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Study of the Structure and Properties of 30CrMnNiMo Steel Subjected to Vibration and Heat Treatment

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Abstract. The paper considers the effect of vibration exposure on changes in the structure of 30KhGSNMA steel after steel treatment by vibration during primary crystallization. Studies have shown that after vibration exposure under certain modes, the contamination index decreases, the grain score decreases, the structure becomes more homogeneous. The second part of the work is devoted to the study of the possibility of using normalization as a replacement for the improvement of 30KhGSNM steel subjected to vibration during primary crystallization. Melt samples of 30KhGSNM steel were subjected to vibration and then heat treatment, which consisted of normalization under different modes. At the end of the heat treatment, the hardness, tensile strength, and impact strength were evaluated. The microstructure of the samples was also studied using the Thixomet Pro software. The analysis showed that, depending on the cooling medium, the dispersion of perlite changes during normalization, which affects the hardness. Based on the studies carried out, it was concluded that for steel subjected to vibration during the primary solidification process, it is possible to use normalization with air-water cooling instead of improvement. The properties of the prototypes are comparable to those after improvement.

Keywords: steel, vibration, improvement, normalization, properties, structure, fineness of perlite.

Introduction

The conducted information analysis [1-6] showed that the vibrational effect on the melt during primary crystallization affects the formation of the structure and the formation of defects such as segregation, formation of gas porosity, shells, etc.

The purpose of this work is to study the effect of vibration exposure during the primary crystallization of complex alloy steel on the formation of its structure.

Steel 30KhGSNM was chosen as the object of research (Table 1). The choice of this steel is due to the fact that, firstly, it is widely used, for example, it is used for the manufacture of pipes, the manufacture of parts and products operating under complex stress conditions.

The second reason is that steel of this grade is quite widely used at the plants of the Republic of Kazakhstan both as finished imported billets and as an investment grade.

The classic heat treatment of this steel is quenching in oil at a temperature of 880-9000C followed by tempering at a temperature of 200-3000C (for pipes) or 540-5600C (for parts) with cooling in water or oil [7].

Table 1. Chemical composition of 30CrMnNiMo steel

Element	WITH	S	P	Mn	Cr	Si	Ni	Mo	Fe
Quantity, %	0.29	0.020	0.020	1.2	1.1	1.1	1.7	0.4	Rest

Steel 30CrMnNiMo is an improved alloy steel used for the manufacture of critical parts such as axles, shafts, gears, flanges and other parts operating under difficult loading conditions in the temperature range up to 200^0C. The main disadvantages in obtaining castings from this steel, as well as other steels of this group, are gas porosity caused by a fairly wide range of liquidus - solidus; dendritic segregation and segregation by penetration phases. In addition, 30KhGSNMA steel is hereditarily grainy; the primary structure influences the formation of the final structure after heat treatment.

1. Research methodology

Experiments on the influence of vibration exposure were carried out as follows. Steel 30CrMnNiMo was melted in a modernized UIP-25 furnace, then poured into a corundum crucible at a temperature of 1620 0C. The choice of the crucible of this brand is due to the following: this crucible withstands high temperatures, does not have a carburizing effect and is chemically inert. The mass of the melt was 0.2 kg. Then the crucible with the melt was subjected to vibration with a frequency of 80 - 120 Hz, an amplitude of 1.8 - 2.6 mm, the vibration time varied from 3 to 7 minutes.

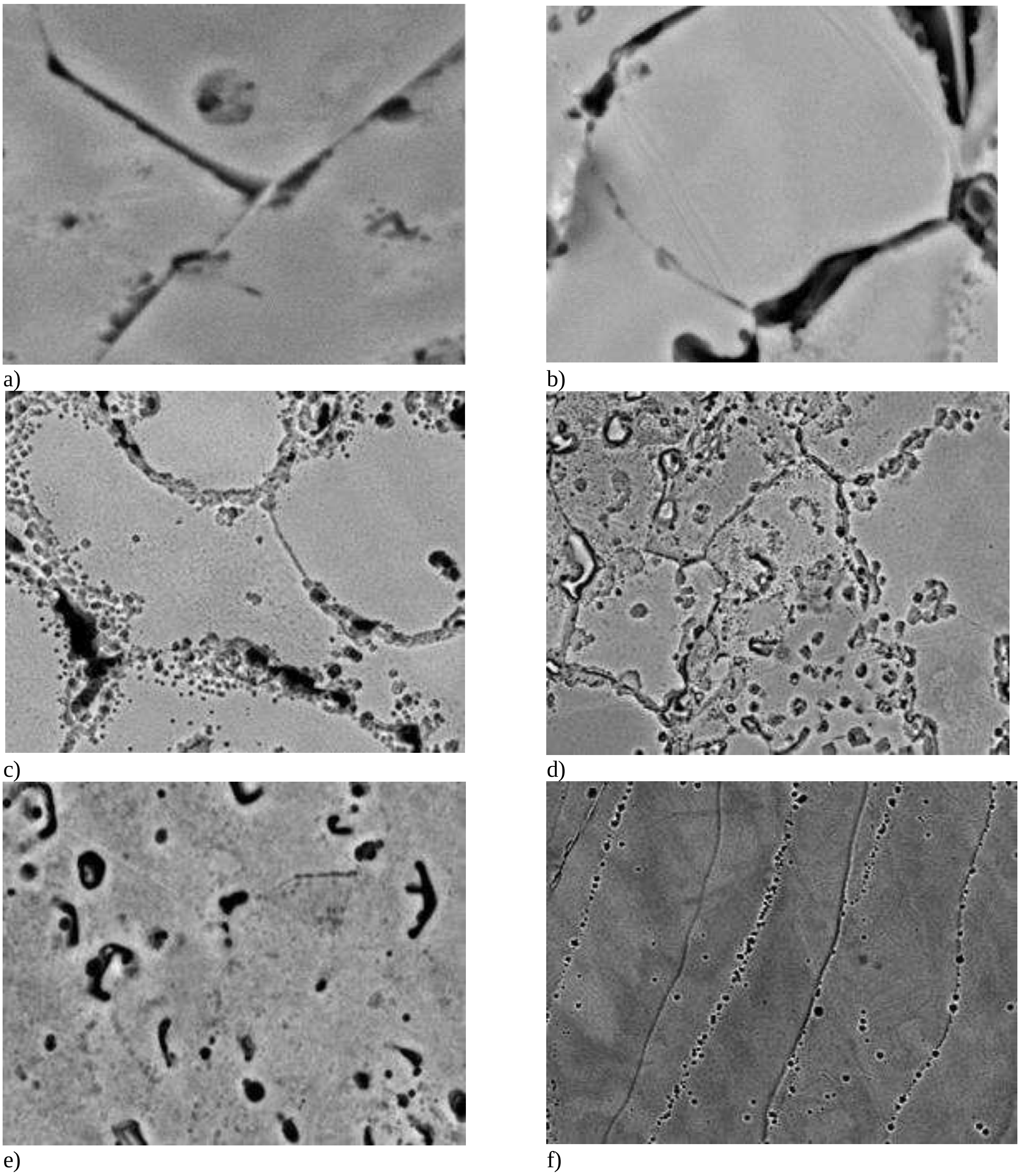
After the specified time, the impact of vibration ceased, then the melt crystallized under natural conditions, after the completion of the crystallization process and complete cooling, the structure and some properties of the casting were studied.

To study the structure, metallographic sections were made from the resulting ingot using a Struers sample preparation complex, etching was carried out using A3 electrolyte for 25 sec. Figure 1 shows some microstructures of steel samples subjected to vibration. A sample of 30CrMnNiMo steel without impact was used as a reference.

When studying the microstructure, the following parameters were studied: grain score, average grain diameter, number of grains per 1 mm^2 area.

2. Results and discussion

Metallographic analysis was carried out using the Thixomet Pro software. The results of the analysis are presented in tables 2 - 3.



a) standard, sample without exposure; b) vibration frequency 80 Hz, vibration time 3 min; c) vibration frequency 80 Hz, vibration time 7 min; d) vibration frequency 100 Hz, vibration time 3 min; e) vibration frequency 100 Hz, vibration time 7 min; f) vibration frequency 110 Hz, vibration time 7 min (X 1000)

Fig. 1. - Effect of vibration on the microstructure of steel 30KhGSNMA

As can be seen from the data in tables 2 - 4 and figure 1, a significant change in grain size occurs at a frequency starting from 100 Hz, at a vibration frequency of 110 Hz, the average grain size decreases by almost 2 times. A further increase in the vibration frequency has practically no effect on the grain size.

Table 2. Influence of vibration frequency on structure parameters, (vibration amplitude a = 2 mm, vibration time t = 5 min)

№ regime	Frequency, Hz	Average diameter grain, mm^2	Average number of grains on an area of $1mm^2$	Grain score
0	0	0.075	168	4 - 5
1	80	0.069	211	4 - 5
2	90	0.064	428	5 - 6
3	100	0.052	483	5 - 6
4	110	0.041	669	6 - 7
5	120	0.039	675	6 - 7

Table 2 shows the results of testing the effect of vibration amplitude on the average grain size, while the vibration frequency and time did not change.

Table 3. Influence of vibration amplitude on structure parameters, vibration frequency h = 110 Hz, vibration time t = 5 min)

№ regime	Amplitude vibration, mm	Average diameter grain, mm	Average grains on an area of $1mm^2$	Grain score
0	0	0.075	168	4 - 5
6	1.5	0.052	312	4 - 5
7	2.0	0.041	669	6 - 7
8	2.2	0.040	765	6 - 7
9	2.4	0.040	762	6 - 7
10	2.6	0.039	802	6 - 7

Starting from an amplitude of 2 mm, the grain size practically does not change; in the interval considered, the influence of the amplitude on the structure parameters is insignificant. It should be noted that it makes no practical sense to further increase the vibration amplitude, since a further increase in the amplitude leads to a strong shaking of the mold and can lead to its destruction (for example, when casting into shell molds), in addition, an increase in the amplitude leads to strong mechanical wear of the vibrating plate.

In the last series of experiments, the effect of vibration time on the average grain size was considered (Table 4).

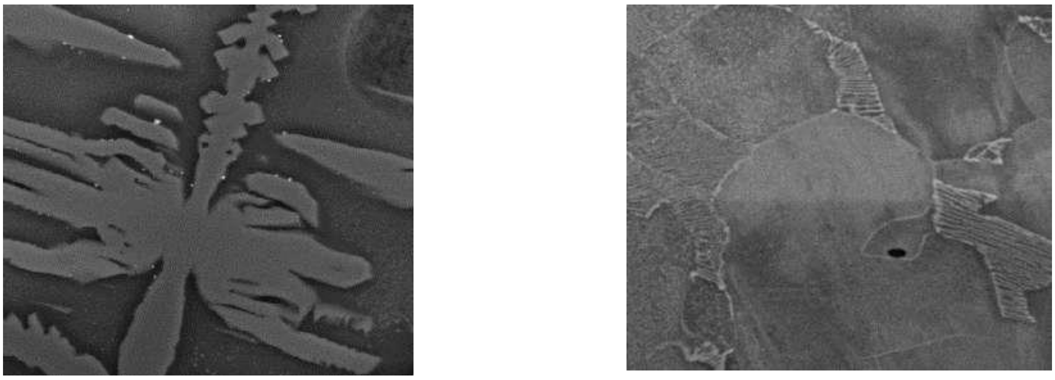
Table 4. Influence of vibration time on structure parameters (vibration frequency h = 110 Hz, vibration amplitude a = 2mm)

Number regime	Time vibration, min	Average diameter grain, mm	Average number of grains on an area of $1mm^2$	Grain score
0	0	0.075	168	4 - 5
11	3	0.060	249	4 - 5
12	4	0.047	456	5 - 6
13	5	0.041	669	6 - 7
14	6	0.037	723	6 - 7
15	7	0.037	729	6 - 7

Increasing the vibration time favorably affects the grinding of grain, however, increasing the time for more than 7 minutes does not lead to a significant improvement in the parameters. Apparently, one should limit the vibration time to 5-6 minutes.

As can be seen from the data in Table 2-4, the vibration frequency and time have the greatest influence on the grain size, while the vibration amplitude in the studied range has practically no effect.

During the crystallization of an ingot subjected to vibration, the tendency to form a dendritic structure is less pronounced than during conventional crystallization (Fig. 2). The decrease in the tendency to dendrite formation apparently also determines the decrease in the average grain size in the structure. The absence or weakly pronounced dendritic structure reduces the anisotropy of properties and chemical segregation, because it is known that chemical segregation is especially pronounced precisely between the dendrite axis and the interaxial space.



a) ordinary crystallization; b) crystallization under the action of vibration, frequency 110 Hz. (X1000)

Fig. 2. - The microstructure of steel after crystallization:

On sections of ingots processed according to modes 0, 4, 13, the contamination index was also determined. The last indicator was determined by the formula (1):

$$I = \frac{b\sum a_i \cdot m_i}{l} \quad (1)$$

where b is the division value of the ocular scale at a given magnification in µm;
a_i is the average size of inclusions in divisions of the ocular scale;
m_i is the number of inclusions in this group;
l is the counting length in µm.

The measurement results are shown in Table 5.

Table 5. Determination of the pollution index

№ regime	Mode characteristic	Index pollution
0	no vibration effect	1.84
4	vibration frequency h = 110 Hz, vibration amplitude a = 2 mm, vibration time t = 5 min	1.56
14	vibration frequency h = 110 Hz, vibration amplitude a = 2 mm, vibration time t = 6 min	1.42

An analysis of the data in Table 5 shows that in the studied range, vibration has a positive effect on the pollution index: in mode 4, the pollution index decreases by 15%, an increase in vibration time to 6 minutes reduces this indicator by almost 23%.

The conducted experimental studies have shown that the vibration effect during the primary crystallization has a beneficial effect on the primary structure of the steel.

A favorable change in the primary structure under the influence of external factors and hereditary graininess, which is inherent to one degree or another in all alloyed steels, allow us to suggest that favorable changes in the structure will persist after heat treatment. This assumption is based on studies of the structure of steels after heat treatment in the presence of a primary ordered structure [6–8]. The results of these studies make it possible to consider various alternatives as heat treatment of prototypes aimed at simplifying the heat treatment of steel treated by an external influence in the process of primary crystallization.

The classical heat treatment of this steel is quenching in oil at a temperature of 880-900^0 C followed by tempering at a temperature of 200-300^0 C (for pipes) or 540-560^0 C (for parts) with cooling in water or oil [9].

As a result of heat treatment, a structure is formed in this steel, consisting of martensite decomposition products - a sorbite-like mixture, which is an alloyed α - solution and carbides, mainly of the $(Fe, Cr, Mn)_3C$ type. The finely dispersed sorbitol-like mixture provides a good combination of strength and viscosity properties, which allow the steel to work after this heat treatment in complex stressed conditions. In this case, the tensile strength is provided by about 600 MPa, impact strength is 0.5 MJ/m^2.

As is known, the simplest type of heat treatment is the normalization of steel [10]. Normalization makes it possible to obtain a quasi-eutectoid ferrite-pearlite mixture, which differs from the true eutectoid in a higher dispersion, which leads to some increase in the mechanical properties of steel. However, normalization has not become widespread as an alternative to the more expensive type of heat treatment - improvement, because. the increase in properties after normalization is much lower than after improvement. In this regard, normalization is used either for heat treatment of cheap carbon steels, or as one of the stages of heat treatment of alloy steels, as a preliminary stage for structure homogenization.

