Volume 3
№3, 2020

ISSN 2706-977X

MATERIAL AND MECHANICAL ENGINEERING TECHNOLOGY

Editorial board

Content

Calculation of the Economic Efficiency of the Rotary-Friction Boring Method

Donenbayev B. S., Filippova T. S., Sherov K. T., Oryntayeva G. J.
Karaganda Technical University, Karaganda, Kazakhstan

Abstract: In the Republic of Kazakhstan, manufacturing and repair of large-sized parts of technological equipment for mining, metallurgical, oil, coal, etc. heavy machine-building plants, in particular, JSC "Petropavlovsk heavy machine-building plant" and JSC "Almaty heavy machine-building plant", are mainly engaged in the industry. The results of the performed studies have shown that most large-sized parts of technological equipment have large holes, which are the bottleneck itself in their manufacture. Processing these holes is carried out mainly by boring out, requiring additional manufacturing of technological and tooling components. In most cases, the boring mechanical operation consists of two transitions: rough and fine boring. With large hole sizes, ensuring the accuracy and quality of processing is difficult, and sometimes even challenging to provide. This is due to the appearance of large vibrations and uneven elastic deformation, the complexity of interlinked accurate installation of the process and tooling, rapid wear and a chip cutting tool, accompanied by readjustment of the technical operations and low accuracy measurement and control. All these problems lead to a decrease in the accuracy and quality of processing and an increase in the cost of manufacturing the part. The goal of any production is to produce high-quality products with maximum productivity. The best way to achieve this goal is to use modern and properly selected equipment with programmed control. However, after installing expensive machines, it often happens that blank parts have been purchased, employees have received a salary, but there are still no finished products. The reason is simple - there is a debugging process, that is, you need to spend money on the tools. The purchasing of tools and equipment leads to new costs, errors, cost adjustments, etc. At this stage, we will consider what approaches can be used in the production support with tools to achieve maximum results on economical preparation technology the example.

Keywords: cost, part, tool, labor intensity, cutting cup, cutting plate, resource saving, billet.

1. Introduction

How to achieve maximum results at this stage and what approaches are applicable in providing production with tools-we will consider below, on the example of the introduction of resource-saving technology for manufacturing parts [1-4].

The cost of cutting tools does not significantly affect the economic efficiency. Often, the owners of enterprises agree, at the first stage, to pay for it "without looking" - just to start the production as soon as possible. And this is the right approach, but only at the beginning. In the future, the struggle for every percentage of the cost of production begins.

There can be only three methods of reducing the cost of machining job:

1. Reducing the cost of the tool as consumables.
2. Increasing the durability (lifetime) of the tool, which means reducing the purchase amount.
3. Changing the processing technology.

The first and second methods are clear, directly affect the procurement budget and, therefore, are most popular among services that regulate procurement at existing enterprises.

The third way is to change the processing technology. The following is an economic analysis of rotary-friction and rotary boring of parts.

2. Experimental studies

Experimental studies on the comparison of the two methods were carried out in the laboratory of the Department of Tomis Karstu, as well as in the production conditions of JSC "Almaty heavy engineering plant". For processing, the mechanism "Glass 711653009 (NG9207-03-04K3)" of the vibrating machine was used.

Figure 1 shows a diagram of the mechanism " Glass 711653009 (NG9207-03-04K3)".

Part material - 45L steel. The calculation of productivity and cost was carried out by a well-known technique for processing the internal cylindrical surface of the mechanism with an internal diameter of 310 mm and a length of 110 mm [5; 6, P.106-110]. Also the order of calculation is made on the basis of the calculation method given in [7, p. 96-103].

Table 1 shows the initial data for calculating the technical and economic indicators of rotary boring (RB) and rotary friction boring (RFB) [6, p. 107; 143].

