I-beam, the material of the ribs is also steel 3, GOST 380-2005. In the longitudinal direction the beam is reinforced with reinforcement ribs (position 4) made of metal sheets, the material is steel 3, GOST 380-2005.

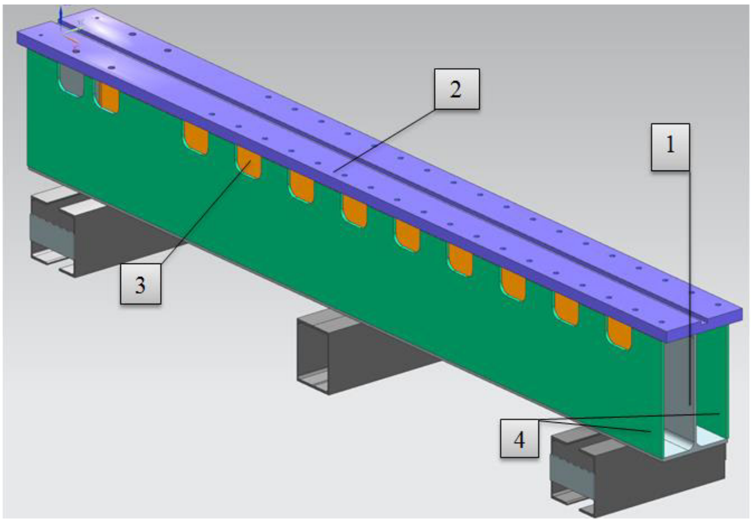
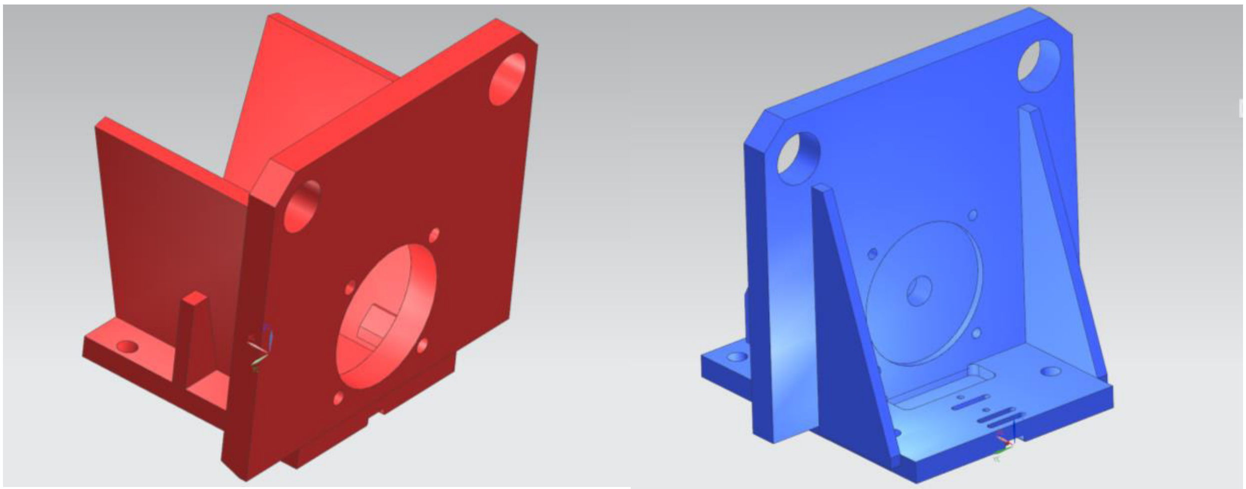


Fig. 2 – General view of the bench base

The support (Figure 3a) is made of sheet steel, grade 35, GOST 1050-2005; it is designed to secure a hydraulic cylinder in it, which transfers the main force to the crimp mandrel. The other support (Figure 3b) is made of steel 35, GOST 1050-2005; it is designed to fix the crimp mandrel and additional supports for crimping short-length rollers.



(a) (b)

a) support for hydraulic cylinder; b) support for crimp mandrel

Fig.3. – Supports of the roller expansion bench

The retaining shafts are made of steel 45, GOST 1050-2013 of circular cross-section; they are designed to prevent the bending of the bench during expansion.

The crimp mandrel (Figure 4) is designed so that it is possible to roll several types of shells at once without changing the mandrels. This significantly saves the time for equipment retooling. The material of the crimp mandrel is steel H12M, GOST 5950-2000. This steel grade is well suited for work with high friction. which is achieved due to high hardness and additional heat treatment; this steel grade also possesses low viscosity.

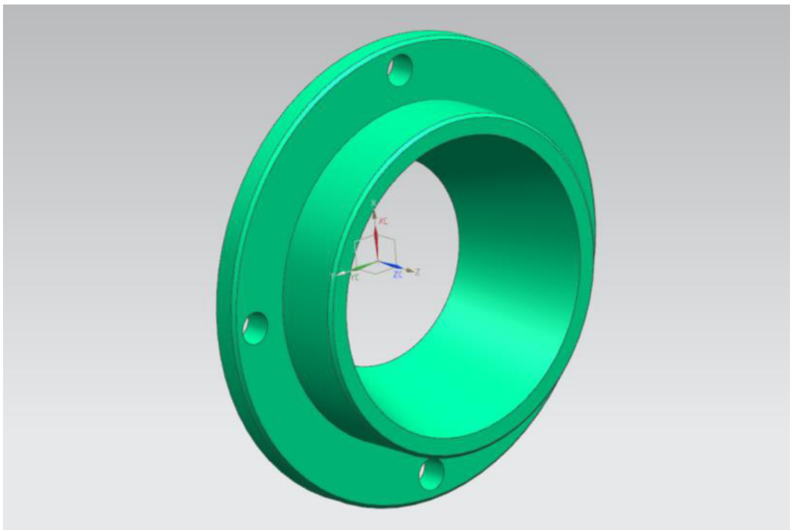


Fig. 4 – Crimp mandrel

2.2 Engineering Analysis of Elements of the Bench for Rollers Expansion in NX

The engineering analysis of the crimp mandrel was carried out in the NX Advanced Simulation.