The conducted studies have shown that the structure of steel under the influence of vibration in the process of crystallization becomes finer-grained and uniform. It can be assumed that the use of normalization as a heat treatment for such a structure will have a more effective effect on the final structure than in conventional practice.

To test this assumption, the following experimental studies were carried out.

As an object of study, samples of steel 30CrMnNiMo subjected to vibration during primary crystallization were used. The steel was poured into shell molds mounted and fixed on a vibrating table. During the crystallization process, the molds with the melt were subjected to vibrations with the following parameters: amplitude - 2.5 mm, frequency - 110 Hz, exposure time - 5 min. At the end of the vibration, the filled molds were left on the vibrating table until completely cooled. Then the molds were broken, the castings were cleaned from the remnants of the mold and subjected to heat treatment under different modes.

Heat treatment was carried out in a Nabertherm LHT 02/17 furnace in air. At the end of the heat treatment, specimens were cut out from the experimental castings for further testing. Properties such as hardness, tensile strength and impact strength were studied. An AXIO Imager A1 microscope was used for research, a Wilson VH1150 Vickers hardness tester was used to determine the hardness, an INSTRON testing machine was used to determine the ultimate strength, impact strength was determined using an MK-30A pendulum impact tester. Table 6 shows the results of the tests.

Table 6. Test results

Sample number	Heat treatment mode	Hardness, HV	Tensile strength, MPa	Impact strength, MJ/m^2
1	After casting, no heat treatment	227	324	0.26
2	Hardening 900^0, oil, tempering 550^0 oil	432	620	0.47
3	Normalization 900^0 cooling - air	385	506	0.33
4	Normalization 900^0 cooling - water-air mixture	424	602	0.43
5	Normalization 930^0 cooling - air	389	517	0.35
6	Normalization 930^0 cooling - water-air mixture	431	613	0.40

As can be seen from the data in Table 6, carrying out a one-stage heat treatment consisting of normalization significantly improves the properties of the steel compared to the initial state. The hardness and strength of steel after normalization compared to the cast state increase by about 40%, impact strength - by 25%. Such an increase in properties is quite natural, because. During normalization, two processes take place. On the one hand, there is a homogenization of the structure, on the other hand, recrystallization with the formation of a quasi-eutectoid, which is characterized by greater dispersion, which leads to an increase in the level of properties.

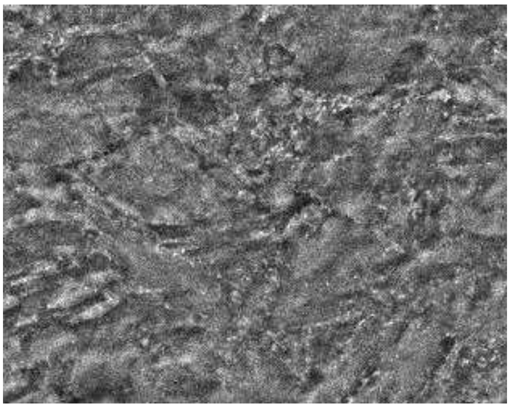
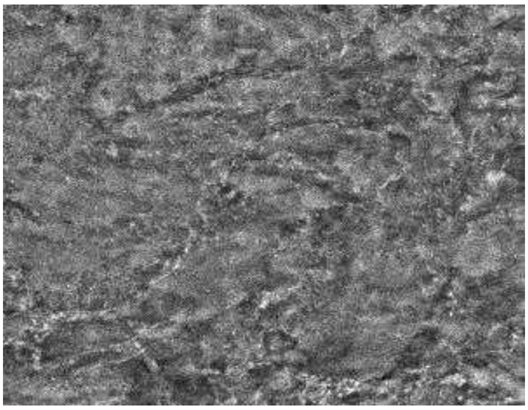
It should be noted that the influence of the normalization temperature within the indicated limits practically does not affect the change in properties. Further expansion of the temperature range for choosing the normalization temperature does not make sense. Temperature normalization below 900^0C is not effective, because. this temperature is already in fact the lower temperature limit of the austenite zone for this steel grade. Increasing the temperature above 930^0C also does not make sense, because. can lead to uncontrolled grain growth, which is typical for hereditary grained steels and overheating.

A much greater influence on the change in properties after heat treatment, as can be seen from the data in Table 6, is exerted by the cooling medium. Two options were used as a cooling medium: air or water - air jet at a water temperature of 20^0C and a flow rate of 15 $cm^3/s*m^2$.

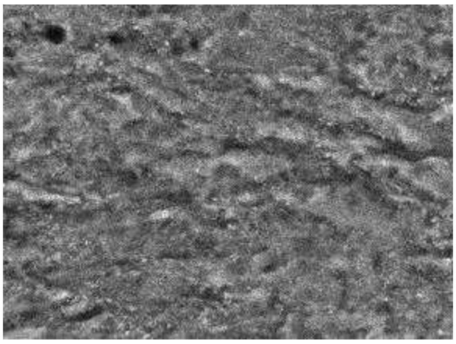
The use of a water-air jet leads to an increase in the cooling rate, which provides other conditions for heat removal and recrystallization. As is known [9 - 11], for carbon steels, such an environment cannot provide the critical hardening rate and, consequently, the occurrence of martensitic transformation. For alloyed steels, due to the increased stability of austenite, martensitic transformation at such a cooling rate is possible in a number of cases, for example, when alloyed with elements that provide increased hardenability.

The composition of 30CrMnNiMo steel contains a composition of chromium + nickel + molybdenum, i.e. elements that provide a sufficiently high hardenability of the steel and, consequently, the possibility of martensitic transformation at a lower cooling rate. On the other hand, when using a single-stage heat treatment, the partial occurrence of martensitic transformation is undesirable, because. in this case, the formation of individual zones of retained austenite is possible.

If we judge the change in the hardness of the test samples after normalization, then we can assume that only recrystallization occurs with the formation of a finely dispersed quasi-eutectoid without phase recrystallization. For this purpose, the microstructure of the prototypes was studied (Fig. 3).

a) b)



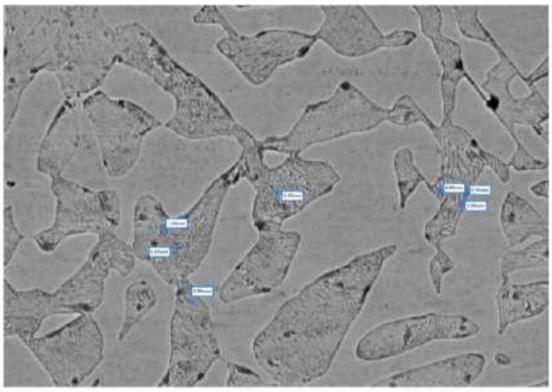
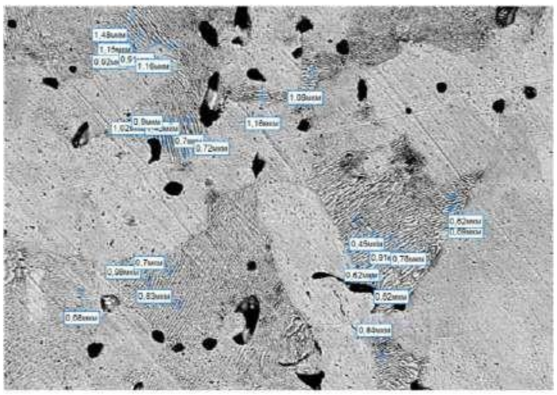
c)

a) sample No. 5; b) sample No. 6; c)sample No. 2 (magnification X400)

Fig.3. - Microstructure of steel 30KhGSNM after heat treatment

As can be seen from Figure 3, the structure of the samples after normalization is indeed characterized only by a sorbite-like mixture, and after cooling with a water-air jet (Fig. 3a), the mixture visually looks more finely dispersed than after cooling in air (Fig. 3b).

Figure 4 shows examples of using the Thixomet Pro software to evaluate the fineness of perlite. The analysis was carried out in 10 fields of view, the average result is given.

a) b)

a - sample 4, perlite fineness - 0.64 μm b- sample 3, perlite fineness - 0.89 μm

Fig.4. - Evaluation of dispersion using Thixomet Pro software

As can be seen from Figure 4, the dispersion of perlite during cooling in a water-air environment really increases significantly (about 30%), which explains a more significant increase in hardness (Table 6). Qualitative changes in the structure, as expected, did not occur: the structure in both samples is represented by a sorbitol-like mixture.

Conclusion

The conducted studies have shown that for 30CrMnNiMo steel subjected to vibration during primary crystallization, the contamination index is significantly improved, the grain score decreases, and the range of grain size variation decreases, i.e. the structure becomes more homogeneous. It has also been shown that in order to improve the mechanical properties of vibration-treated steel, the improvement can be replaced by normalization with a higher cooling rate than in still air. In such steel, which has a relatively ordered structure as a result of processing during primary crystallization, a finely dispersed sorbitol-like mixture is formed, comparable in properties and structure to the tempering sorbitol formed after improvement.

The use of one-stage heat treatment (normalization with accelerated cooling) makes it possible to shorten the heat treatment cycle of steel and, thereby, increase the productivity of thermal equipment.

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Polyamide 6 is an Integral Component of the Protective Coating for Steel ST3

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Abstract. In this study, an attempt was made to use PA 6 as a component of an experimental composite anticorrosive coating that increases the adhesion of hydrophobic coatings (iron stearate and zinc stearate) to protect structural steel St3. The phosphating primer leads to the formation of a film of iron salts insoluble in water on the steel surface and adsorption of PA 6 on them. Hydrophobization of the surface formed in this case zinc stearate leads to the formation of a coating with high adhesion and anticorrosive properties.

Tannin is a corrosion inhibitor. The advantage of the tannin primer is that its molecules are able to bind to the metal surface and the PA 6 macromolecules simultaneously, forming a strong coating on the metal. Zinc stearate gives the coating hydrophobic properties and additional protection of the metal from corrosion.

Keywords: anticorrosive coating, St 3, polyamide 6, tannin, phosphating, iron (III) stearate, zinc stearate

Introduction

In recent decades, research on the protection of metals from corrosion has focused on the problem of creating polymer coatings. Coatings created on the basis of polyester, plastisol, polyvinylidene fluoride, pural, etc., provide metal structures with optimal technological qualities, high corrosion resistance and decorative appeal.

One of the leaders in resistance to mechanical and chemical influences, sharp temperature fluctuations is pural. Polyurethane modified with polyamide granules is used for the manufacture of the pural. It is believed that polyamide gives the polymer high mechanical strength and elasticity.

Polyamide 6 (PA 6) is a semi–crystalline, thermoplastic polymer with amphiphilic properties [1]. It has high hardness and impact strength; high resistance to dynamic loads, to abrasion in dry friction conditions; to the effects of organic media. The polymer retains high impact strength at low temperatures and good sliding properties in contact with steel. PA 6 is used in the automotive, shipbuilding, mechanical engineering, food and medical industries.

Despite the high technological qualities and widespread use, the question of the possibility of using PA 6 as a basis for the creation of protective anticorrosive coatings has not yet found close consideration. The inclusion of polyamide in the pural is only one of the ways to solve this problem.

One of the probable reasons for the narrowing of interest in PA 6 as a component of anticorrosive coatings may be a high degree of moisture absorption (3.5% – 6%). The physico-mechanical properties of the moisture-saturated polymer deteriorate markedly. When moisture is absorbed, the electrical resistance of the polymer can decrease by several orders of magnitude [2].

1. Materials and methods of research

The purpose of this study was an attempt to create a protective anticorrosive coating for St3 using PA 6. The study used polished steel samples with a size of 4 ×6 mm and a thickness of 3 mm.

A high degree of corrosion protection, resistance to mechanical damage and chemical influences is provided by high-quality adhesion, which requires careful preparation of the metal surface.

The coating operation was carried out in stages.

1. Before testing, the surface of the samples was subjected to mechanical cleaning, degreasing, washing and drying.

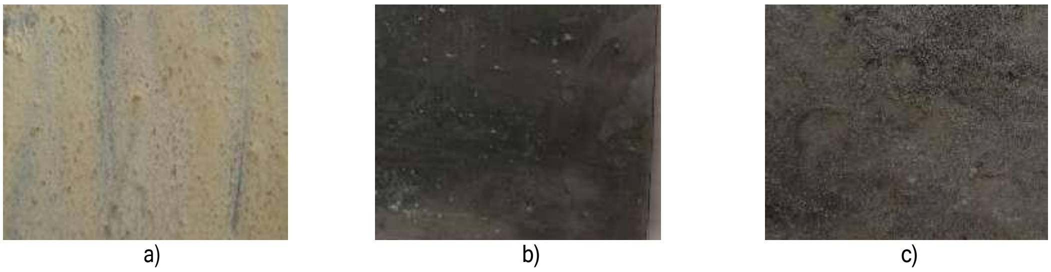
2. The cleaned surface was treated with reagents that increase adhesion and anti-corrosion properties (phosphating, treatment with an alcohol solution of tannin).

3. The granules of PA 6 were dissolved in 75% formic acid (1:3 by weight), when heated, a viscous transparent solution was obtained. Liquid RA 6 was applied twice to the surface of the samples by the roll method. They were kept for 48 hours at a temperature of 26 – 29^{0}C, followed by drying at 50^{0}C until the formate evaporated and a porous polymer layer formed.

4. Modification (hydrophobization) of the polyamide coating surface was carried out by applying ethanol solutions:

– iron (III) stearate (Figure 1a);

– zinc stearate (Figure 1b, 1b).



a) coating: tannin + RA 6 + iron (III) stearate; b) coating: tannin + RA 6 + zinc stearate; c) coating: phosphating + PA 6+ zinc stearate

Fig. 1. – Test samples

The function of the primer is not only to ensure a high bond of the metal with the coating. It should also reduce the surface tension. To provide such properties, the primer must have a physico-chemical affinity for both metal and polymer coating at the same time. Such characteristics are possessed by a phosphate coating that forms a film of water-insoluble iron salts on the surface of steel. The coating is characterized by high adhesion and electrical insulation properties [3].

Phosphating of steel samples was carried out with a mixture of 10% orthophosphoric acid with iron (III) orthophosphates and citric acid. Iron orthophosphate was obtained by exchange reactions (equations 1, 2):

$$FeCl_3 + 3NaOH = Fe(OH)_3 + 3NaCl \quad (1)$$

$$Fe(OH)_3 + H_3PO_4 = FePO_4 + 3H_2O \quad (2)$$

2. Results and discussion

In the study, another method of anticorrosive priming of samples was used – coating with 1% alcohol solution of tannin [4]. Tannin is a natural polyphenol. The advantage of the tannin primer is that its molecules are able to simultaneously bind to the metal surface and the macromolecules of PA 6. The phenolic groups of tannin interact with both the surface Fe2+ ions and the free terminal NH2 groups of PA 6, forming a protective layer on the metal surface. The tannin reaction with the sample surface proceeds at a high rate at room temperature with the formation of a blue-violet film.

Iron stearate was obtained by the exchange reaction of sodium stearate with iron III chloride (Equation 4). Sodium stearate was obtained by the exchange decomposition of stearic acid with alkali (equation 3).

$$C_{17}H_{35}COOH + NaOH = C_{17}H_{35}COONa + H_2O \quad (3)$$

$$3C_{17}H_{35}COONa + FeCl_3 \rightarrow (C_{17}H_{35}COOH)_3Fe \downarrow + 3NaCl \quad (4)$$

Iron stearate is a plasticizer and polymer modifier, a siccative. It is able to improve the mechanical and protective properties of coatings, increase their hydrophobicity and corrosion resistance.