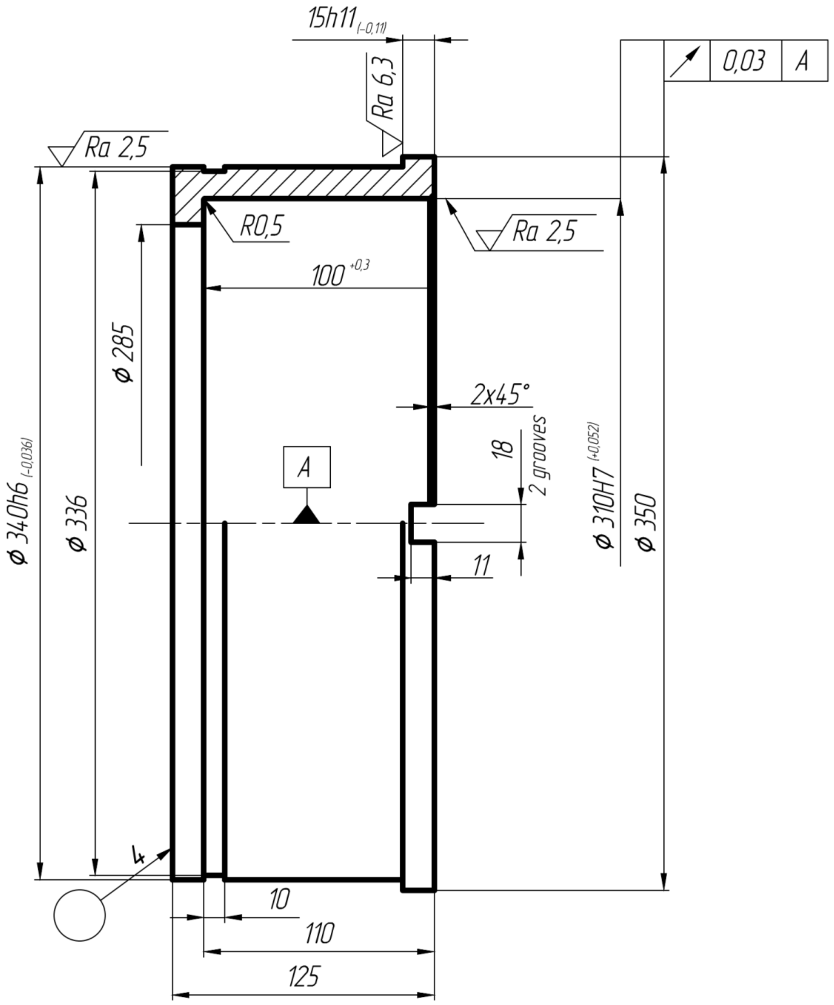


Fig. 1. - Diagram of the part " Glass 711653009 (NG9207-03-04K3)"

Table 1 - Initial data for calculating technical and economic indicators during boring

Comparable indicators	Unit of measurement	RB	RFB
Processed billet	-	Steel 30HGSA (0,3% carbon, 1% chromium 1% manganese, 1% silicon, the steel is of high quality)	
The diameter of the inner surface of the workpiece	mm	310	
Length of the blank part surface to be processed	mm	110	
Drilling depth (radial direction)	mm	1,0	
Surface roughness	microns	Rz 20	R*a* 20
Diameter and material of the Cup	mm	80	80
The angle of installation of the Cup (tool)	deg	15	
Cutting speed	m/min	237	597
The spindle rotation frequency	rpm	250	630
Feed rate	mm/rev	0,07	0,07
The saddle feed	mm/min	17,5	44,1
The calculated values			
Machine time, T_{M1}	min/hr	6,3/0,105	2,5/0,0417

The following expression determines the cutting speed:

$$V = \frac{\pi(D_{bl} + 2t)}{1000} \cdot n_{sp} \cdot \cos\beta_{inst}\,, \tag{1}$$

where D_{bl} - diameter of the inner surface of the blank part (mm);

n_{sp} – spindle speed (rpm);

β_{inst} – the angle of installation of the cutting tool (tool) (deg.).

To determine the economic efficiency of the process under study, we determine the cost of an hour of machine operation using the formula:

$$C_{r.c.} = C_e + C_{h.c.} + E_s \cdot (K_c + K_l) + C_{elect} + C_{c.pl}\,, \tag{2}$$

where $C_{r.c.}$ – hourly reduced costs (KZT/hr);

C_e – basic and additional earnings (KZT/hr);

$C_{h.c.}$ - hourly costs for the use of the workplace (KZT/hr);

E_s - standard coefficient of economic efficiency of capital investments in the machine and building. For mechanical engineering, E_s = 0,15.