When performing the engineering analysis using the FEM (Figure 5), the main stages are as follows [3, 4]:

- the stage of developing an idealized model. This stage is needed for transition from a physical model to a simplified model. The fact that mathematical models have a large number of degrees of freedom is obvious, which leads to the impracticability of solving in practice the needed problem for a complex model;

- developing a discrete model, where the number of degrees of freedom is limited, i.e. discretization of the idealized model occurs;

- direct solution of the systems of equations that correspond to the selected type of analysis.

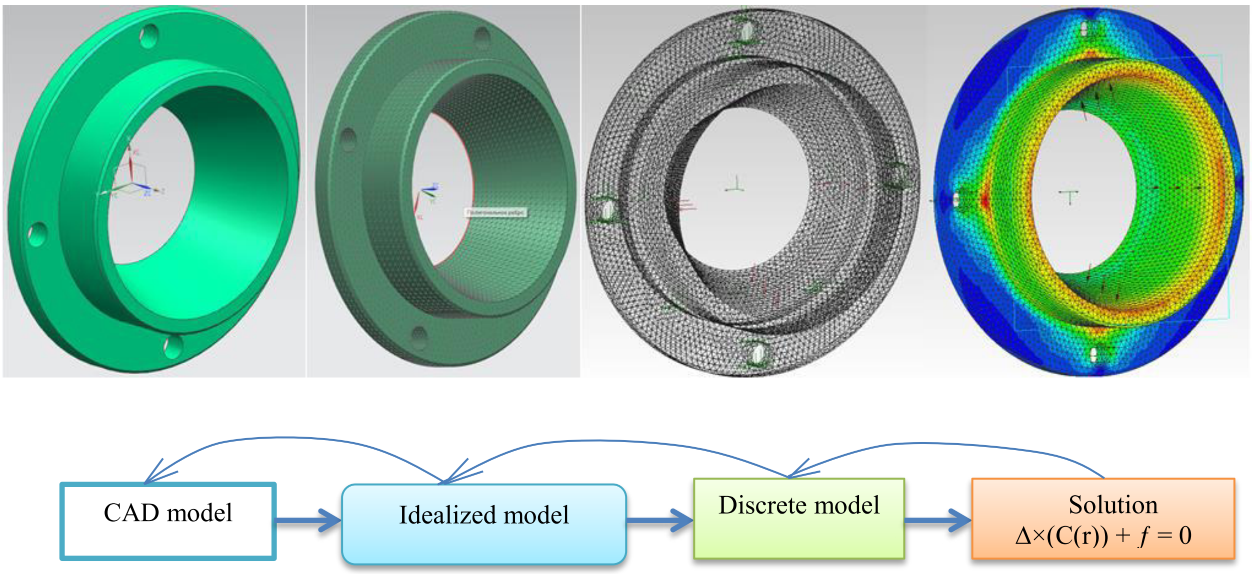


Fig. 5 – Pattern of carrying out the engineering analysis

In order to carry out the engineering analysis in the NX Unigraphics CAE module and to obtain more accurate results, it was necessary to perform laboratory tests for breaking the samples of materials that make up the bench. A tensile test is necessary to obtain physical-and-mechanical parameters and characteristics needed for further calculation. To carry out this test, samples of materials were cut and turned (steel 3; steel 35; steel 45; steel H12M) (Figure 6). The overall dimensions of the samples comply with the requirements and regulations for tensile testing. The tests were carried out on a tensile testing machine manufactured by MTS (Figure 7).

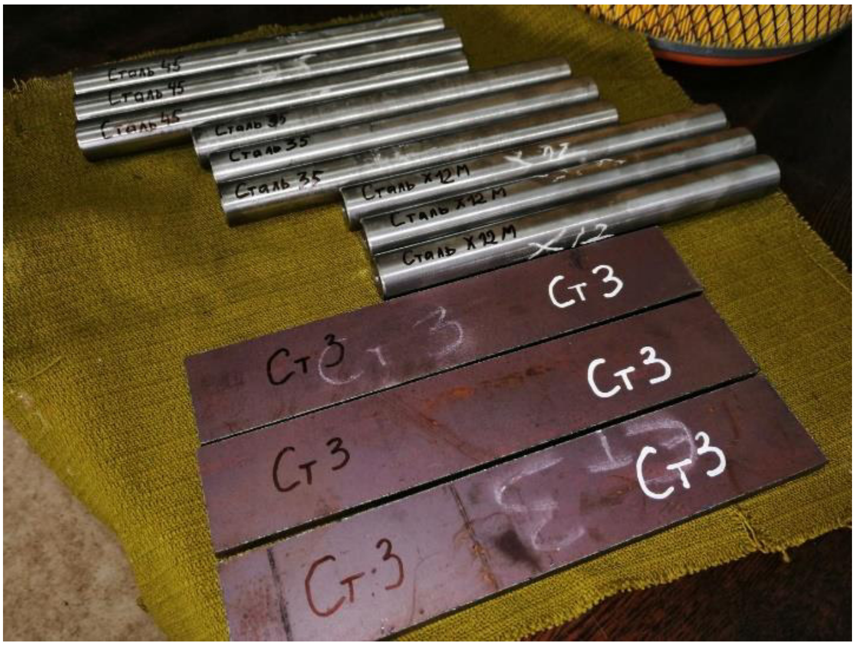


Fig. 6 – Samples of the materials

Fig. 7 – Machine for break testing the samples (MTS Company)

As a result of testing it was established that the steel 3; steel 35; steel 45; steel H12M provide the needed ultimate strength for the rolling bench elements (Table 1).

Table 1 – Ultimate strength of steels for the rolling bench elements

Steel grade	Maximum load, kN	Ultimate strength, MPa
Steel 3	227.024	22724.9
Steel 35	331.199	33119.9
Steel 45	341.187	34118.7
Steel H12M	384.890	38489.0

After the stage of introducing the materials and their physical and mechanical properties, we performed the finite element modeling and developed a simulation file for this in the SAE module, in the menu of the simulation navigator, selecting “New FE Model and Simulation”.