Zinc stearate was obtained according to a similar scheme (equations 5, 6):

$$C_{17}H_{35}COOH + NaOH = C_{17}H_{35}COONa + H_2O \quad (5)$$

$$2\, C_{17}H_{35}COONa + ZnCl_2 = (C_{17}H_{35}COO)_2Zn + 2NaCl \quad (6)$$

Zinc stearate is hydrophobic, it is an adhesive, a leveling agent of lubricants in the processing of plastics [5].

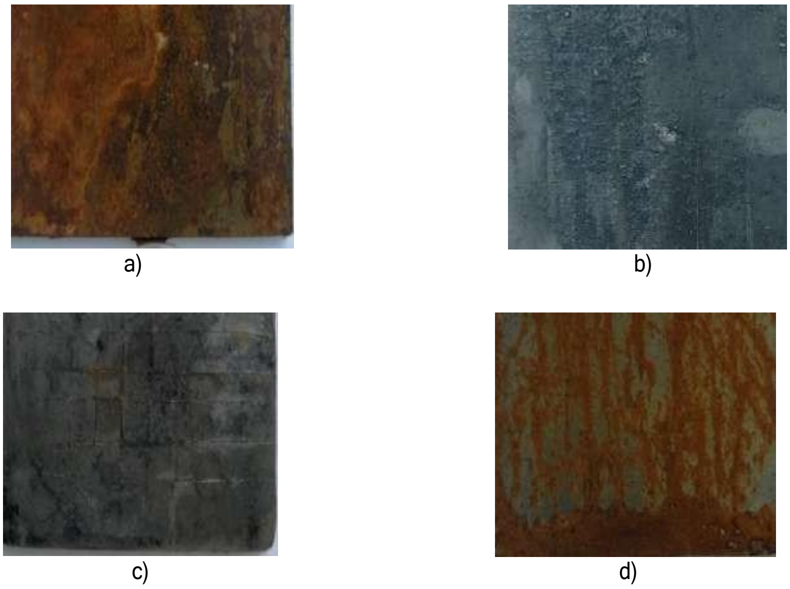
For corrosion tests, the samples were immersed in a 3% NaCl solution followed by air drying (GOST 9.308-85). The dive was carried out for 10 minutes (five times during the day) for 96 hours.

The control of the adhesion strength of the coating to the substrate surface was carried out by the method of drawings (GOST 9.302-88). The assessment of corrosion damage was determined by the degree of damage to the surface of the samples and expressed as a percentage.

As the results of the study have shown, the most important stage in the creation of protective hydrophobic coatings on steel is the priming of the metal surface.

Neither iron stearate nor zinc stearate have sufficient adhesion to the polished surface of St 3. The application of PA 6 to a cleaned and degreased surface without a primer is accompanied by peeling of the coating in an aqueous medium, which also indicates a very low adhesion of the polymer (4 points on the scale of adhesive strength assessment).

When the phosphating mixture was applied to the samples, a high-strength film was formed, which enhanced the adhesion of the polymer (1 point on the scale of adhesive strength assessment).



a) coating: tannin + PA 6 + iron (III) stearate; b) coating: tannin + PA 6 + zinc stearate; c) phosphating + PA 6+ zinc stearate; d) control

Fig. 2. – Samples after corrosion tests

Priming the samples with tannin also enhanced the adhesion of polyamide to the metal substrate (1 point on the scale of adhesive strength assessment).

However, in both cases, after applying the primer, the coating surface remained hydrophilic due to the properties of the polymer itself.

Hydrophobization of the polymer coating was achieved by applying iron (III) stearate (1a) and zinc stearate (1b, 1c) to the surface of the samples. Compositions 1b and 1c have demonstrated good water resistance. The coating "tannin + PA 6 + zinc stearate" completely prevented corrosion under experimental conditions (pic. 2b), the degree of corrosion damage to the surface of the sample coated with "phosphate + PA 6+ zinc stearate" was approximately 2% (pic. 2, c). However, the coating "tannin + PA 6 + iron (III) stearate", despite the high degree of adhesion in atmospheric conditions, turned out to be less water-resistant, peeled off as a result of corrosion tests and did not prevent metal corrosion (2, a). The control sample was subjected to uniform corrosion (pic. 2, d).

It can be assumed that certain prospects for obtaining new anticorrosive coatings using RA require further development of methods to increase the adhesive strength of the polymer and its hydrophobicity, as well as evaluation of these methods in operational studies

Conclusions

1. PA 6, solubilized with formic acid, can be considered as an integral component of an anticorrosive composition for the protection of St3. The most important condition for its application is careful treatment of the metal surface with primers having a chemical affinity for metal ions and fragments of polyamide molecules. Tannin and phosphates can act as such primers.

2. The anticorrosive properties of the coating revealed in laboratory tests using PA 6 occur only after hydrophobization of the polymer layer, including zinc stearate.

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Deoxidation of electric steel in arc steelmaking furnaces using complex silicon-aluminum ferroalloys

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Annotation. The article presents the results of studies on the effect of deoxidation by complex silicon-aluminum alloys (including with barium) on the chemical composition, the degree of assimilation of the leading elements, the quality, structure of the electrical steel, the nature and quantity of non-metallic inclusions in comparison with similar indicators of steel deoxidized in the traditional way using ferrosilicon and secondary aluminum.

Keywords: deoxidation, electric steel, ferrosilicon, aluminum, complex deoxidizer, ferrosilicoaluminium, deoxidation ability, assimilation of elements, non-metallic inclusions, quality of steel.

Introduction

Deoxidation of steel is carried out for the maximum possible reduction of oxygen dissolved in it during the smelting process, as well as for the removal of nitrogen and hydrogen. The deoxidation process can be carried out: by a precipitating (deep) method, when special elements are added to the metal, which binds oxygen into strong oxides; by a diffusion method, which consists in deoxidation of slag, which causes the diffusion of oxygen from the metal into the slag to an equilibrium distribution between both phases; special deoxidation methods are also used (treatment with synthetic slags, vacuum deoxidation).

As deoxidizers, elements with a greater affinity for oxygen than iron are used: manganese, silicon, aluminum, titanium, calcium, titanium, zirconium, which are introduced into the melt not in pure form (except aluminum), but in the form of an iron-based alloy or a complex alloy. The most widely used for deoxidation of steel were: manganese (ferromanganese, silicomanganese), silicon (ferrosilicon), chromium (ferrochrome, silicochrome) ferroalloys, as well as secondary aluminum in ingots.

In the traditional method of producing electric steel, ferromanganese, ferrosilicon, aluminum, silicomanganese, silicocalcium and alloying elements are used for deoxidation [1].

Ferrosilicon and aluminum are used in the production of all steel grades, including alloyed and high-alloy steel grades. In addition, silicon is also an alloying element. Therefore, the replacement of ferrosilicon and ingot aluminum with ferrosilicoaluminium is economically advantageous due to the cheapness of FSA alloys.

Ferrosilicoaluminium is an alloy of silicon, aluminum and iron, one of the advantages of which is a lower cost than traditional deoxidizers (ferrosilicon and aluminum). This is due to the fact that during the electrothermal melting of FSA, a fairly large amount of aluminum is recovered along with silicon and iron, and at the same time the energy costs for aluminum recovery are half as much as during electrolysis.

The deoxidizing ability of FSA is higher than that of individual deoxidizers - aluminum or ferrosilicon. Polish researchers back in 1981 [2] noted the high deoxidation ability of the alloy and its modifying effect on sulfides.

The separate deoxidation of steel by silicon and aluminum leads to the formation of silicon oxide and aluminum oxide - solid silicate and corundum, which are not capable of coagulation and are difficult to remove into the slag. This leads to contamination of the steel with stitch silicates and corundum of crystal sharp-angled shape and a corresponding deterioration in mechanical properties.

The method that allows to significantly increase the economic and technological efficiency of deoxidation and alloying of steel is the use of deoxidizers in a complex in one alloy. The essence of this method is to increase the reactivity of the elements due to more favorable energy conditions, under which the reactions of the interaction of the elements with oxygen dissolved in liquid steel are more complete [3]. A well–known and widely used complex alloy, silicomanganese, is more effective in deoxidation and alloying of steel than ferromanganese and ferrosilicon supplied in adequate quantities.

Complex deoxidation makes it possible not only to deoxidize the metal deeply, but also has a positive effect on its quality, affecting the amount and nature of the reaction products formed, which form the basis of non-metallic inclusions in steel.

According to the data obtained on the basis of pilot tests on the deoxidation of calm and low-alloy steel grades with ferrosilicoaluminium, the authors of [4,5] developed a technology according to which experimental melting of calm and low-alloy steel grades was carried out with the determination of optimal consumption and composition of complex alloys of several grades of FSA. Special attention was paid to the study of the influence of complex alloys on the nature of non-metallic inclusions, on the structure of the metal and comparative analysis of the results of mechanical tests of rolled products from experimental and comparative steel.

1. Experimental part

Experimental melting of electric steel for the replacement of ferrosilicon and aluminum ingots with FSA and FSAb alloys was carried out in a shaped foundry on an ASF-6MT electric furnace. Experimental meltings were carried out on carbon steel grades St20, 35, 45 and high-alloy grades: chromium, corrosion-resistant and heat-resistant - 40Kh, 35KhM, Kh18N9T, 20Kh13L, 30KhGSA and manganese - 110G13L, 65G, differing from converter steels, except for the smelting method and chemical composition, methods of further processing and purpose (casting, forging, thermal and mechanical processing). At the same time, methods of feeding the alloy into steel and a sequence of technological operations were developed to ensure maximum efficiency of the experimental alloy used.

Alloy additives were carried out according to several variants, differing in the amount and order of its introduction into steel, depending on its brand and smelting technology:

1. All the necessary ferrosilicoaluminium in an amount adequate to the replaced ferrosilicon, according to the steel grade, was fed into the furnace for slag in 15-20 min. before the release of steel (the method of diffusion deoxidation of steel), which was pre-oxidized when it was released into the bucket by feeding pig aluminum in a reduced amount;

2. The same amount of ferrosilicoaluminium was fed into a bucket to a jet of steel (in kinetic deoxidation mode) when it was released without aluminum supply;

3. Half of the calculated amount of alloy was fed into the furnace before release and the remaining amount was fed into the ladle, while, according to the series of melts, the amount of alloy varied according to the schemes: 1/3 of the mass into the furnace - 2/3 into the ladle, 2/3 into the furnace - 1/3 into the ladle and 1/2 into the furnace and into the ladle.

2. Results and discussion

During the experimental smelting, steel and slag samples were taken for chemical composition analysis, as well as samples of the finished metal for metallographic analysis.

A total of 84 melts were carried out using two types of FSA, i.e. FS55A20 and FS45A15. 49 smelts of these brands, smelted at the same time, were used as comparative ones. Ferrosilicon in electric melting is used for preliminary deoxidation and alloying of steel, and aluminum for the final deoxidation of metal introduced into the furnace or into the ladle in the form of ingots in 2-3 minutes. before the release of the melting. The consumption of deoxidizers for melting is given in table 1.

The table shows that ferrosilicon and aluminum ingots were not used for deoxidation in experimental melts. Table 2 gives the chemical composition of the finished metal of experimental and comparative heats.

It follows from Table 2 that, despite the fact that secondary aluminum was not used in the experimental smelts, the average aluminum content on the experimental and comparative metal was 0.029%. With the same consumption of silica manganese on the experimental metal, the manganese content is 0.04% higher than on the comparative metal, which indicates a high deoxidizing ability of the FSA alloy. The sulfur content on the test metal is 0.001% less. There are 5-6% fewer visible cracks on the experimental ingots, which can be explained by a decrease in the contamination of the experimental metal.

Table 1. Specific consumption of deoxidizers

Melts	Number of melts	Consumption of deoxidizers, kg/t; min:max/average			
		FS75	CMn	AB90	FSA and FSAb
Experienced	84	-	4,60:6,80 5,50	-	6,16:10,2 8,83
Comparative	49	5.90:10,34 8,60	4,70:7,00 5,50	1,17:2,20 1,53	-

Table 2. Chemical composition of finished steel

Melts	Number of melts	Chemical composition of finished steel, % min:max/average				
		Al	Mn	S	P	Si
Experienced	84	0,011:0,099 0,029	0,35:0,92 0,65	0,011:0,026 0,019	0,013:0,026 0,018	0,13:0,50 0,28
Comparative	49	0,012:0,060 0,029	0,43:0,79 0,60	0,011:0,027 0,020	0,014:0,031 0,018	0,15:0,48 0,27

Already the first experiments on the deoxidation of high-alloyed steel grades have shown the high efficiency of ferrosilicon aluminum alloys not only as a deoxidizer, but also as a reducing agent of oxidized and slag-converted alloying components, such as [Cr] and [Mn], the average content of which in the final samples of experimental steels increased compared to the composition of steels smelted using the basic technology with ferrosilicon, on different brands from 0.5 to 0.8% (Fig. 1.).

This circumstance makes it possible to evaluate the efficiency of the ferrosilicoaluminium alloy taking into account another indicator – significant savings in alloying materials during the smelting of high-alloy steel grades. Experiments have established that the assimilation of [Si] and [Al] in the electric steel is higher than in the converter, due to the lower oxidation of the first.

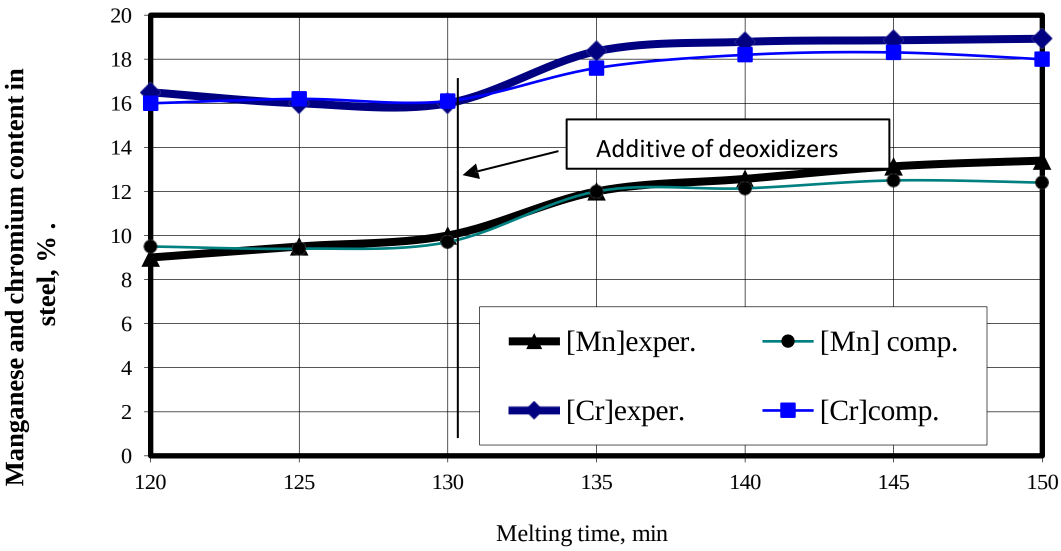

Fig. 1. – The behavior of manganese and chromium in the smelting of 110G13L and X18N9T grade steels during deoxidation of FSA (experimental) and FS65 (comparative)

Similar to the FSA melting, pilot-industrial melting using ferrosilicoaluminium with barium was carried out. The quantity and variants of FSAb additives did not differ from the parameters given above with FSA. Experimental and industrial studies have established that FSA with barium as a deoxidizer is not inferior to FSA.