For the accuracy of calculations, we take into account the cost of electricity, cutting plates.

$$C_e = \varepsilon \cdot C_{tf} \cdot K, \tag{3}$$

where C_{tf} - is the cost of the tariff rate of the worker on the machine depending on the category (KZT/hr);

ε - coefficient that takes into account the additional salary and the cost of social insurance. For mechanical engineering, ε =1,53; *K* - coefficient that takes into account the salary of the adjuster, *K* = 1, if the adjuster is performed by the worker himself, and if the adjustment is performed by special technical personnel, then *K* = 1,1 ÷ 1,5.

$$C_{h.c.} = C_{h.c.}^{\;bas} \cdot K_m, \tag{4}$$

where $C_{h.c.}^{bas}$. – hourly costs at the base workplace;

K_m - coefficient that shows how many times the loss of operation of this machine exceeds the analog versions.

$$K_c = \frac{P}{F_H \cdot m}\,, \tag{5}$$

where *P* - the book value of the machine (KZT);

F_H – the actual annual time fund of the machine (hr);

m - is the load factor of the machine;

$$K_l = \frac{F \cdot 78{,}4}{F_H \cdot m}\,; \tag{6}$$

where *F* - production area of the machine, taking into account trans itions (m^2).

$$F = f \cdot K_f\,, \tag{7}$$

where *f* - is the area of the machine in plan (m^2);

K_f - coefficient that takes into account additional production areas, taking into account transitions;

C_{elect} – cost of 1 kW/hr of electricity (KZT/kW);

$C_{1c.pl.}$ – - cost of 1 cutting plate (KZT);

T - the period of resistance of the plate (min.).

Initial data for calculating economic indicators are entered in table 2.

Substituting the data of the table 2 in the formula (1), we get the following values:

$$C_{r.c.} = 1025{,}1 + 783{,}9 + 0{,}15 \cdot (863{,}9 + 10{,}1) + 15{,}3 + 600 = 2555{,}4 \text{ KZT/hr } - \text{RB};$$

$$C_{r.c.} = 1025{,}1 + 1260 + 0{,}15 \cdot (863{,}9 + 10{,}1) + 15{,}3 + 100 = 2531{,}5 \text{ KZT/hr} - \text{RFB}.$$

Table 2 - Initial data for calculating economic indicators

Indicators	Unit of measurement	Types of technologies	
		RB	RFB
The annual program, *N*,	pieces	1000	1000
Operating time, T_m	hr	0,105	0,0417
Hourly rate of the working machine in accordance with the category, C_{tf}.	KZT/hr		670
Hourly costs at the basic workplace	KZT/hr	603	603
Coefficient showing how many times the loss of operation of this machine exceeds the analog versions, K_m		1,3	2
Type of equipment used		1K62	1K62
Book value of the machine, *P*	KZT	3 446 000	3 446 000
The production area of the machine with transitions, *F*	m^2	5,17	5,17
The area of the machine in plan, *f*	m^2	3,36	3,36
The coefficient that takes into account additional production areas, taking into account transitions, K_f		1,5	1,5
Machine power, *N*	kW	10	10
The cost of 1 kW / h of electricity, C_{elect}	KZT	15,3	15,3
Cost of 1 cutting plate,	KZT	600	100
Effective annual Fund-time of the machine, F_H	hr	4029	4029
The calculated values			
The cost of an hour of machine operation	KZT/hr	2555,4	2531,5
Cost of processing the inner cylindrical surface of the part 110 mm	KZT	268,32	105,56

To calculate the cost of processing the inner cylindrical surface of the part with a size of 110 mm, use the following formula:

$$C_{total} = C_{r.c.} \cdot T_m. \tag{8}$$

Substitute the existing values in the formula (7) and get:

$$\text{RB: } C_{total} = 268{,}32 \text{ KZT/m}$$
$$\text{RFB: } C_{total} = 105{,}56 \text{ KZT/m}.$$

The obtained values are entered in table 2.

Compare the values for the first and second options:

$$\frac{T_{total1} - T_{total2}}{T_{total1}} \cdot 100\% = \frac{0{,}105 - 0{,}0417}{0{,}0417} \cdot 100\% = 151{,}8\%$$
$$\frac{C_{total2} - C_{total1}}{C_{total1}} \cdot 100\% = \frac{268{,}32 - 105{,}56}{105{,}56} \cdot 100\% = 154{,}2\%$$

To calculate the annual economic effect, use the following formula:

$$E_a = (C_{total1} - C_{total2}) \cdot N,$$
$$E_a = (268{,}32 - 105{,}56) \cdot 1000 = 162760 \text{ KZT}, \tag{9}$$

where E_a - the annual economic effect (KZT);

C_{total1} – the cost of manufactured products with the basic technology (KZT/pieces);

C_{total2} – the cost of manufactured products with resource-saving technology (KZT/pieces);

N – annual program of manufactured products (pieces)).