In the window that appeared, the option "Develop an idealized part" was selected [3]. Auto-generated files are also shown here: "rod_fem1.fem" and "rod_sim1.sim". In addition, the following parameters were selected in all the tabs: Solver: "NX NASTRAN"; Type of analysis: "Structural" (Figure 8).

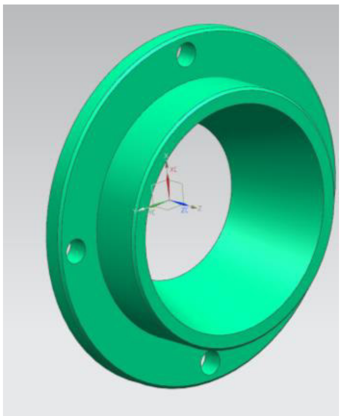


Fig. 8 – Starting the engineering analysis

After that, the geometry of the model was simplified before the stage of developing the computational mesh [5]. Then, in the "Mesh Collector" window, the necessary material parameters were entered, then the mesh itself was set in the Simulation navigator (Figure 9).

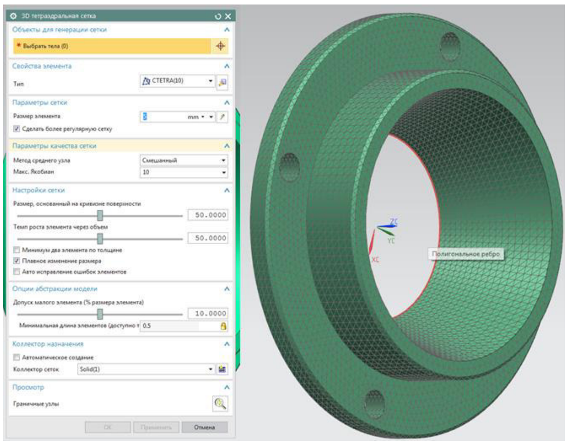
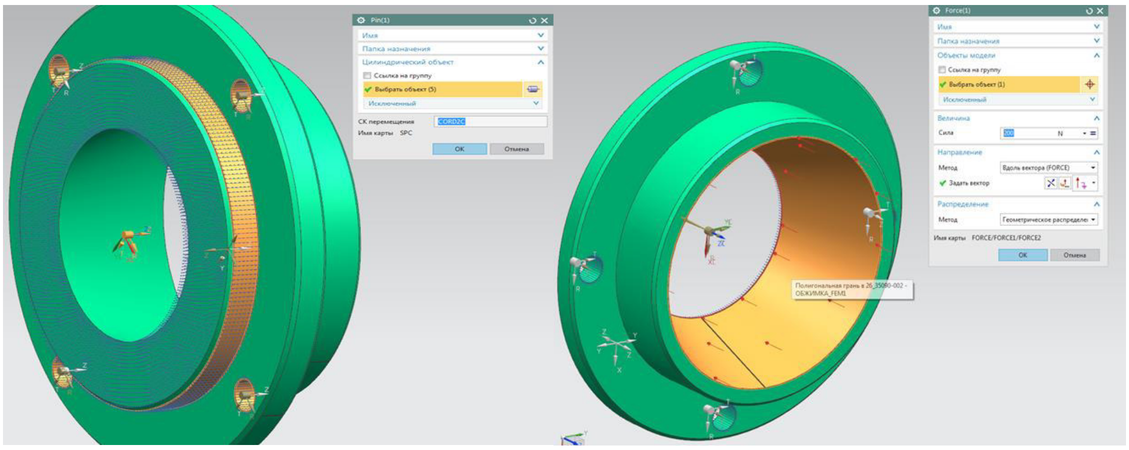


Fig.9 – Developing the model mesh

In the Simulation navigator there were indicated the loads and limits, removed in the model the degrees of freedom by which it was fixed (Figures 10, 11).



a) b)

Fig. 10 – The part fixture (a) and applying loads (b)

After selecting the Solution fold, there was presented stress distribution in the crimp mandrel (Figure 11).

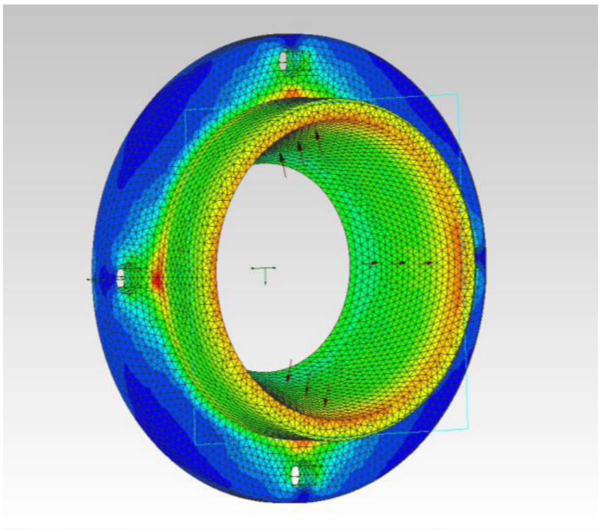


Fig.11 – Stress-strain state of the crimp mandrel

There was also determined the stress-strain state for the conveyor roller (Figure 12).

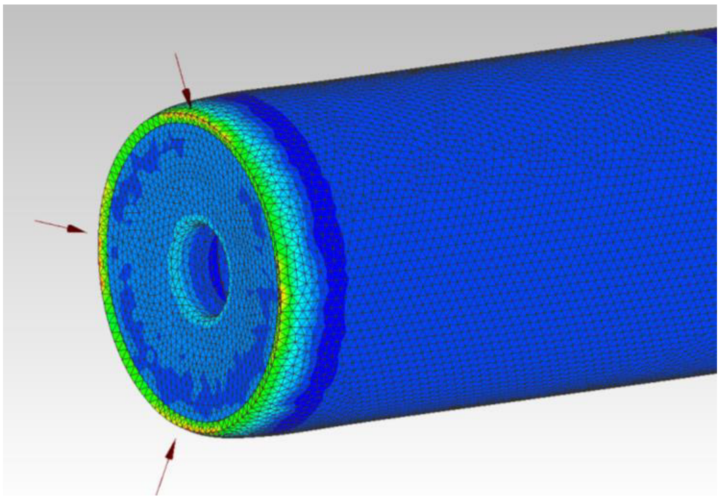


Fig. 12 – Stress-strain state of the conveyor roller

As a result of the tests it was found that the necessary pressure for the roller expansion varies in the range of 150 - 200 MPa (Table 2). This pressure provides the needed ultimate strength with a single draft [6].