The obtained data on the deoxidizing ability and the possibility of diffusive reduction of alloying elements from slag to metal were somewhat better, which is explained by the presence of an active deoxidizer – barium [6]. Therefore, much attention was paid to the influence of FSAb on the quality indicators of steel, especially the influence of barium on the formation and nature of non-metallic inclusions formed in cast alloy steel. Based on the traditional technology of steel smelting, when deoxidized steel is immediately poured into molds and is not subjected to such significant deformations as steel rolled into a sheet, we assumed to detect the influence of barium, expressed in a more visual form. Moreover, the time that passes from the deoxidation of steel to its pouring into molds and crystallization lasts much less.

For these purposes, nonmetallic inclusions were studied in samples of comparative steel deoxidized by FS65 and AB87. The nonmetallic inclusions most present in comparative steel can be divided into several types (Fig. 2.).

All inclusions (sulfides and oxysulfides) have a complex composition, large. They tend to coagulate in the form of globules with a metal substrate in the center (Fig. 2. b, c).

a) b) c)

Fig. 2. – Non-metallic inclusionsin cast steel grades 110G13L (a) and 35HGS (b), (c) x 100

The size and shape of non-metallic inclusions suggest their significant deformation during hot forging of these ingots in the forging and pressing shop and a negative impact on the quality of products, which is generally confirmed by a high degree of rejection of forging blanks for defects – transverse-longitudinal cracks and hot fracture, reaching 20% of the finished steel.

Then samples of steel deoxidized with ferrosilicoaluminium without barium were examined. As can be seen from the photos of the steel grinds cast with FSA deoxidation, the appearance and shape of non-metallic inclusions have significantly changed into a favorable pronounced globular shape (Fig. 3.). At the same time, the metal substrate forming the center of inclusions disappeared. Subsequent analysis of steel billets deoxidized by FSA and subjected to forging and machining in forging and pressing and mechanical workshops showed a 5-6% reduction in defects due to cracks and hot fracture.

The function performed by barium, first of all, is to suppress the formation of sulfide inclusions and changes in the shape of these inclusions in order to obtain poorly deformable or finely dispersed globular inclusions [7].

Due to the limited number of experimental batches of the alloy, the number of pilot smelts with FSAb was not enough to carry out a representative series of smelts with the determination of all the parameters studied and the development of technology to achieve maximum efficiency of the alloy. Nevertheless, the results of metallographic analysis confirmed the expected shapes and distribution of inclusions in steel.

a) b)

Fig. 3. – Globular nonmetallic inclusions in steels of grades 110G13L (a) and 40X (b), deoxidized by FSA

Studies of the quality of cast metal and metallographic analysis have shown that the additives of FSA with barium significantly change the nature and character of non-metallic inclusions (Fig. 4.). At the same time, there was a significant grinding and a 1.5-2-fold decrease in inclusions due to a decrease in the number of independent n/a, probably due to the formation and effective removal of complex inclusions of a rounded shape evenly dispersed over the entire surface of the slot.

a) b) c)

Fig. 4. – Non-metallic inclusions in steel deoxidized FSAb: 35XM (a); 110G13L (b); 40X (c), x 100

As can be seen, inclusions are presented in the form of small, disoriented oxides (corundum) with the predominance of individual small inclusions of sulfides and silicates of a more favorable nature.

Thus, complex silicon-aluminum alloys, including those with alkaline earth elements, are good deoxidizers and modifiers and their use will contribute to improving the quality of steel without disrupting the technological chain adopted in steelmaking.

Cast parts showed high strength characteristics when breaking Barton samples. A detailed study of the fractures in 110G13L steel does not reveal plate and film inclusions of sulfides located in clusters. That is, the fracture does not occur due to sulfide inclusions, but due to the impact of multiple alternating bending forces applied to the sample. The latter indicates the absence of sulfide and oxysulfide inclusions of dendritic origin in the steel treated with FSAb, along which the fracture should have passed.

Analyzing the morphology and sizes of the sulfide inclusions encountered, we can say that they were formed in a liquid state, but at relatively low temperatures, as evidenced by the absence of signs of their coagulation.

Conclusion

The conducted studies allow us to conclude that the results obtained indicate a positive effect of the deoxidation of electric steel by complex alloys of FSA and FSAb on the size, quantity and nature of the non-metallic inclusions formed (corundum, sulfide and oxysulfide inclusions), metallographic studies of rolled and cast samples of converter and electric steel grades deoxidized using alloys containing AEM (barium), a significant change (towards improvement) in the quantitative and morphological nature of non-metallic inclusions was found.

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Mechanism for loading wheelchairs in the car – a review of technical solutions and a new concept

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Annotation. One of the main difficulties for wheelchair users is the change of transportation mode, such as from a wheelchair to a car, and especially the subsequent loading the wheelchair to or unloading from the car. The rapid development of mechanics and mechatronics in numerous industries is also being recognised in the transportation industry dedicated for people with motor disabilities. The article presents an overview of solutions to assist in loading or unloading a wheelchair from a car. The latest solutions available on the market and among those under patent protection were demonstrated. Prominent structures include lifts and cranes. The available solutions may differ in terms of: the level of muscle power use, the energy intensity of the loading process, the occupied space in the car, the convenience of loading and unloading, the need for third-party assistance, versatility in mounting to the car, purchase cost, weight, etc. The aim of the review presented here is to raise awareness in terms of choosing a device that assists in loading a wheelchair to and unloading from a car.

Key words: handicapped cars, drivers with lower extremity mobility disabilities, wheelchair, transportation of the disabled, mobility-enhancing structures.

Introduction

Handicapped person employment support programs and their return to society are often assisted by technologies that take the ergonomics of the car interior into account. Designing devices to assist people with dysfunctions in their control is a challenge to combine convenience and functionality [1]. A number of people with physical disabilities who meet the legal requirements for being allowed to drive motor vehicles drive passenger cars on their own, individually adapted to the type and severity of their disabilities. The issue of using a car by a disabled driver can be divided into two areas, the first relates to driving the vehicle and the second relates to getting in and out, combined with the independent loading and unloading of a wheelchair [2]. Assistive measures to enable people with disabilities to use a car can be divided into; adaptive, driving-assisting, and boarding-assisting. Wheelchair loading aids can be distinguished in the second group [3]. Many countries with high technological and assisting development enable handicapped people with motor disabilities to lead independent lives. One area of support is transportation, and specifically: enabling people with disabilities to drive a passenger vehicle [4]. One's own means of transportation, such as a personal car, is a supporting element to counteract activity limitations and participation restrictions. Unfortunately, market realities force handicapped people to purchase cars designed for people without disabilities, and then to make the necessary modifications already on their own, to ensure that these cars can be driven effectively [5].

This article addresses a problem of loading a wheelchair into a car. The purpose of the article is to raise awareness of the mechanism selection to help load a wheelchair into a car. The article presents design solutions facilitating changing the means of transportation from a wheelchair to a car. Manufacturers' websites and patent databases were used for the review. A new conceptual solution has been proposed.

1. State of the art review for wheelchair-loading car mechanisms

1.1. Electric wheelchair transport device

The electric wheelchair transport device is shown in Fig. 1., this technical solution by Jacek Wołosz, Ryszard Rusinowski, Zbigniew Wołosz is the subject of a patent application in the Patent Office of the Republic of Poland from 2018 (patent application number P.425504). The mechanism of the cited invention involves moving a wheelchair into the trunk using a mechanical winch. Loading of the wheelchair inside the trunk is completed by means of takers locked on the front wheels using linkages driven by an electric motor powered by a car battery [6].

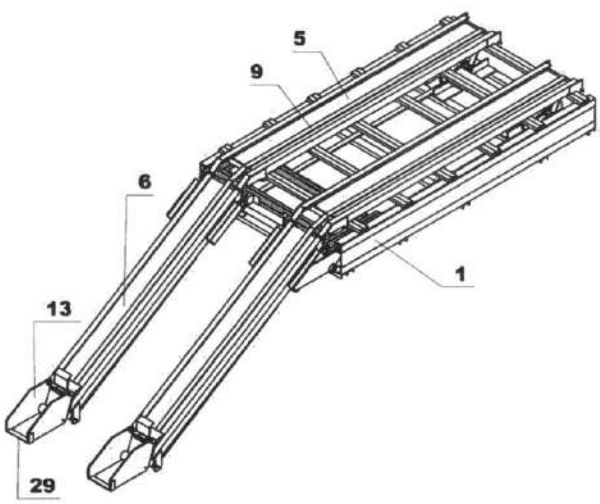


Fig. 1. – Electric wheelchair transport device [6]

1.2. Electric lift for loading and unloading assisting equipment for handicapped people, including wheelchairs and scooters, weighing up to 160 kg, from cars or van-type vehicles

An electric lift for loading and unloading assisting equipment for handicapped people, including wheelchairs and scooters weighing up to 160 kg, from cars or van-type vehicles is shown in Fig. 2. The technical solution by Ryszard Juszczak is a utility model in the Patent Office of the Republic of Poland from 2009 (patent application number W.117924). It is a lift with a maximum load of 5 kg to 160 kg. The premise of the utility model is the independent operation of the device by a person with impaired mobility, maintaining a standing position. No force is required for operation, and the lift is operated by wired or wireless [7] remote control.

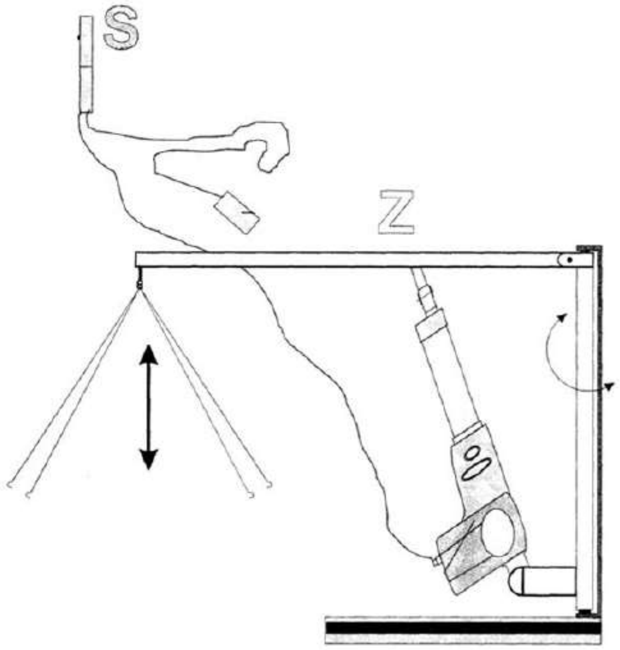


Fig. 2. – Electric lift for loading and unloading assisting equipment for handicapped people, including wheelchairs and scooters, weighing up to 160 kg, from cars or van-type vehicles [7]

1.3. Vehicle for the disabled

A vehicle for the disabled is shown in Fig. 3. The technical solution by Egeniusz Kucharczyk is a utility model in the Patent Office of the Republic of Poland from 2017 (patent application number W.126337). The main structure of this utility model is a vehicle for handicapped people. The user, using a U-shaped arm equipped with a lifting and lowering drive, can drive a wheelchair inside the vehicle and operate the vehicle in traffic [8].

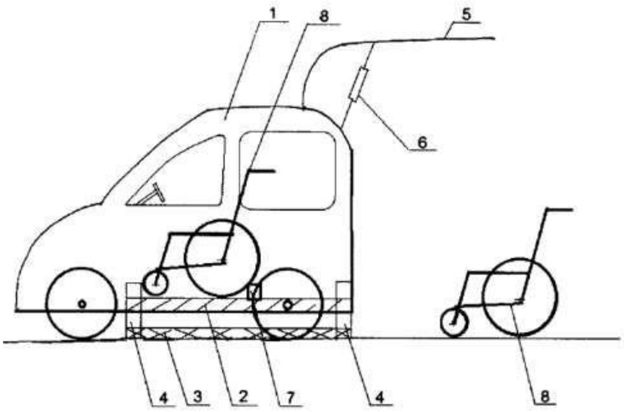


Fig. 3. – Vehicle for disabled persons [8]

1.4. BraunAbility wheelchair roof box

A roof box (Fig. 4) allows loading a wheelchair located at the driver's side door. The mechanism of the cited solution transports the wheelchair to be placed in the roof box, providing convenient loading without force [9].

Fig. 4. – Box dachowy na wózek inwalidzki firmy BraunAbility [9]

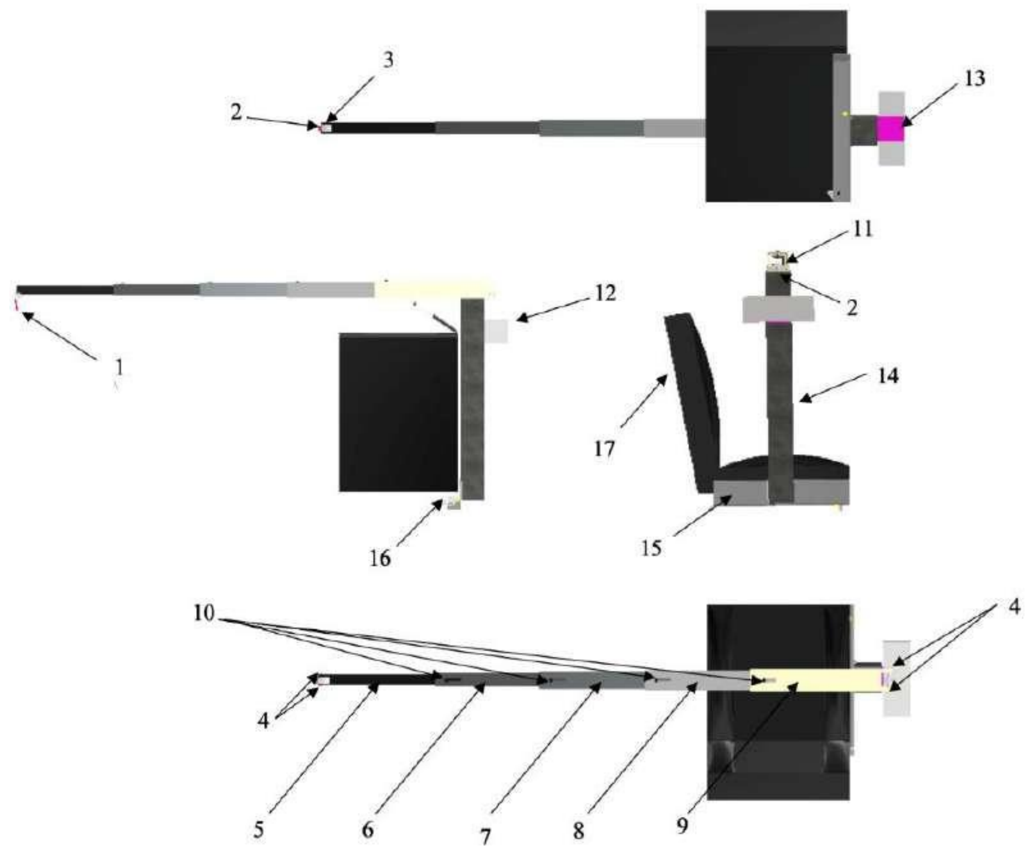
1.5. BraunAbility wheelchair car lift

BraunAbility car lift (Fig. 5) is an electric device to facilitate the loading of a wheelchair. This equipment provides for lifting and locating the wheelchair in the car trunk [10].