A mutual comparison of the cost and labor intensity of two variants of the process of processing the inner cylindrical surface of the part "Glass 711653009 (NG9207-03-04K3)" with a length of 110 mm and a diameter of 310 mm showed that the rotary-friction boring of the inner surfaces with the initial data accepted in the table wins over the rotary boring by labor intensity of 151,8% and by cost of 154,2%.

3. Conclusions

Summing up, it becomes obvious that the resource-saving technology is due to the third method described an above-an increase in the woodcutter's cutting speed. Performing holes by rotary boring from high-speed steel at high speed leads to significant tool costs. The proposed design of a rotary-friction cutter made of structural steel allows it to be processed at higher rates, increasing productivity. However, it requires the rigidity of the cutting tool assemblies

4. References

[1] Sherov K.T., Sikhimbayev M.R., Donenbayev B.S., Ainabekova S.S. and etc. Experimental Research of Rotational-and-Frictional Boring of Big Holes in Large Parts / / Journal of Theoretical and Applied Mechanics. - Sofia, 2017. - Vol. 47, No. 4. - P. 23-36.

[2] Konovalov E. G., Sidorenko V. A., Soush A. V. Progressive Schemes of Rotational Cutting of Metals, Minsk, Science and Technology, 1982, 272p.

[3] Sherov K. T., Sikhimbayev M.R., Sherov A. K., Donenbayev B.S., Rakishev A. K., Mazdubai A. B., Musayev M. M., Abeuova A. M. Matematical Modelling of Thermofrictional Milling Process using ANSYS WB Software. Journal of Theoretical and Applied Mechanics, Sofia, 47 (2017), No. 2, 24-33.

[4] Sherov K. T., Sikhimbayev M.R., Musayev M. M., Rakishev A. K., Donenbayev B.S. Experimental Study of Turn-milling Process using Special Friction Mill made of Steel HARDOX. Metallurgical and Mining Industry, 11 (2016), 52-59.

[5] Gorbatsevich A. F. Kursovoe proektirovanie po tekhnologii mashinostroeniya / A. F. Gorbatsevich, V. A. Shkred / / Ucheb. posobie dlya mashinostroit. spec. vuzov – 4th ed., reprint. and additional-Mn.: Vysh. SHKOLA, 1983 – - 256 p.

[6] Musayev M. M. Thermopylai presale jaun TSL technical-economical timign of esatau / M. M. Musaev, K. T. Sherov, O. S., Tusupova S. S., Ainabekova S.S. // Innovative approaches in modern science: collection of articles based on the materials of the IX International scientific and practical conference "Innovative approaches in modern science". - No. 9(9). - M., Publishing House "Internauka", 2017. - P. 105-111.

[7] Selivanov A. N. Improving the productivity and quality of processing of bodies of rotation from titanium alloys by high-speed milling and milling: dissertation ... candidate of technical Sciences: 05.02.07, 05.02.08 / - Saratov, 2011. - 141 p.: Il. RGB OD, 61 12-5/1050.

Activation of Cement Binderin Heavy Concrete Technology

Mashkin N.A. [1], Esirkepova A.B.[2], Sherov K.T.[2], Rakhimova G.M. [2], Zharkevich O.M.[2], Mussayev M.M.[2]
[1]Novosibirsk State Technical University, Novosibirsk, Russia
[2]Karaganda Technical University, Karaganda, Kazakhstan

Abstract: The article discusses the issues of improving the quality of heavy concrete by activating a cement binder in hydrodynamic dispersants. It was established that as a result of activation, the strength of cement stone increases up to 2 times and the strength of fine-grained heavy concrete up to 1,5 times.
As activation parameters in the experiment, we varied the time of cyclic processing of a unit volume (1,7 *l*) of the suspension in the activator and the mass concentration of cement in the suspension. The concentration was varied in the range from 20 to 65%, the processing time - from 15 to 55 s. The output parameter was the compressive strength of the specimens hardened under normal conditions. The strength was controlled on the 3rd, 7th, 14th and 28th day of hardening.
Fine-grained concrete on an activated cement binder has shown increased resistance in aggressive environments. Studies of fine-grained concrete show that cavitation treatment of Portland cement is an effective method for intensifying the technology of reinforced concrete products and improving product quality, since it can significantly improve the properties of concrete based on Portland cement binder.