Table 2 – Roller expansion efforts

Rolling pressure, MPa	Ultimate strength, MPa
100 MPa	25145.8
120 MPa	27245.8
150 MPa	30724.9
170 MPa	33129.6
200 MPa	34118.7
220 MPa	38974.6
250 MPa	40134.5

After simulation a bench for rollers expansion was made. During the first operation of the new bench (Figure 13), the percentage of “non-rotating rollers” from the batch decreased to 20 % compared to 40 % before manufacturing the new bench.

Fig. 13 – Bench for roller expansion

This confirms that the bench is operational, but additional measures are required to adjust the effort of rolling the edges of the rollers, which would reduce the percentage of "non-rotating rollers".

The bench allows rolling rollers in a rather large range of lengths up to 2 meters inclusive. This bench, with some refinement, can also be used for other roller assembly operations: inserting bearings, bushings, retaining rings. This will entail simplification of the working personnel labor and, as a consequence, reducing the production time.

3. Conclusions

After carrying out the studies, the following results were obtained:

1) there was designed a bench for rolling rollers of belt conveyors produced in the CAD system NX Unigraphics;

2) the base of the bench, the upper shelf of the I-beam, reinforcement ribs should be made of steel grade 3; the support should be made of steel 35, the retaining shafts should be made of steel grade 45; the crimp mandrel should be made of steel H12M;

3) there was established the relationship between the pressure of the rollers and the ultimate strength of the bench elements;

4) the pressure for rolling rollers should be from 150 to 200 MPa;

5) the defect "non-rotating rollers" decreased by 20 % from the batch after rolling on the new bench.

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The Ways to Solve the Problems of the Effectiveness of Mining Equipment Through Specialization of Production and the Formation of Dealer Networks

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Abstract: The article is devoted to the problems of the effectiveness of mining equipment in the Karaganda region. The author describes what kind of difficulties the mining enterprises face when installing, operating and repairing equipment. Then, the author analyzes the problems and gives the most acceptable, in his opinion, ways to solve these problems through the specialization of production and the formation of dealer networks.

Keywords: repair, efficiency, mining equipment, production specialization.

1. Introduction

In accordance with the republican concept, one of the main tasks of Kazakhstan's energy policy is to establish a gradual transition to a more extensive use of the coal resource in the republic's energy sector. With a constant reduction of reserves such as oil and gas, coal is becoming increasingly important stabilizing component in the fuel and energy balance of the country.

In this regard, the Karaganda region is acquiring a special need for the development of the coal industry on a more intensive scale, which in turn acquires a close connection with the basic idea of the new energy strategy of the Republic of Kazakhstan.

And for the implementation of this idea, one of the main criteria is to maintain the mine process equipment in working and good condition, which will significantly increase the efficiency of the mine as a whole, and as a result we can see that the reliability of each mining equipment is an important efficiency criterion, and this reliability is formed not only by the primary level of this indicator, provided by the manufacturer, but also how its planned and unplanned repair and maintenance works on the mines.

2. Results and discussion

In its turn, the main factor that closely connects such concepts as efficiency and reliability is the constant worn-out of the mining equipment park. Today, the rate of worn-out of mining equipment is ahead of its modernization, reproduction and renovation. There are such types of mining equipment, in which the developed resource exceeds 50%, and in rare cases even more (Figure 1).

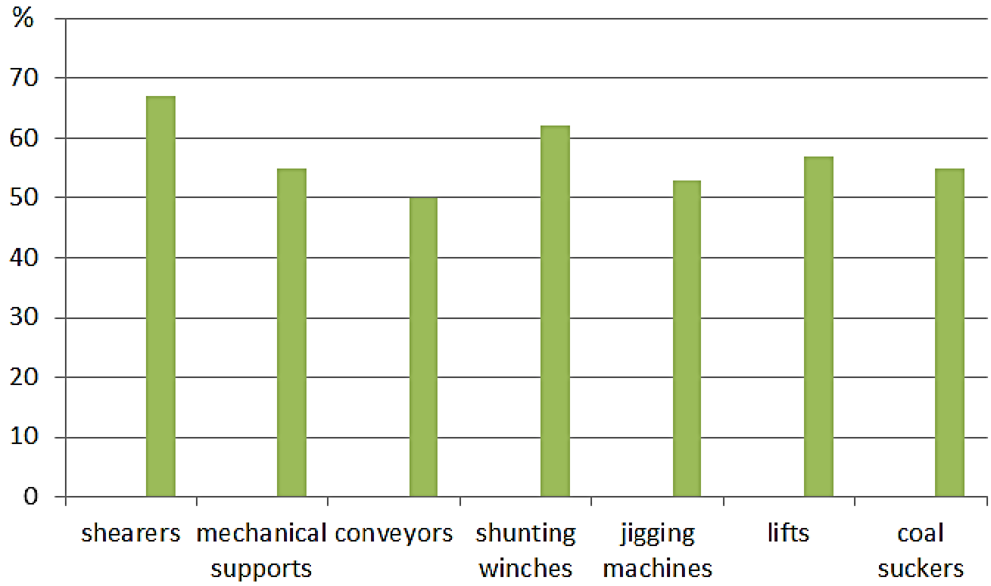

Figure 1 - Developed resource of mining equipment at the enterprises of the Republic of Kazakhstan

Also, the impact of loads and impacts as the machine worn-out does not stop; therefore, its worn-out is constantly increasing.

To the operation of the machine, performed for the last day, month or year, is added the operating of that day, month or year. Also consistently to the worn-out of the machine, caused by work for the previous period, the corresponding worn-out for the given period is added.