Fig. 5. - BraunAbility wheelchair car lift [10]

2. New Concept – overhead crane module to assist in loading wheelchair onto a passenger seat

The concept of a module that assists in loading a wheelchair onto the passenger seat is shown in Fig. 6. The wheelchair loading support module consists of parts such as five telescopic profiles (5-9), four pins (10), two shafts (3), (11), two rollers (2), steel cable with stops, self-locking hook (1), winch (12), winch shelf (13), column (14). Each of the five profiles (5-9), has a bean-shaped hole, inside of which is a pin that limits the extension range of one profile relative to another. A steel cable is led through the telescope, at the end of which a self-locking hook (1) is placed, attached to the wheelchair frame to allow it to be lifted. A winch (12) was used to wind the steel cable. When retracting the cable, one of the stops on the cable leans against the profile and folds the entire telescope. At the end of the first (5) and last (9) profiles, there are holes cut out, with a suitably selected shaft (3 and 11) passed through them, according to the dimension of the given profile, on which a C45/6Ł plastic polyamide profiled roller with a diameter of 45 mm was placed on a 6 mm line with bearing (2) for smooth line sliding. The ejection of one shaft, as well as the other, is prevented by two DIN471 external spring rings (4). The same rings were used to block the roller's ability to move along the shaft. A brace made of sheet metal construction (18) was welded between the column and profile 5. Telescopic profile 5 is welded to the column (14), which is then welded to the curved surface of the angle bracket (15). The lower surface of the angle bracket is connected to the car seat guide bars (16) with two screws originally used to attach the guide bars to the vehicle floor. The guide bar provides the movement of the rail, which is connected to the car seat.



1 – self-locking hook, 2 – C45/6Ł roller, 3 – first shaft, 4 – spring ring, 5-9 – telescopic profile, 10 – pin, 11 – second shaft, 12 – Dragon Winch Maverick DWM 2500 ST winch, 13 – shelf, 14 – column, 15 – right angle bracket, 16 – guide bar, 17 – car seat, 18 – reinforcement

Fig. 6. - Visualisation of a car seat with a module that assists in loading a wheelchair onto the passenger seat

Operation of the wheelchair loading support module on the passenger seat is based on folding and unfolding telescopic profiles. The user, sitting in the driver's seat, grabs the cable and pulls it. When one of the stops rests on the roller on the telescopic profile first (from the centre of the profile), further pulling on the cable will start unfolding the telescope Fig. 7a, whereas when the cable begins to wind on the winch, and the second of the stops rests on the roller located on the first telescopic profile (from the outside), the folding of profiles 7b will start.

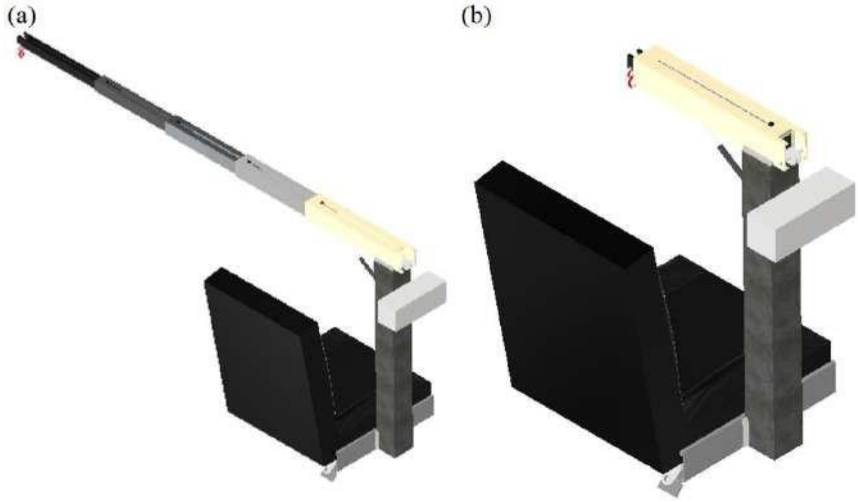


Fig. 7. - Module to assist loading the wheelchair onto the passenger seat (a) with the profiles unfolded during use, (b) with the profiles folded after use is over

This paper presents an example implementation of a module design that assists a person with a mobility disability to transfer from a wheelchair to the driver's seat, with a module that assists wheelchair loading onto the passenger seat. The premise of the designed module is that a driver with impaired movement will approach the car sill from the driver's side after opening the door. The first thing the user should do after locking the wheels of the wheelchair is to operate the transfer assistance module – unfolding the bar and the board Fig. 8. Once this is done, the driver moves their lower extremities from the footrest of the wheelchair to the interior of the vehicle, and then moves to the seat on the unfolded board. Once the transfer procedure is complete, the user begins to assemble the module – folding the board into an upright position and raising the bar. Another activity performed is the operation of a module that assists in loading a wheelchair onto the passenger seat. To unfold the telescopic profiles, when sitting on the seat, the driver grabs the cable and pulls it towards themselves. When one of the stops rests against the roller on the telescope (from the centre of the profile), further pulling on the cable will start unfolding the telescopic profiles. After unfolding the profiles, the driver attaches the self-locking hook to the wheelchair frame. At this stage, the user can wind some of the cable onto the electric winch to lift the wheelchair, making it easier to freely remove the wheels, which are then put into the car on the floor in front of the front passenger seat. Once this procedure is completed, further winding of the cable on the winch starts, thus loading the wheelchair into the car. When the second stop leans against the roller located on the first telescopic profile (from the outside), the folding of the profiles will start. When the telescopic profiles are fully folded into the telescope, the wheelchair attached on the cable is at the passenger seat height. At this point, the user places the wheelchair on the bottom of the seat and can secure it with straps.

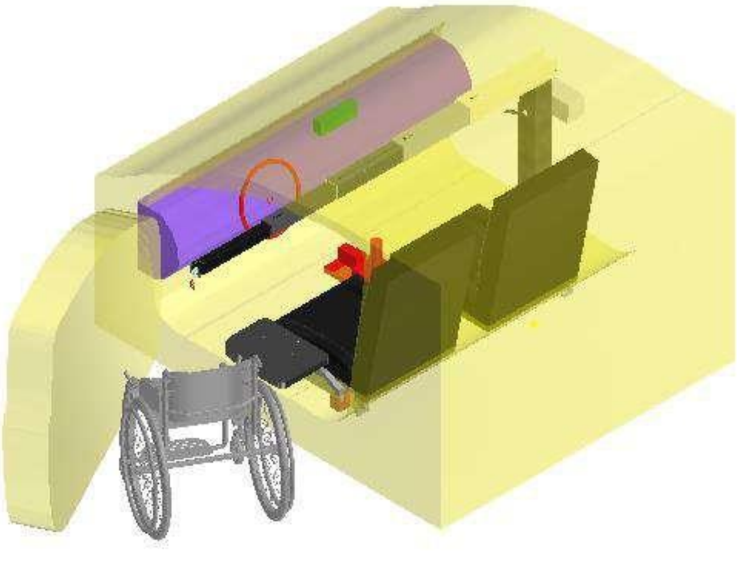


Fig. 8. - Demonstration of the wheelchair setting after the user approaches the car from the driver's side

3. Discussion

The authors characterised the main advantages and disadvantages of the presented solutions in terms of, e.g.: the muscle power level, energy intensity of the loading process, space occupation in the car, convenience of loading and unloading, the need for third-party assistance, versatility in mounting to the car, purchase cost, weight, etc. Tables 1 to 5 show the main features of the available mechanisms for loading a wheelchair into a car. It can be noted that there are solutions available on the market with varying characteristics, from simple in design to highly sophisticated. The review presents different solutions from those published by Zabłocki and Sydor in 2008 [3], Sydor, Zabłocki and Gabryelski in 2008 [2] and Grabarek and Choromański in 2014 [11].

Table 1. Advantages and disadvantages of electric wheelchair transport device

Disadvantages	Advantages
Uses battery power	Does not require using muscle power
Reduces the amount of free space inside the vehicle	Convenient transport of the wheelchair to/from the car
The need for a large amount of free space behind the vehicle	Simple operation

Table 2. Disadvantages and advantages of an electric lift for loading and unloading assisting equipment for handicapped people, including wheelchairs and scooters, weighing up to 160 kg, from cars or van-type vehicles

Disadvantages	Advantages
Only for people with disabilities maintaining a standing position	Maximum load up to 160 kg
Device takes free space in the trunk	Does not require using muscle power
Handling assistance is necessary from third parties – packing the device into the car trunk	Easy operation with wireless remote control
	Quick installation of the device

Table 3. Advantages and disadvantages of a vehicle for disabled people

Disadvantages	Advantages
The need to purchase a new vehicle	Simple operation
Adapted for use only by people with disabilities	No need to move to a car seat
Safety and driving convenience not ensured at the highest level	Does not require using muscle power
Lack of free space inside the vehicle	Does not require third party involvement

Table 4. Disadvantages and advantages of BraunAbility wheelchair roof box solution

Disadvantages	Advantages
Accommodates only wheelchairs with a folding frame weighing up to 20 kg	Quick and easy operation
Not compatible with every car model	Preserves free space in the car
High cost of purchase	Does not require using muscle power
	Allows parking in tight spaces

Table 5. Disadvantages and advantages of BraunAbility car wheelchair lift

Disadvantages	**Advantages**
Third part involvement is necessary	Quick and easy operation
Takes up the entire trunk space	Maximum payload weight: 181 kg
High cost of purchase	Does not require using muscle power
	Compatible with almost any car model

Conclusion

The article filled in the missing areas reviewing the state of the art in the field of mechanisms to help load a wheelchair into a car. Two dominant construction types were recognised: cranes and lifts. It was found that the presented designs can significantly differ in terms of: space occupied, weight, level of interference with the car's structure, difficulty of operation, level of muscle power involvement, need for third-party assistance, cost of purchase. It seems that this is an area with still plenty of room for refinement by improving the quality of life for handicapped drivers. The development of these solutions should be linked to the parallel development of assisting systems for transferring from a wheelchair to a car.

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Prerequisites for developing a technological preparation database of small- and medium-scale machine-building industries

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Abstract. The article deals with the analysis of currently popular databases and their control systems in order to select the most suitable for implementing the goals of the grant project funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No AP14972804). The authors considered the main modules of the automation system for small-scale production. Most of attention was paid to the module of evaluating technological routes; the basic concept of algorithms was described and the requirements for the database architecture were presented. The analysis of various data formats was also made for the convenience of their use in the software product and storage in the database. In the future, based on the analysis carried out, implementation of the system for evaluating technological routes will be carried out, namely, the calculation of the time and the cost, both for each method and for the project as a whole, for further optimization of production.

Keywords: automation, technological route, small-scale production, technological preparation of production.

Introduction

At present, an actual trend in the IT-sphere in the field of mechanical engineering is automation of human labor costs to increase labor productivity and to ensure the product stable quality.

Replacement of human labor by machine, science-based distribution of work between a person and a computer, in the process of technology management that leads to increasing the efficiency and quality of technological solutions, reducing the time of their implementation, reducing costs, more complete use of the available reserves of the production system, ensuring the maximum level efficiency and flexibility, significant limitation in the number of engineering and technical personnel, etc. [1].

Within this trend, the defining tendency of the future material production of goods and services is the use of production networks with network-centric control [2]. Examples of modern manufacturing sites that are integrated into the network to implement parallel-executed technological processes are as follows:

1. Complexes of multifunctional machine tools with numerical control (CNC), which first appeared in the market in 1955.
2. Industrial robots that appeared in production in 1962.
3. Robotic technological complex (RTC) first appeared in the 1970s.
4. Hybrid production systems (HPS) distinguished by a combination of robots controlled by an electronic computer (ECM) and technological processes (units).
5. Automated warehouse systems (AWS) that provide for the presence of robots controlled by a computer system for moving and arranging products in a warehouse by receiving certain commands from a computer for treatment.
6. Computer-based quality control systems: applications for computers to check the quality of products.
7. Computer-aided design systems (CADP) are used by designers when working at new products and writing technical and economic documentation.
8. Automated technological preparation of production that contains software products (SP) that help automating the process of preparation of production, namely designing and planning technological processes.

A feature of technological processes is their adaptability to small-scale and piece production.

Piece production is characterized by an extensive range of manufactured products and a small volume of their output. The main features of this production are as follows:

- absence of sustainable TP, which implies a need for highly skilled workers;
- using universal equipment with a large set of technological equipment;
- long production time, since when using universal tools and equipment, it takes a lot of time for transiting to another type of operation;
- a high percentage of manual work.

Small-scale production, in terms of technological features, differs very little from piece production and is characterized by a large range of products that are produced in small batches with a rare frequency using universal equipment.

Any technological process is a part of a more complex organization process and is considered as a set of elementary operations. In turn, a technological elementary operation is a complete part of the technological process performed at one workplace [2] and consisting of technological transitions that are completed parts of elementary operations performed by the same means of technological equipment.

The basis of the technological process can be conditionally divided into 4 stages:

1. The initial stage is collecting the initial data and their registering. In accordance with the method of carrying out these operations, TPs can be divided into the following types:

- mechanized oned: collecting and analyzing the initial data is carried out by a person using manual measurement procedures using the simplest instruments;
- automated ones: an automated system (AS) is responsible for collecting the initial data by obtaining the information from the sensors, including that in real time.

2. Preparatory stage is control of the initial information and its transfer to the data storage system.

3. The main stage is the processing of information; they allow previous performing service operations, such as sorting.

4. The final stage is analyzing and obtaining the results for their further use.

1. Research methods

For the system of evaluating technological routes, it is necessary to have a database (DB) in which the data is stored for analysis and evaluation, as well as a DBMS (database management system) for its administration.

Currently, there are a lot of different databases and management systems for them. The purpose of this work is to analyze and to select the most appropriate database for implementing a grant project funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No AP14972804).

In the process of developing systems with a DBMS or applications with a client-server one, it is necessary to select a format for data exchange between the system modules. The solution of this problem can significantly affect both the operation of the system and further modernization.

There are a small number of popular information exchange formats in the developer community, namely XML, JSON, YAML.

To compare the above formats, the following criteria were selected, which are currently of the greatest importance:

1. Readability. It characterizes the simplicity and convenient markup in the data file.
2. Serialization is converting a data object into a stream of bytes for further work with them.
3. Deserialization is converting a stream of bytes into an object.
4. Data verification is the presence in the format of the language of the structure description that is necessary to check the received data for compliance.
5. Prevalence is the presence of a large amount of developers using the data format.
6. Development is updating the format and introducing new features for ease of use.

To analyze the information, there was used the information from the Internet resources, documentation [3, 4, 5] and statistics of discussions among developers. After analyzing the data in the Internet resources, it was concluded that the JSON format was the most convenient for perception.

2. Results and discussion

To analyze the data formats according to the serialization criterion for all three formats, the translation into a byte stream is the same and does not require much effort. The authors of article [6] came to the same conclusion when comparing serialization described in the C# language.

To analyze the data formats according to the deserialization criterion for all three formats, the operation of transferring an object from a byte stream is the same and does not require much effort. The authors of the article described above came to the same conclusion when comparing deserialization described in the C# language.

The analysis of the prevalence, updates and development of formats showed that the JSON format was the leading one, most developers prefer it. The XML format is used for highly specialized systems and is less common, while YAML is a fairly young format and is still developing, gaining its community.