Keywords: cement activation, hydrodynamic dispersant, cavitation, fine-grained concrete.

1. Introduction

The need of the construction industry for high-performance cements to obtain high-strength structural concrete is growing. At the same time, the cement industry mainly produces cement with strength of 32,5-52,5 MPa, which is not enough to produce effective concrete.

In construction, heavy concretes are widely used (beams, trusses, slabs, railway sleepers, bridges and culverts, lining of tunnels, etc.). To ensure the high strength of such concretes, high-strength cements or activated standard cements are used [1].

The main ways to increase the activity of cements include mechanical (mechanochemical) activation using special ball mills, vibratory mills or roller crushers [1, стр.29].

Binder activation can be carried out in a “dry” or “wet” manner. The essence of activation is to increase the specific surface of materials with a simultaneous increase in surface energy, which provides an increase in the reactivity of the cement.

The disadvantages of the dry method of activating cement include the processing time of up to several hours, the high energy capacity of the equipment and its low productivity, short life periods and the difficulty of storing activated cement.

The cavitation treatment of a cement-water suspension or grout in thermodynamic or hydrodynamic dispersing activators (cavitators) embedded in the process of preparing concrete mixtures is more effective [2].

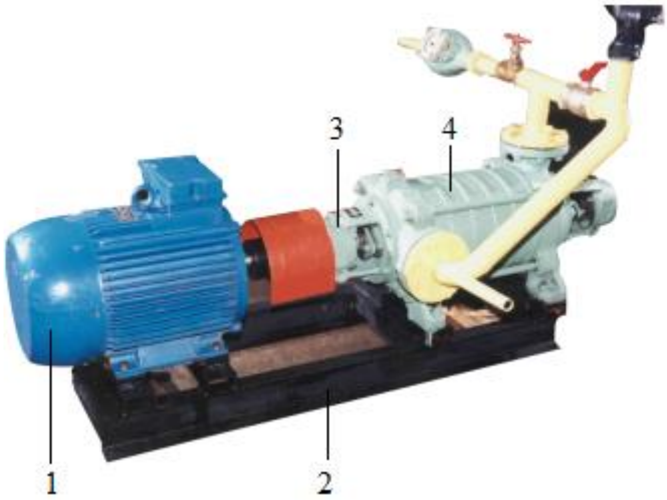
The principle of operation of cavitation installations is the creation in the liquid medium passing through the working parts of the installation, the effects of hydrodynamic and acoustic cavitation, when the resulting ultrasonic acoustic oscillations disperse and activate the particles of the material. The intense impact on the cement-water suspension of micro-blows, cavitation breaks, stretching and ultrasonic vibration leads to its heating, surface grinding of particles of the dispersed phase and the formation of stable activated suspensions.

2. Experimental part

In federal state budgetary educational institution of higher education Novosibirsk State Technical University (Russia) and Karaganda Technical University (Kazakhstan), experiments were conducted on the use of dispersant-activators in obtaining efficient heavy concrete. Subjected to cavitation effects cement compositions acquire a more advanced structure organization and improved quality characteristics.

For industrial activation of cement binders, industrial five-section hydrodynamic dispersant-activators can be used (Fig. 1). In such a disperser (under the action of a deep vacuum in cavitation bubbles), physical and chemical bonds in solutions and dispersions are broken to form ultrafine particles of less than 100 Å in size [2-4].

As variable activation parameters, cavitation time and cement concentration in the cement-water slurry were investigated. For example, with one pass through five activation (cavitation) sections of the dispersant and 60% concentration of cement in the suspension, the strength gain of cement stone in comparison with control samples reached 100%, that is, the activity of cement after activation increased twice.