When repairing the machine, it not worn-out only that parts which are not entered yet into this machine (for example, Spare parts in stock), or that which has already been worn out over the past period of the machine's operation (parts rejected or subject to rejection due to worn-out).

It differentiates also from the conventional and the flow of worn-out of the structural element at the end of its service life in the car. Most of the time related to the forced wear of many structural elements is actually included in the turnaround time, so as soon as for structural elements whose forced wear leads to an accident, particularly strict conditions of control and culling during wear are used.

Consequently, a new structural element in a running machine wears out during the turnaround time, as well as the original, with unsteady worn-out mode, at least at the beginning and at the end of its service life [1].

The use of such equipment in the work leads to a continuous increase in the share of the cost of its maintenance, and sometimes the dependency, in the cost of mining and processing of mining products. At this time, increasing the cost of operating and repairing mining equipment in coal mines is ahead of the rising cost of primary products. If this trend remains the same, then within 5-8 years the cost of repairs will be equal to the market price of the new mining equipment.

Another serious problem is the short period of production equipment operation. Under the production operation understand the stage of the life cycle of the equipment, which consists in its use as intended. The stage of the equipment life cycle includes the following stages: reception, installation, commissioning, organization of operation, service for a certain period of time, depreciation, storage, disposal of equipment [2]. The short life cycle of the equipment is due to the almost uninterrupted operation of the equipment, since the operation of the mining enterprises of the Karaganda region does not stop for more than one day a year. The work of the equipment is, for the most part, stopped by accidents and repairs that occur due to the difficult working conditions of the equipment, as well as mentioned above, because of almost uninterrupted work, since the time period for changing workers is very short and does not exceed 20 minutes.

The acuteness of the problem of increasing the efficiency of the repair and engineering production, in order to ensure the success of solving the problems of controlling the reliability of the mining equipment, is shaped by the work of a whole mechanism of factors, among which, besides equipment aging, it is necessary to highlight [3]:

- directly related to the decrease in the reliability of the equipment, the decrease in the level of safety and efficiency of the equipment;
- poor qualification of the staff in the engineering and repair production, which does not allow to reach an acceptable ratio of the "price-quality" criterion;
- adverse effects of the collapse of the mining machinery complex (both a reduction in the nomenclature and a decrease in production volumes);
- monopolization processes in mining engineering;
- the tendency of forming the predominant part of the production capacity of repair production at mining enterprises, determined by the change in the structure of industrial production, with the simultaneous cessation of the functioning of the previously existing centralized industry repair structures

As for the topic of equipment repair in mines, it is done if a breakdown or accident is not significant, by a group or by one worker, which significantly increases the temporary period of equipment downtime, rather than if qualified teams were engaged in the elimination. If the accident is large-scale, the equipment is raised to the surface, where a team of specialized workers is engaged in troubleshooting, but it can be noted that the teams of such workers are busy repairing not specific equipment or machinery, but those that are raised to them from the mine, be greater than the number of workers in which emergency mining equipment was distributed, therefore the quality of work with respect to emergency equipment may not be as high as required by technical documentation, due to lack of sufficient time. Thus, we can sum up a logical result - the laboriousness of repairs greatly exceeds the labor intensity of production of mining equipment.

The trends that have developed in this area can be overcome using the specialization of repair production. We can see that, both in domestic and in foreign experience, its most productive form of implementation is the development of intersectional production facilities for repairing gas equipment in places where mining enterprises are mostly located. It can be noted that to the same extent, in addition to the planned to the construction of specialized repair facilities, development and corporate repair of the equipment is required, which the manufacturer is engaged in.

If we compare the quality of repair provided by the company (manufacturer) with other forms of organization, then we can certainly say that the company (manufacturer) provides higher quality due to the work of qualified personnel who fully and fully use standard and effective material technical support. At the same time, the repair carried out by firms (manufacturer) helps to establish interconnection between manufacturers and enterprises using their equipment, which makes it possible to use the necessary information about the efficiency and reliability of mining equipment to improve existing and create new models of mining equipment, subsequently quality management repair and reliability takes the character of continuity and consistency.

Also, with the increase in repair work and the development of repair production specialization, it is necessary to centralize and increase the number of manufactured spare parts and products at specially equipped repair shops. Mining machinery enterprises still produce spare parts and products which are not enough for their equipment, considering that the production of spare parts is very laborious and not profitable, because, unlike the sale of the machine as a whole, the implementation of spare parts of the enterprise is 2-3 times less than profit per unit of labor costs [4].

In this case, the price for spare parts needs to be done such that the profitability of their production would be at least 3-7 times higher regarding to the main product, since for enterprises producing mining equipment they will be much cheaper if compare with those which were made by small repair brigades.
It is impossible to ignore the organization of specialized production of spare parts for mining equipment removed from serial production due to the fact that their service life is considered exhausted, since the maintenance of the primary (or close to them) equipment parameters mainly depends on the quality of spare parts and repairs [5].

However, at the current stage, the work of such systems is satisfied only with technical aspects. As the information database on the current technical condition and the residual life of the equipment is developed, rather convincing mechanisms for estimating the residual value of equipment begin to form.

The ways of specialization of machine-building, as well as repair production, which we could observe above, do not allow to reduce the unit costs for the repair and operation of equipment without long-established ratios regulating ratios on the market, such as "price-quality repair" and "quality of mining engineering - the cost of manufacture. The solution of this task can be accomplished by forming a structure of control over these ratios in mining enterprises, but it will also have to apply this structure both in the repair services market and in the market for products that develop and create mining equipment. If in the first case it is not expedient to find an acceptable solution on the scale of the existing structures of the repair production of mining enterprises, in the second case it is necessary to form dealer networks for the production of mining equipment, as well as a database of corporate maintenance and repair.