Table 1 shows that the best data exchange format is JSON, as the developer community notes that this format is rapidly developing and easy to exchange data in systems. It should be noted that the YAML data exchange format was proposed relatively recently and is just beginning its development path, but already now, in some respects, it is seriously competing with analogues.

Table 1. The results of analyzing the exchange format

Name	Readability	Serialization	Deserialization	Abundance	Development
XML	Medium	Good	Good	Medium	Medium
JSON	Medium	Good	Good	Good	Good
YAML	Medium	Good	Good	Weak	Weak

A database is a set of data for information and user systems organized according to certain rules and having a structure that is set individually for each project.

Currently, there are a lot of types of databases, namely:

1. A hierarchical database. This type of a database is based on a hierarchical data model, where information is presented in the form of a tree structure consisting of certain nodes. Databases that have a hierarchical model emerged in the 1960s and are progenitors of many modern database systems. The main disadvantages of a database with a hierarchical model are its inefficiency, slow access to data nodes located at the lower level of the hierarchy, complexity of processing data with a sufficiently large amount of relationships, and inability to implement many-to-many relationships.

2. A network database is based on a logical data model, which is an extension of the hierarchical model based on the mathematical theory that describes the structure of the model, integrity and data *processing*. The main disadvantages of a network database are its complexity and rigidity of the database schema. In other words, in order to change the structure of the database, one will have to make changes to the application that provides the ability to interact with the database.

The difference between the hierarchical and network models is that in the hierarchical model, a descendant can have only one ancestor, while a network one can have several ones [1].

3. An object-oriented database (OODB) is a database in which data is modeled in the form of objects and their methods; this database is recommended to be used when a short time is required to process data with a complex structure.

4. A relational database (RDB) is based on a logical data model, which has the following aspects:

- a structural aspect: the data in the database is presented as a set of relationships;
- an integrity aspect: declarative data type integrity constraints are supported;
- an aspect of treatment: in the database there are operators for working with relations.

In addition, a relational model includes the theory of normalization as a process for structuring the data model, providing connectivity and absence of redundancy.

5. An object-relational database is a system that supports technologies used in the object-oriented approach and the main aspects of the RDB. Its appearance is explained by the fact that relational databases work well with built-in data types but much worse with user-defined ones.

6. A functional database is based on a functional model and is used to solve analytical problems.

A functional model is intended to describe business processes in an enterprise, which are a set of graphic objects used in modeling, and allows you to identify all information objects that are used in the work of an enterprise.

Having considered and analyzed all the above types of databases, taking into account the above task, one can conclude that the most convenient type for working with a large data system is currently an object-relational DBMS. In a more detailed examination of various types of object-relational database management systems, there are distinguishedthe following ones: Oracle Database, Informix, DB2, PostgreSQL.

The main aspects for selecting database management systems are as follows:

1. JSON support. The data structure in the project requires some flexibility, for example, if the structure is still changing during the development process or it is not known which fields the data object will contain.

2. Support for a custom type. The list of data types provided by the DBMS developers is often not enough, so it is necessary to be able to create the custom data.

3. Cost. The cost of the license and support of the DBMS is estimated;

4. Development and popularity. If the DBMS has a good development team and community, you can always find the required information of web resources or contact technical support.

To analyze the DBMS, there are used the Internet resources, official documents and websites of developers of database management systems.

Having studied the documentation [7, 8, 9, 10] and information of the official DBMS websites, one can conclude that all four database management systems support the JSON data type.

The documentation [7, 8, 9, 10] for all the DBMS describes instructions for supporting user-defined types, which consist of a set of types standard for DBMS.

The most famous and most reliable Oracle Database has the highest cost, Informix and DB2 have a lower cost compared to it, but PostgreSQL is a free project, which attracts a large number of developers.

The most popular and currently developing, according to the data obtained from the Internet resources and when communicating with IT industry specialists, are Oracle Database and PostgreSQL.

Based on the results shown in Table 2, the analysis was carried out and it was concluded that PostgreSQL is a free DBMS with great popularity among specialists and a group of developers in Kazakhstan cunder the name of Postgres Professional [11], which is a big plus for the project, though there are some minuses: official updates are released less frequently than for the other DBMS. Due to the large community, this problem can be easily avoided, since this system can be modified to meet the requirements of the project.

Table 2. DBMS analysis

Name	JSON support	Custom type support	Cost	Development (updates)	Popularity
Oracle Database	There is	There is	High	Active	High
Informix	There is	There is	Medium	Active	Low
DB2	There is	There is	Medium	Active	Low
PostgreSQL	There is	There is	High	Medium	High

Figure 1 shows a general block diagram of a system being developed to automate small batch production. The system consists of 6 main modules that will be considered in more detail.

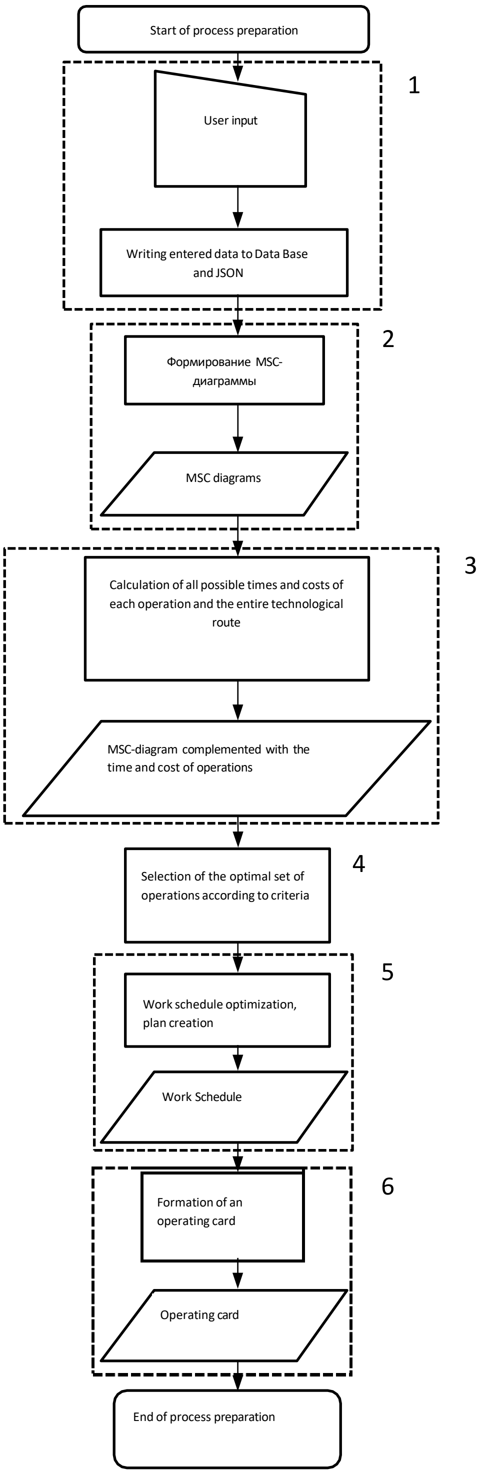

Fig. 1. - The system block diagram

1. A module for entering data that characterize various surfaces of the manufactured part, surface treatment methods with parameters: the types of machine tools and cutting tools, etc. The information entered by the user is checked and written to the database or JSON file; the set of user interface screens forms the automated workplace of the technologist.

2. A module for generating an MSC diagram consisting of a sequence of surface treatment methods with indexed parameters: the number of the treatment stage, the type, the category, the elementary surface number, etc. [12].

3. A module for assessing the technological route; the evaluation is carried out both for each method separately and for the entire technological route, according to certain formulas.

4. A module for determining the optimal set of operations according to the criteria. The criteria for selecting the best set of methods can include minimizing the total operating time, minimizing the downtime of machines, etc. At this stage, the production schedule is analyzed to determine how much run time each machine has.

5. A module for implementing the work schedule that contains the distribution of methods of treating elementary surfaces by machine in time [13].

6. A module responsible for compiling the operational map: a part of the technological process documentation automatically developed on the basis of the established form filled in by the technologist, entered and received during the system operation.

The main module considered in this work is module number 3. It is responsible for evaluating the technological route, according to the data stored in the database for further displaying of the evaluation results in the MSC diagram and formalization of technological processes.

The task of formalizing technological processes is to develop a schedule for their execution when working with the resources of the production site.

The schedule is (Figure 2) is a static model of implementing technological processes in the network-centric system of an industrial site. To check the correct execution of technological processes, it is necessary to develop a dynamic model of their implementation. Figure 2 shows an example of a schedule of technological operations, where there is distributed the information that is highlighted in red, namely, in this example, the items in the technological documentation corresponding to the specified processes.

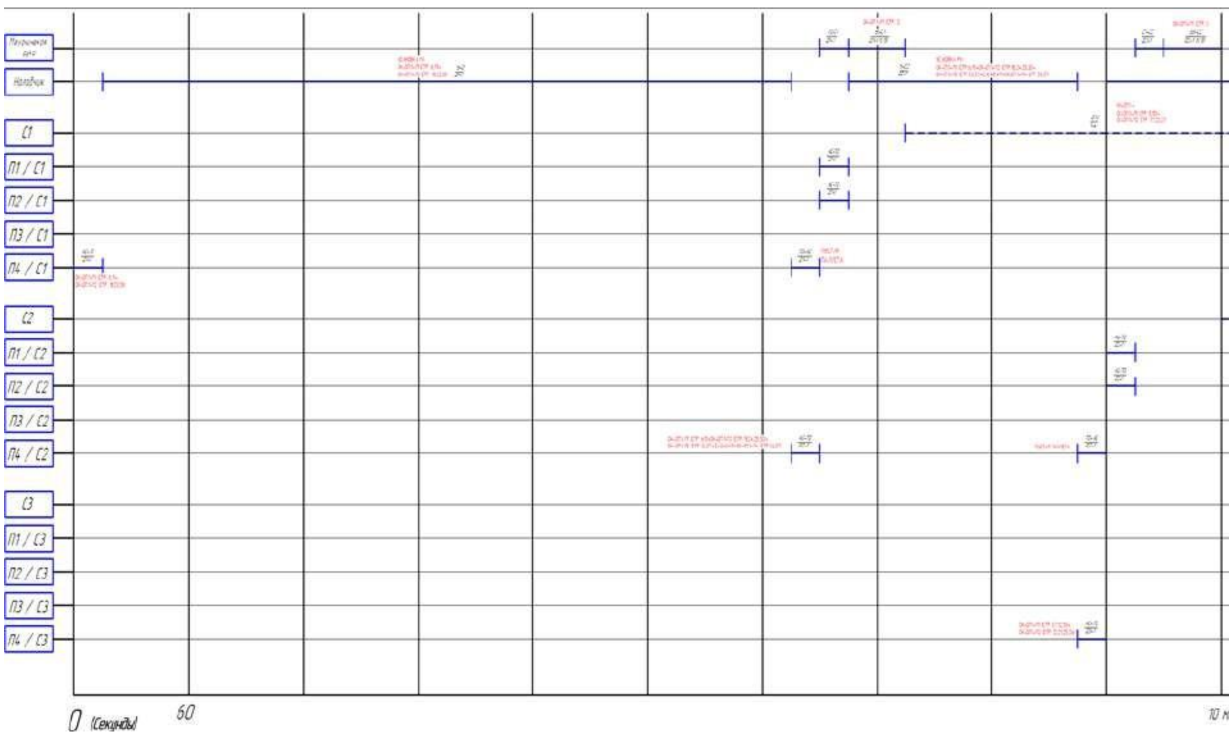

Fig. 2. - An example of the technological operation schedule

The input language for the behavioral model is the standardized Use Case Map (UCM) language, one of the family of languages representing system specifications, which uses paths of system behavior scenarios to illustrate causal relationships between events [14]. The models built with the use of the UCM language combine both behavioral and structural description of the system.

In the process of symbolic verification using UCM descriptions, the development of a correct and reliable behavioral model is automated, and then behavioral models of technologies are formed in the form of the Message Sequence Chart (MSC) scenarios or MSC traces. The MSC is a standardized language for describing behavior with the use of message exchange diagrams between parallel functioning objects [15].

Figure 3 shows an example of the TP description in the MSC language.

Below there are comments on technological operations.

1. From the database there is obtained the information of the batch of blanks of the part that will be machined and check whether it can be t treated.

2. From the database there is obtained the information of which machines are needed to treat a batch of workpieces; the available machine is found.

3. The first machine is available; it is taken for treatment.

4. From the database there is obtained the information of the applicable cutting tools for treating the selected batch of workpieces; there are found available ones from them.

5. The cutting tool is got from the warehouse and sent along the rails on the pallet to the first machine.

6. Check if the pallet has delivered the cutting tool to the first machine.

7. The adjuster installs the cutting tool on the first machine.

8. The adjuster re-adjusts the first machine.

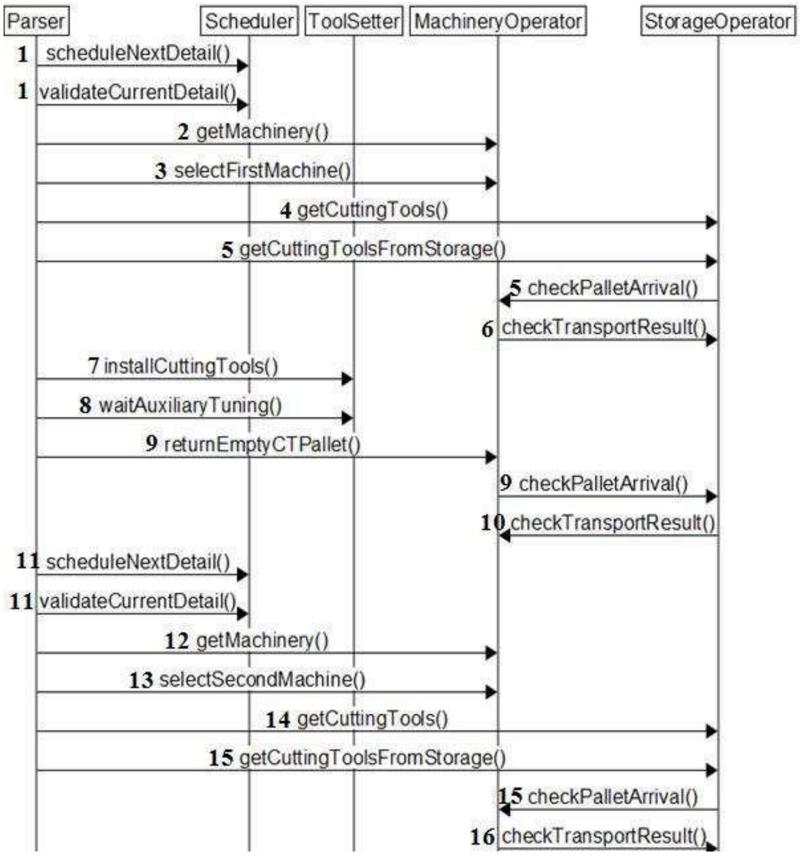

Fig. 3. – Technological process description in the form of the MSC diagram

The use of MSC diagrams for coding technological routes and technological processes allows for a static analysis of the correctness of their implementation.

In this production process, the database is responsible for data formalization, storing information both of the entire system being developed, and of the data needed for operation of the remaining modules of the system described in Figure 1. The advantage of this approach is that the data can be used repeatedly.