An important role that affects the productivity of mining enterprises is played by the state of the mining equipment park (Pioma 25/45-OZ complex with the SL300 shearer at the Kuzembaev mine of Arcelor Mittal Temirtau) Increasing the degree of specialization by increasing the number of enterprises with an insufficient production cycle requires the formation of closer production relations among themselves for the production of the same product, and also requires that repair companies be connected into a common complex within the region. The combination of detailed and substantive specialization will create an additional, positive economic effect due to the unification of the organization of labor, auxiliary and repair production.

But a problem arises, the growth of the number of enterprises with insufficient cycle and the strengthening of production relations make it very difficult to maintain control over production, causing the need to develop production structures prepared for the production and repair of spare parts and subassemblies of enterprises, based on specialization and unity of labor production cycle. Such collaborations can organize common procurement enterprises in order to service the entire group of mining enterprises or the region as a whole. It is possible to cope with the current failure of the procurement production of machine-building, as well as repair enterprises, by creating updated procurement areas, at the same time disabling low-power and outdated procurement units. In procurement enterprises, which will be created in a new way, as a result of the same type of production, there will be requirements that are necessary for the inclusion of automated, in-line and mechanized technology.

Thus, the increase in the efficiency of the repair and production processes of mining equipment creates the need for specialization and concentration of stockpiling, conservation in the production structure of repair and machine-building enterprises, machining units aimed more at assembling products and main parts.
The combination of service companies, closely located mining companies, is another important side of the exploded specialization, with an incomplete and complete cycle. Judging by experience, it can be seen that detailed specialized enterprises, as well as brigades, create an increase in production relative to one worker by 15 - 20% along with a large decrease in the cost of repair and production, while there is no regression regarding the working degree of product suitability. In the course of further improvement of such trends, it is possible to prepare for the fact that repair and engineering enterprises of special purpose will be transformed in the future into technologically-specialized assembly enterprises.

The assessment of the nature of the improvement of repair and engineering production notes the need for comprehensive improvement of each type of specialization with the creation of production units and parts for specialized details, and blanks for special-purpose technological enterprises, sending them to the main enterprises. The combination of the same type of work divides the production process of manufacture or repair into the easiest processes, saves them for a specific workplace and equipment. As a result, labor productivity, product quality and the necessary environment for the typification and development of technological processes, their automation and mechanization, significantly increase.

Efficiency of repair and specialization of branded production, as you can see, looking at global practice, to a greater extent depends on the degree of improvement of the dealer network, which provides a steady supply guarantee, a holistic pricing system and high quality of the supplied products.

3. Conclusions

The study found:

1) The residual life of mining equipment in the Republic of Kazakhstan is more than 50%;

2) Factors ensuring the success of solving problems of monitoring the reliability of mining equipment: aging equipment; lack of qualification of staff; decrease in production volumes; monopolization processes in mining engineering;

3) Compliance with the ratio of "price-quality" and "quality product of mining engineering-manufacturing cost" gives an increase in the life of mining equipment;

4) Improving the dealer network of repair and engineering production gives a guarantee of deliveries on time, an integrated pricing system and high quality products.

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The Use of Granulated Blast-Furnace Slag of JSC “ARCELOR MITTAL TEMIRTAU” as a Binder With The Purpose of Partial Replacement of Cement in the Production of Concrete

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Abstract. The paper presents the development of modern concrete manufacturing processes, where granulated blast-furnace slag is used as a binder. The effect of ground granulated slag as a binding component on the strength features of concrete with partial replacement of cement is studied.

Key words: cement, concrete, construction, mixture, Portland cement

1. Introduction

Concrete has now become the most used material in the world, its use has had a huge impact on the formation of modern civilization and on all forms of modern infrastructure.

Concrete is used everywhere, on the surface of the earth and underground, in water and under water. It can take the most unusual forms and satisfy the most capricious desires of people; economically and environmentally, it has proved its suitability for the sustainable development of human society. One of the recent achievements in construction, using concrete, are the beginning of the construction of the world's longest bridge (35.6 km) over Hangzhou Bay and the start of operation of the “Three Gorges” hydropower plant in China, with a dam height of 185 m and a capacity of 26,700 MW. Currently, an ultra-tall building has been built in Dubai, which has surpassed all the famous skyscrapers (Sears Tower-s - 442 m, Petronas - 452 m and the building of the Financial Center in Shanghai - 492 m). However, society has not yet fully understood the role and significance of this universal material.

Ensuring the integrated and rational use of mineral raw materials at all stages of production and processing is one of the most important economic and social tasks. The development of highly efficient resource-saving technologies provides not only economically justified completeness of the extraction of basic and accompanying elements, but also waste disposal in the extraction and enrichment of minerals, as well as processing and integrated use of technogenic raw materials, i.e., metallurgical slag. [1]

The properties of granular slags allow them to be used both for the production of cements and as a filler for concrete and mortars.

Granulated blast-furnace slag is currently used in the cement industry (40%), for the production of various local binders, as well as aggregates for concrete.

2. Experimental Part

To implement the work, portlandcement of Aktau plant brand 300 was used. Application: the production of concrete and reinforced concrete prefabricated and monolithic structures from concrete of grades up to B 20 (M 250), especially with the use of thermal and wet processing. For internal bodies of hydraulic structures (low-heat concrete). For mortars. Characteristic features: low rate of hardening; low weather resistance; low frost resistance; high sulfate resistance; high shrinkage deformation, high strength, high adhesion to mineral substrates, environmental safety [4].

The mineralogical and chemical composition of the clinker of Aktau plant is presented in the table 1. The main physical and mechanical properties of portlandcement grade 300 are presented in Table 2.

Table 1 - Chemical and mineralogical composition of clinker

Chemical composition, %					Mineralogical composition, %						
SiO_2	Al_2O_3	Fe_2O_3	CaO	$CaO_{св}$	C_3S	C_2S	C_2A	C_4AF	КН*	П**	Р***
22,19	7,52	4,07	63,09	-	59,7	17,1	8,6	14,3	0,90	2,0	1,4

Note: КН - saturation coefficient;
П - silicate saturation;
Р - calcium saturation;
C_3S - tricalcium silicate;
C_2S - dicalcium silicate;
C_2A- dicalcium aluminate;
C_4AF- tetracalcium aluminumoferrite.