To evaluate technological processes, the database must contain at least two tables responsible for storing the results of calculating formulas, namely, the time and the cost of working methods of treating elementary surfaces for the final part, as well as tables that store the initial values and the formulas themselves, which are subsequently transferred to system modules for calculating final values and their analysis.

Conclusions

The DBMS working with the database must meet the following criteria.

1. In the database management system used in the project, the user functions must be implemented: the database objects that are a set of SQL statements that are compiled once and stored on the server, which support checking the correctness of the information called from the database and simplifying query calls in other parts of the system being developed.

2. To store formulas and voluminous values that often change during operation, it is necessary to write them in the JSON format, which will facilitate further work with them.

3. To facilitate obtaining the required information, it is necessary to use custom types made up of standard ones.

Confirmations

The article was executed within the framework of implementing the IRN grant AP14972804 "Development of software for technological preparation of production on the basis of the formalized design methodology" (project manager N.A. Savelyeva).

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The Choice of Rational Parameters in Designing the Impact Mechanism

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Abstract. This paper presents the process of a hydraulic hammer designing. The terms of reference for hummer is corresponded to the requirements for conducting a wide range of works related to the crushing of rocks for producing hydraulic and road tunnels, for trenching works on rocky soils and others. For this purpose, simulation models of programs «Research» and «Zolotnik», which provide the solution of two sequentially performed tasks in the design and operational settings.

Key words: hydraulic drives, hydraulic hammers, driven link, circuit diagram, design, computer program, dimensional chain.

Introduction

The design object is the hydraulic hammer MGP-2, the technical documentation for which is formed at the stages of the draft, technical and working projects by developing and calculating a sequential series of diagrams that parametrically describe the object:

1) a schematic diagram;
2) structural diagrams of functional groups;
3) dimensional diagrams of functional groups, nodes and a general view;
4) a general layout diagram.

1. Research methodology

For this purpose, simulation models of the programs «Research» and «Zolotnik» are used [1], which provide the solution of two sequentially performed tasks in the following formulations [2, 3]:

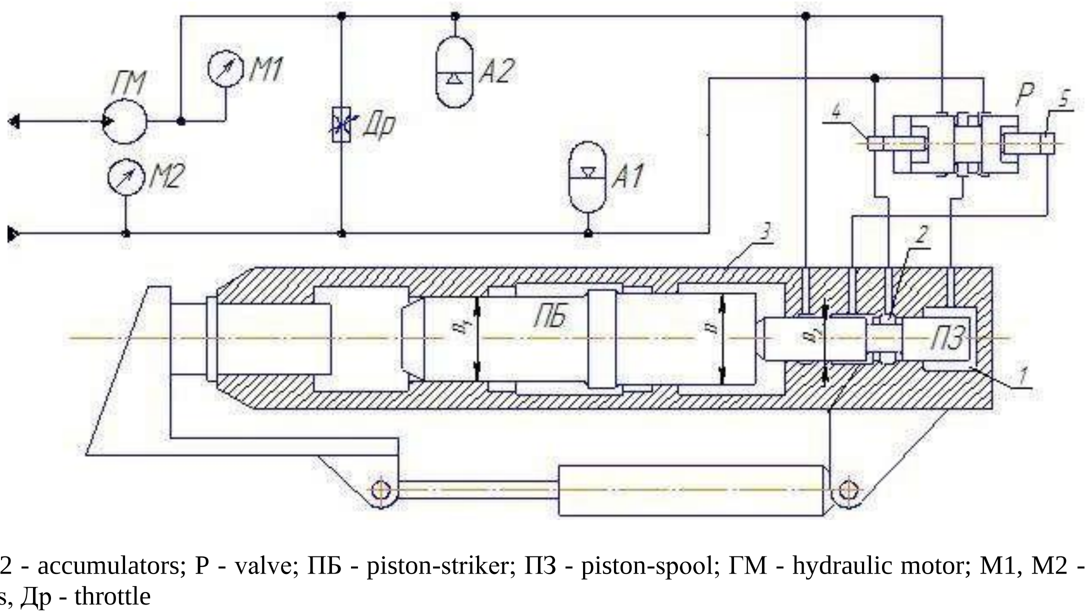
- design: to determine the design parameters that provide the specified energy and frequency of impacts A and n, within the constraints that characterize the specifics of a particular application case;

- operational: to determine the energy characteristics and parameters of the impact hydraulic engine (IHE) of the hammer, provided by rational values of the power supply, obtained from the results of solving the design problem, tuning and regulation parameters.

Such, obtained in the process of machine research, rational design parameters are:

- for the power unit - stroke, weight, diameters of the steps of the striker;

- for the control unit - the diameters and flow sections of the valve, the volumes of accumulators, as well as the dimensions of the belts of the piston-spool of the IHE driven link.



A1, A2 - accumulators; P - valve; ПБ - piston-striker; ПЗ - piston-spool; ГМ - hydraulic motor; M1, M2 - pressure gauges, Др - throttle

Fig. 1. - Scheme of the hydraulic hammer MGP-1 with elements of the test bench

The schematic diagram for the design of the MGP-2 hammer is retained from the analogue of the MGP-1 (Figure 1) and is the basis for the design of dimensional diagrams of functional groups [4].

The design parameters are calculated using the «Research» computer program, the generalized calculation scheme of the simulation model of which is shown in Figure 2.

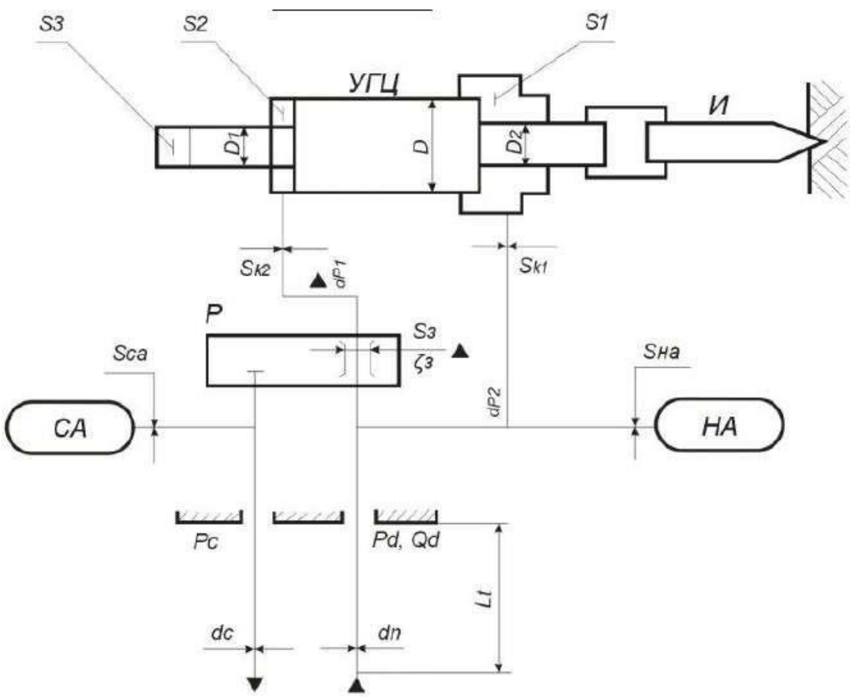


Fig. 2. - Generalized design scheme of the hydraulic hammer simulation model for the «Research» program

2. Results and discussion

The design part of construction development begins according to the deductive principle, with the hydraulic connection diagram (hydraulic control system) shown in Figure 3.

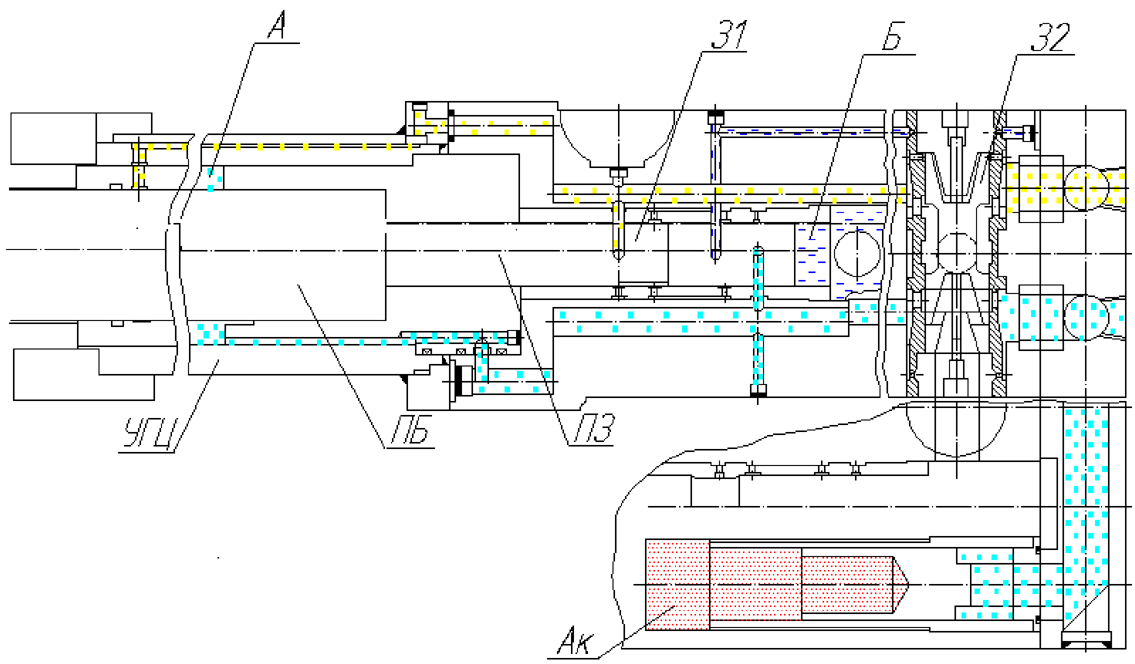


Fig. 3. - Scheme of hydraulic control system of hydraulic hammer MGP-1

The scheme allows you to trace the functional features of the design scheme of the hydraulic hammer. On the diagram in the housing of the impact cylinder there are elements of the driven link of the IHE: a piston-striker ПБ and a piston-spool П3, forming the front A and rear Б chambers of the IHE. All elements including the valve of the first stage 32 and the accumulator Aк are connected by controlled hydraulic lines.

Figure 4 shows the graphs constructed according to the printout of the calculation results. Here, the characteristics of the parameters at h = 0.095 m on the supply pressure Pd: graphs 1, 2 and 3 are the diameter of the rear stage D2, the flow area of the valve Sz and the volume of the accumulator Va.

Analysis of the results of calculating the effect of supply pressure (Figure 5) allows us to note the following: within [hl]-[hf] we select h=0.095 m; Sz = 7.93 cm^2 at Pd = 15 MPa and Sz = 6.5cm^2 at Pd = 20 MPa. The narrowest limits for the choice of Pd are due to the limitations of [Va] and [Pd], while the required volume of the accumulator takes value beyond the limit Va = 1.02 l at Pd = 15 MPa and Va = 0.82 l at Pd = 20 MPa.

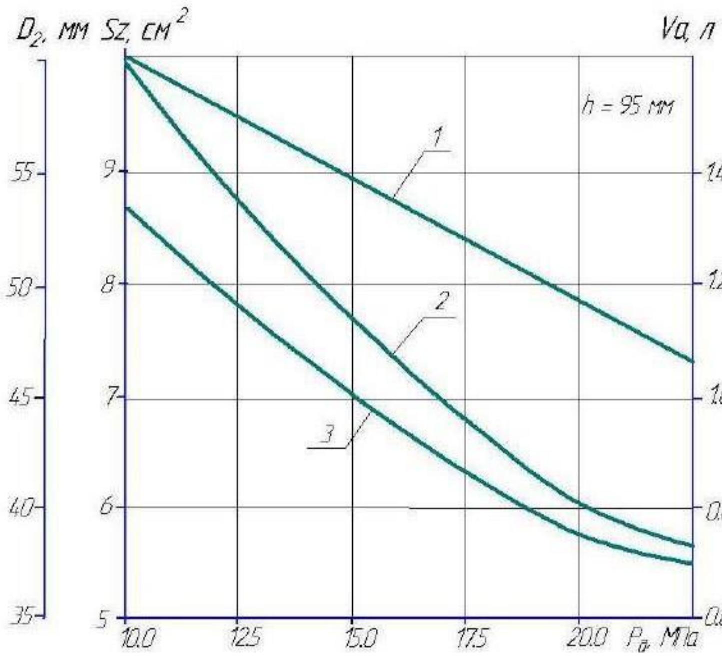
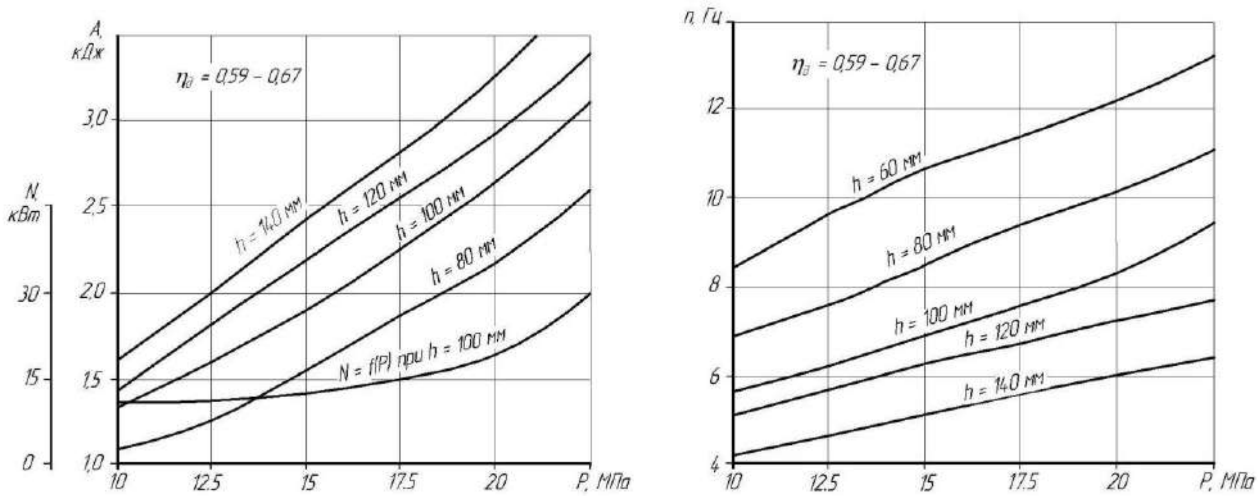


Fig. 4. - Graphs for choosing rational values of the design parameters of the hydraulic hammer



a) b)

a) impact energy A and power N; b) beat frequency n

Fig. 5. - Influence of supply pressure on the energy parameters of the hydraulic hammer for striker stroke settings in the range of 60 - 140 mm for

Analysis of the control system of the hydraulic hammer MGP-1 (Figure 3) shows that the valves of both control stages are characterized by the combination of the three most characteristic functions: control, valve and throttle. Structurally accepted spool design. Thus, it seems possible to calculate the hydraulic equipment using the «Zolotnik» program [1, 3] in relation to the generalized scheme shown in Figure 6. The working body of the spool valve is a cylindrical plunger 2 moving in the axial direction in the sleeve 1. The fluid is supplied and discharged through the windows supply 3 in the sleeve and the corresponding plunger grooves. The letter designations of the dimensions in Figure 6,a are used in the «Zolotnik» program.