Table 2 - Basic physical and mechanical properties of portlandcement grade 300

Properties	Value
Strength during steaming, not less, MPa	27
Flexural strength, 28 days, MPa	4,4
Compression resistance, 28 days, MPa	29,4
Fineness of grinding, passed through a sieve № 008, %	89 - 95
Volumetric weight of portlandcement in a loose state, kg/m^3	1010
Volumetric weight, g/ cm^3	3,0 - 3,2

As fine and coarse aggregate, ground granulated blast-furnace slag, crushed stone from blast-furnace slag of a fraction of 10÷20 mm and sand and gravel mix (SGM) of Tokarevski quarry were used.

Blast-furnace slag is an unavoidable by-product of iron smelting. It is formed in blast-furnaces under the influence of high temperatures (~ 1550^0 C) as a result of melting of waste rock of iron-containing materials and fluxes, to which the ash of a burnt coke is added in the furnace.

The composition of blast-furnace slag is complicated. They contain up to 30 different chemical elements, represented mainly in the form of oxides. The main are SiO_2, Al_2O_3, CaO, MgO. In smaller amounts, usually are FeO, MnO, S, BaO, TiO_2.

In addition, during the release of a slag from the furnace, it contains up to 2% of cast iron. During the transportation of a slag from blast furnaces to slag processing sites, a significant part (~ 70%) settles at the bottom of the bucket and hardens in the form of “lenses”.

The blast-furnace slag of JSC “ArcelorMittal Temirtau” is acidic and has a basic modulus, i.e. the ratio of the content of the sum of oxides of CaO and MgO to the content of the sum of oxides of SiO_2 and Al_2O_3 equal to 0.93 ÷ 0.97.

Liquid slag usually contains a significant amount of the gas phase, which does not have time to remove from the melt and, during cooling, it forms a slag mass with an inhomogeneous porous and dense texture. Gas saturation of blast-furnace slag of various plants varies in the range of 1100 ÷ 1600 cm^3 per 100 g. of slag.

The amount of gas inclusions determines the structure of a slag and its properties.

The physical and mechanical properties of solid slags are connected with a complex set of factors, the most important of which are the mineralogical composition and nature of crystallization, including the degree of crystallization, the shape and size of crystals, the spatial ratio of crystalline and glassy phases, thermal and phase stresses.

Blast-furnace slag by activity, determined by the compressive strength of samples made from a ground slag refers to active slag.

The physical and mechanical properties of solid blast-furnace slag were studied in accordance with GOST 3344 - 83 “Crushed stone and sand for road construction” and GOST 8269 - 76 “Crushed stone from natural stone, gravel and crushed stone from gravel for construction work. Test methods” [6].

The chemical and phase composition of granulated blast-furnace slag is presented in Table 3.

Table 3 - Chemical and phase composition of granulated blast-furnace slag

Chemical composition, %									Phase composition		
										Slag structure, %	
SiO_2	Al_2O_3	CaO	MgO	BaO	S	TiO_2	FeO	MnO	Main module	Glassy	Crystalline
36,75	14,19	39,96	8,27	0,27	0,97	0,58	0,37	0,74	1,09	85	15

Physical and mechanical properties of granulated blast-furnace slag are presented in table 4.

Table 4 - Physical and mechanical properties of granulated blast-furnace slag

Name of indicators	Granulated blast-furnace slag
Bulk density, g/cm^3	1,10
True density, g/cm^3	2,80
Fineness modulus	from 3,07 to 1,52
Average density, g/cm^3	2,28
Water absorption, %	10,9

The grain composition of a fractionated crushed stone from blast furnace slag and sand and gravel mix (SGM) of Tokarevski quarry is presented in Table 5.

Table 5 - The grain composition of a fractionated crushed stone from blast furnace slag and sand and gravel mix (SGM)

Name of aggregate	Particular residue / total residue, on a sieve with a hole size, mm											
	25	20	15	12,5	10	5	2,5	1,0	0,63	0,31	0,16	<0,16
Crushed stone fractions 10 ÷ 20mm	12,0 / 12,0	24,7 / 36,7	42,8 / 79,5	19,3 / 98,8	1,2 / 100	-	-	-	-	-	-	-
SGM	-	-	-	-	5,0 / 5,0	15,5 / 20,5	21,0 / 21,0	18,0 / 39,0	32 / 71,0	21,0 / 92,0	6,0 / 98,0	2 / 100

Equipment was used to carry out the research:

1) Drying cabinet СНОЛ-3,5.3,5.3,5/3,5-И1;
2) Vibratory chopper 75T – DrM;
3) Sieve for determining the fineness of cement type grinding «КСВ»;
4) Electronic scales IV class model ВЛЭ – 1 kg;
5) Laboratory stirrer PM – 1A;
6) Molding vibrating table CB-700;
7) Laboratory steaming chamber КУП – 1;
8) Hydraulic press for testing building materials П-50.

Portlandcement of grade 300 has a granulometric composition of less than 0.08 mm, because the longer it is crushed, the higher its quality, the more cohesiveness it has. The surface of grains will be the larger, the higher the fineness of grinding. According to previous conducted researches in the laboratory of JSC "ArcelorMittal Temirtau", it was experimentally proved that blast-furnace slag has a chemical composition similar to portlandcement. With a fractional composition of more than 0.1 mm, blast-furnace slag has very low binding properties. To conduct the research, it is possible to use blast-furnace slag as a binder. The 0.08 mm fraction was taken as the basis. In order to efficiently use the equipment and the initial slag, the optimum time for sifting was taken the time, providing 85% of the 0.08 mm fraction. In this regard, at the first stage of the work, the goal was set to study the effect of grinding time on the fractional composition of granulated blast-furnace slag.

The work was carried out in the following sequence:

Previously, the slag was dried in a drying cabinet. Then, a 100 g. slag sample was crushed in a vibratory chopper, model 75T – ДрМ, for 30, 60, 90, 120, 150, 180, 210, 240, 270, 300, 330, and 360 seconds. After that, each portion of the obtained powder is again weighed on electronic scales and sieved through a sieve with a fraction of 0.08 mm for 5 minutes each. The amount of powder remaining after sifting on a sieve was weighed on electronic scales and recorded.