The calculation algorithm includes solutions to the following problems [1, 3]:

1) geometric calculation designed to find the geometric parameters of the valve (diameter dz, stroke h, mass mz of the spool, etc.);

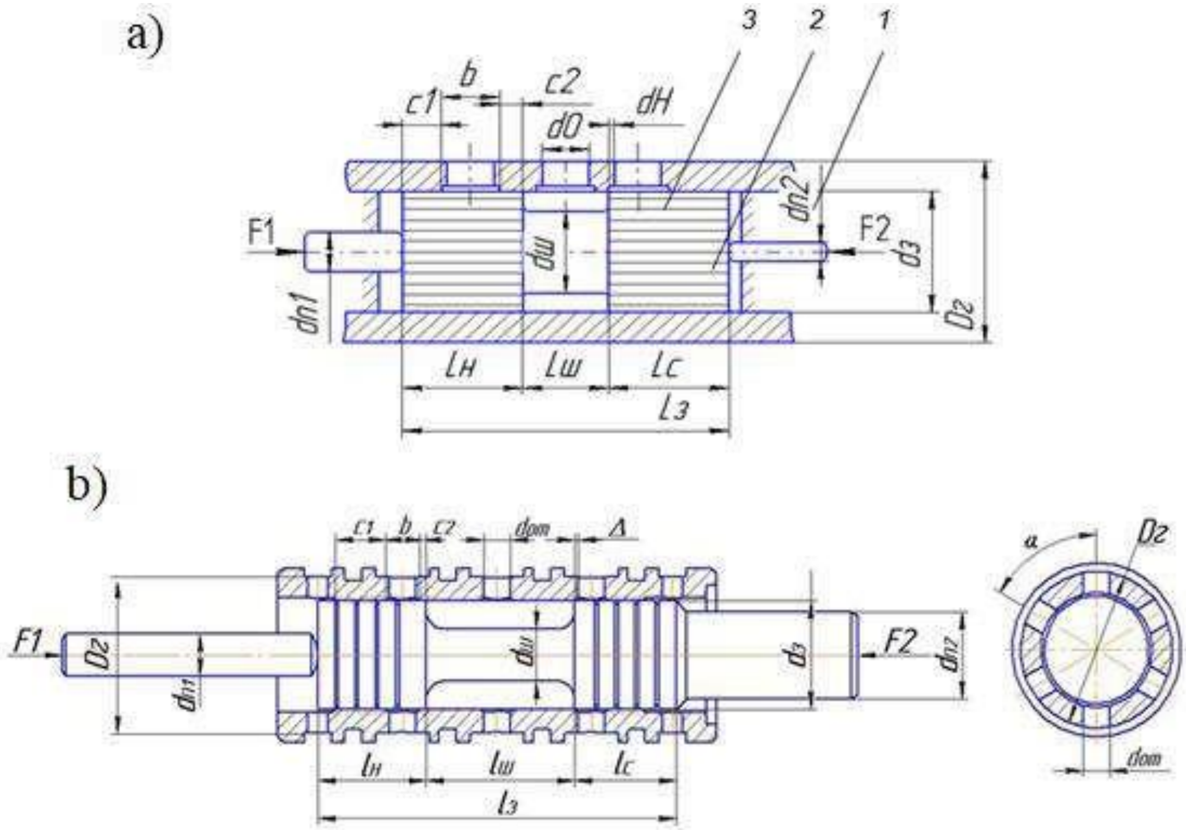
2) calculation of leakages in the cylindrical conjugation of the spool-sleeve, which includes the solution of two problems:

- determination of the value of the radial clearance in the spool pair;
- finding liquid leakages $Q_{у.к.}$ through an annular concentric slot;
- calculation of data to build the dependence of leaks $Q_{у.к.}$ from the sealing part C1 $Q_{у.к.} = f(C1)$;

3) calculation of the switching mechanism, including the determination of the forces acting on the spool plunger.

The processing of the calculation results is presented by graphs in Figures 7 and 8. Analysis of the graphs shows the following:

- the main factor influencing the external, design parameters of the valve (figure 3.3): diameter Dz, length Lz, stroke hz and mass mz of the spool is the size of the flow section, determined in this case by the speeds of the passed flow $v_ж$;
- an attempt to improve the geometric parameters is effective up to a flow velocity of the order of 10m/s, and in the real range for impulse technology $v_ж \geq 10$ m/s, this efficiency is significantly reduced;
- reduction of volumetric leakage $Q_{у.к.}$ and reduction of spool stroke $h_з$ (figure 3.4) due to overlap values C1 is not very effective;
- gap leakage characteristics in the spool-sleeve cylindrical interface exponentially depend on the radial gap ε, the value of which, for the purpose of technological simplification, can be brought to the value $\varepsilon \leq 50$ mcm. Thus, the research results allow us to recommend the following rational parameters for the design of the MGP-2 hammer: spool diameter Dz = 50 mm, spool length Lz = 120 mm, spool stroke hz = 12 mm and spool mass mz = 0.95 kg.



a) design scheme; b) the design of the hydraulic hammer valve MGP-1

Fig. 6. - Design model of a spool valve

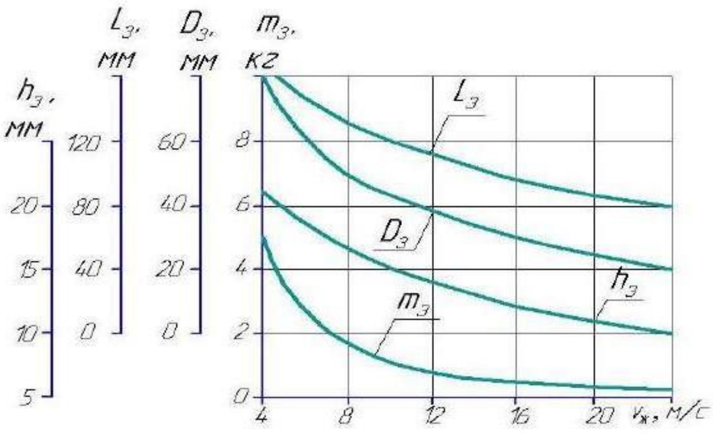


Fig.7. - Influence on the geometric parameters of the distributor of flow rate restrictions

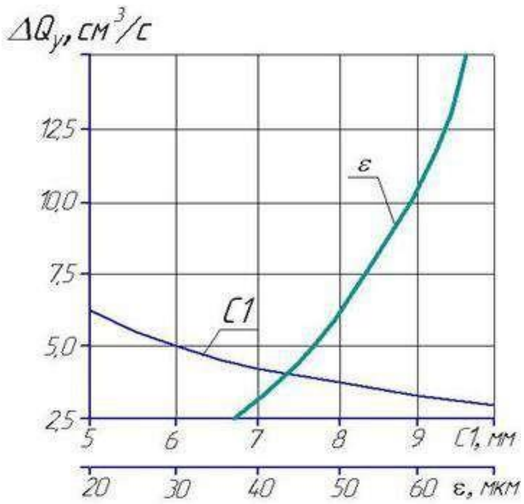


Fig. 8. - Dependences of fluid leakage in the gap on the sealing parameters

The design of working drawings of the power unit (impact cylinder) is carried out in accordance with the general recomendations for the design of technical objects (TO) [5, 6]: 1) design of the functional structure of technical objects (FS TO); 2) design of a schematic diagram (SD); 3) calculation of rational design parameters; 4) development of a constructive scheme (CS); 5) division of the constructive scheme into technological units and parts, their links; 6) calculation of dimensional chains and development of dimensional schemes, units and structures in general.

Rational parameters are determined by calculation using the computer program «Research». The construction of the object is a cylinder with two support bushings for piston-striker ПБ.

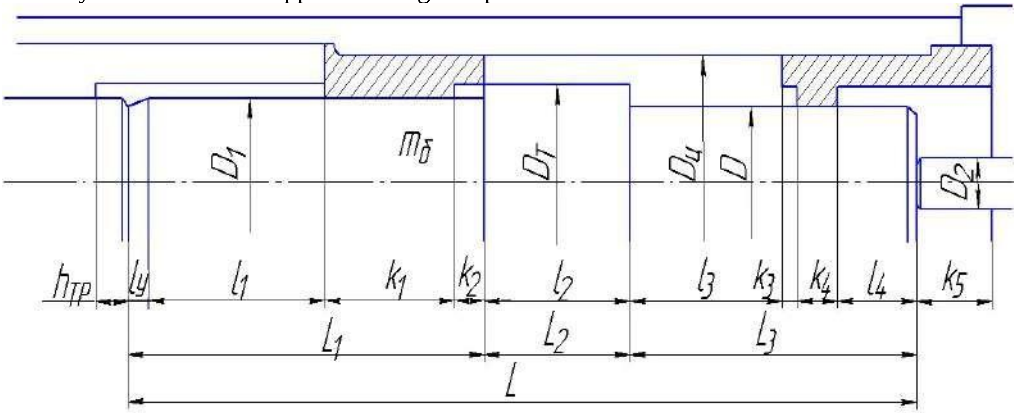
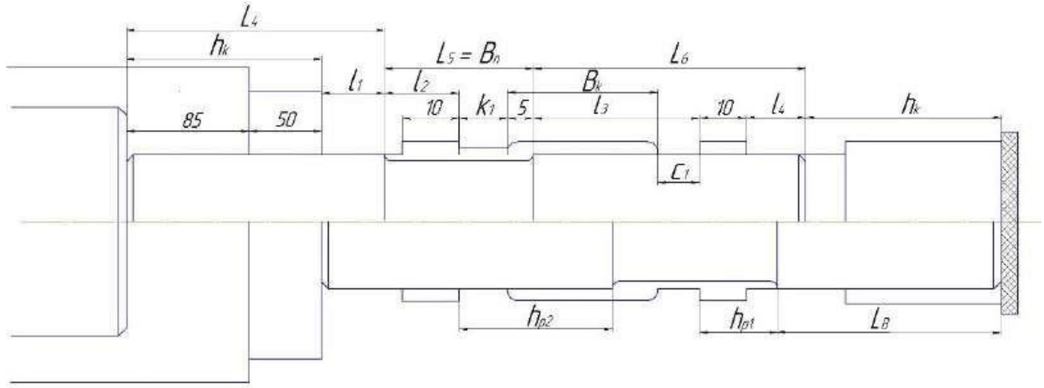


Fig. 9. - Dimensional circuit of the power unit

The size and layout diagram of the impact cylinder is shown in Figure 9, where the dimensional chains that ensure the accuracy of the layout are made up of previously calculated parameters: 1) calculated diametrical dimensions: D = 100 mm; D_1 = 98 mm; D_2 = 60 mm; D_c = 130 mm; D_T = 110 mm; 2) calculated kinematic parameters of the movement of the striker h = 100 mm. This is the acceleration stroke of the striker; 3) $h_и$ = 20 mm - the joint stroke of the striker and tool; $h_{тр}$ = 30 mm – striker braking stroke at the end of the working stroke; $h_{тв}$ = 15 mm – striker deceleration stroke at the end of the return phase; $m_б$ = 49.64 kg - the total mass of the driven link of the IHE, as well as from the parameters that are the result of geometric calculations: 1) dimensions along the body: k1 = 180 mm; k2 = $h_{тр}$ +5 = 35 mm; k3 = $h_{тв}$ +5 = 20 mm; k4 = 50 mm; k5 = h + $h_и$ + $h_{тв}$ = 135 mm; 2) dimensions for the driven link ПБ: l_1 = h + $h_и$ = 120 mm; l_2 = 140 mm (calculated by weight); l_3 = h + $h_и$ = 120 mm; l_4 = $h_{тр}$ +5 = 35 mm; 3) generalized dimensions L_1 = 360 mm; L_2 = l_2 = 140 mm; L_3 = 225 mm; L = 725 mm.



h' = 5 mm;
$h_п$ = 20 mm;
$l_г$ = 50 mm;
$h_т$ = 30 mm;

$B_к$ = l_3 + 5- c_1;
c2 = 12 mm;
c3 = 15 mm;
$\Delta l = h_{p2} - h_{p1}$ - dead area;

h_k = h + $h_{тв}$ + h_u =135 mm;
l_1 = $h_{тр}$ + $l_г$ = 80 mm;
l_2 = h' + h_u = 25 mm;
l_3 = h + h_u - h'' = 99 mm.

Fig. 10. - Dimensional diagram of the 1-st stage valve

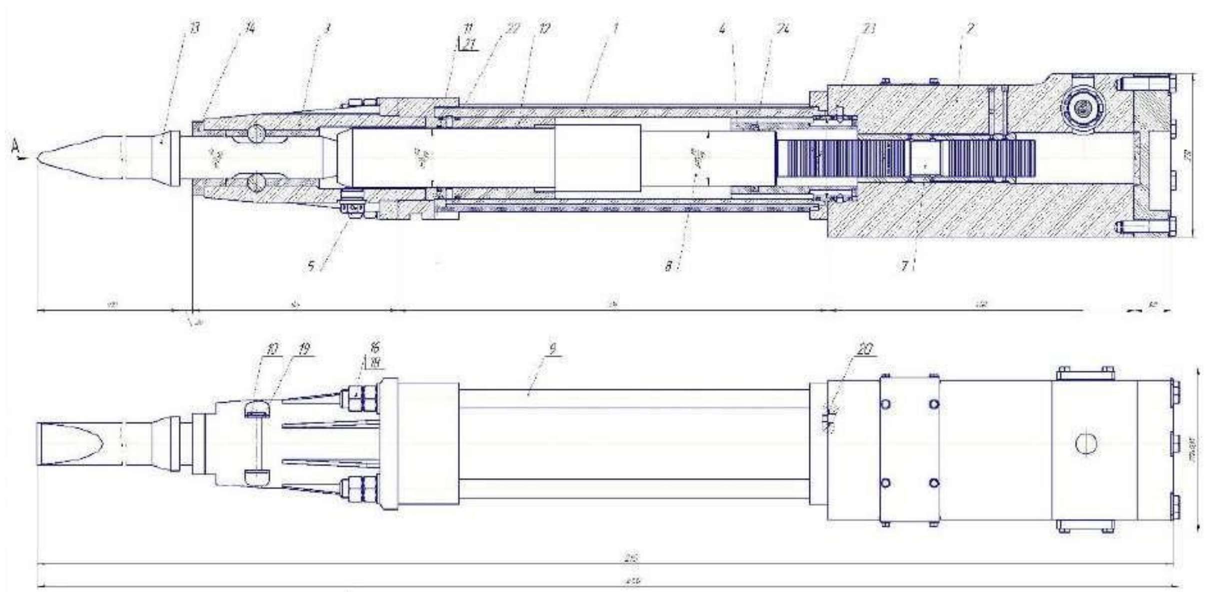


Fig. 11. - General view of the hydraulic hammer MGP-2

Conclusion

The axial dimensions of the valve's plunger of the first stage П3 mainly determine the longitudinal dimension of the control unit. Its size and layout scheme is shown in Figure 10, the features of which are determined by the asymmetry of the movement cycle of the driven link of IHE. Accordingly, the piston-spool П3 is shown in the diagram in two extreme positions: above the center line at the end of the working stroke, and below - at the end of the «return» phase. The figure below shows the algorithm for calculating the elements of a dimensional scheme.

The general layout of the hydraulic hammer units is presented in the general view drawing of the MGP-2. The drawing is shown in Figure 11. Here, the tool assembly 3, the assembly of impact cylinder 1 with the piston-striker ПБ, the control unit 2 are connected in series, interconnected by four pins 5. The rear cover of the unit 2 completes the layout.

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