At the second stage of the research, the effect of ground granulated slag as a binding component on the strength features of concrete was studied to partially replace cement.

Concrete composition was approved as basic:

1) Cement = 16,8 %;
2) Crushed stone of fraction 10 ÷ 20 mm = 39 %:
3) Sand and gravel mix = 44,3 %;
4) Water over 100 % = 10.

During research, 5%, 10%, 15%, 20%, 25% of cement was replaced in the basic mixture with ground blast-furnace slag.

The composition of concrete cubes with 5%, 10%, 15%, 20%, 25% by replacing cement with ground slag is shown in Table 5.

When performing work, concrete samples were prepared in batches, changing the flow of cement.

The concrete composition was selected according to GOST 27006 - 86 “Concretes. Rules for the selection of composition”, SNiP 5.01.23 – 83 “Typical rates of cement consumption for the preparation of precast and monolithic concretes, reinforced concrete products and structures”.

The calculation of concrete composition on slag consists in determining the ratio of cement / slag, as well as the consumption of materials per 1m^3 of concrete, at which its specified strength is achieved at the lowest cement consumption.

The correct choice of the consistency or technical viscosity of the cement and slag mixture is of great importance in the technology of slag concrete products, since it largely determines their quality. To assess the consistency of the slag and concrete mixture, there are many ways. The cement and slag mixture differs from the cement and sand mixture in terms of the features of the shape and the topography of the aggregate.

To prepare the cement and slag mixture, a PM - 1A type mortar mixer was used.

The work was carried out in the following sequence:

At the beginning of the work, dry (crushed stone, cement, ground granulated slag, sand and gravel mixture) components of the mixture were weighed on a technical scale. The content of components in each prototype is shown in table 5. After that, dry components of the mixture were loaded into a PM - 1A type mortar mixer and mixed for 2 minutes. Then water was added and all components were mixed for another 3 minutes. The moisture of concrete mixture was maintained at 10%. After preparation, the mixture was released from a mortar mixer into demountable molds to manufacture standard samples with geometric dimensions of 100 × 100 × 100 mm and within 1 minute the mixture was compacted on a vibrating table of a molding type CB – 700. The obtained ground granulated slag from the first stage of the research, with an increment of 5% replaced with cement in each prepared mixture. To gain strength, concrete samples were subjected to thermal and humid processing (THP) according to the following mode: 2 + 8 + 2 - 2 hours. Raising the temperature to 85^{0}C, 8 hours. Cure at this temperature is 2 hours.

Next, the compressive strength of the samples was determined using a hydraulic press for testing building materials P-50. The experimental results are summarized in table 6 and a graph is constructed (Figure 1) of the dependence of the strength features of concrete on ground granulated slag, which are presented below.

Table 6 - The effect of grinding time on the fractional composition of a slag

Time, sec	The percentage of ground granulated slag on a sieve 0,08
30	46
60	37,3
90	22,6
120	15
150	8,3
180	4,6
210	4,3
240	3,9
270	3,5
300	2,7
330	2,2
360	1,45

According to the obtained data, a curve of the change of the fractional composition of a slag from the duration of grinding on a vibrating grinding mill is constructed, which is given below. The change in the fractional composition of a slag from the duration of grinding on a vibrating grinding mill is shown in Figure 1.

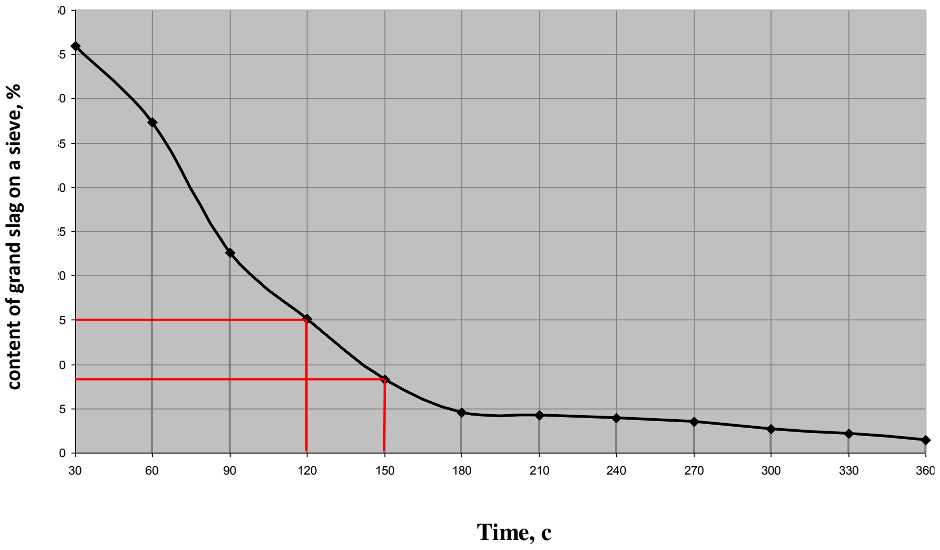

Fig. 1 - The change in the fractional composition of a slag from the duration of grinding on a vibrating grinding mill

3. Conclusions

1. Thus, we can conclude that the minimum grinding time, providing a slag residue of less than 15% on a sieve of 0.08 is 150 seconds, since an increase in time does not further reduce the sieve residue. Replacing in concrete of cement with blast-furnace slag leads to a decrease in strength characteristics.
2. Moreover, with the introduction of up to 10% of ground blast-furnace slag, the decrease in strength is insignificant and ranges from 97 ÷ 96%.
3. A further increase in the content of blast-furnace slag in concrete leads to a gradual decrease in the strength properties of concrete (25% slag – 83%).
4. Mixtures containing up to 10% slag can be used in the construction of small residential premises, the production of paving slabs, in the casting of landings, roads subject to heavy loads, in the production of pipes. It is proposed to use mixtures containing up to 25% slag in the production of wells, tapes, fences, and for facing residential premises.

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