1 – electric motor; 2 – base; 3 – clutch; 4 - pump

Fig. 1. - Dispersant-activator

Activation treatment of Portland cement is very promising, as it can significantly improve its properties, such as strength, mobility and hardening time. In addition, the activation of cement can eliminate such a widespread lack of factory mixing of the concrete mix, such as the heterogeneity of the distribution of the binder.

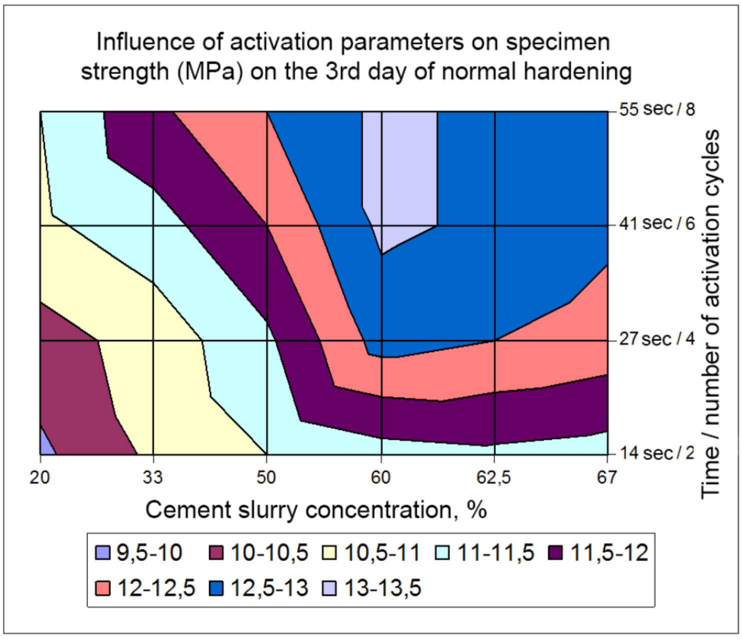
Experiments on the activation of cement binders were carried out in a laboratory thermodynamic disperser, which provides a sufficiently strong cavitation effect on the material being processed. Engine power – 4,5 kW, water capacity - 1 m3 / h, cavitation chamber volume – 1,7 *l*.

As raw materials for the manufacture of fine-grained concrete, ordinary Iskitim Portland cement CEM II 32,5 N (M400 D20) and quartz sand from the Krivodanovsky deposit with Mk = 1,3 were used.

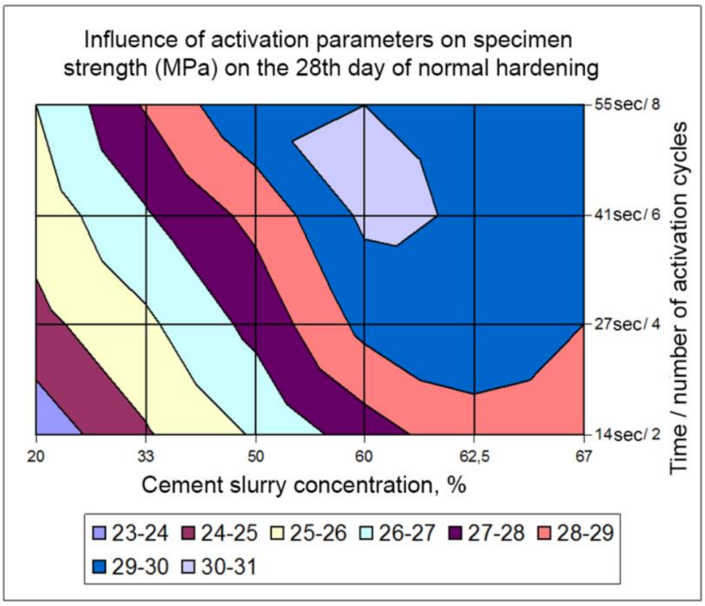
The activation parameters in the experiment varied the time of cyclic processing of a single volume (1,7 *l*) of the suspension in the activator and the mass concentration of cement in the suspension. The concentration varied in the range from 20 to 67%, the processing time from 15 to 55 s.

3. Results

As an output parameter compressive strength of samples that were hardening under normal conditions was adopted. Strength was controlled on the 3rd, 7th, 14th and 28th day of hardening.



a)



b)

a) influence of activation parameters on the strength of samples on the 3rd day of normal hardening; b) influence of activation parameters on the strength of samples on the 28th day of normal hardening

Fig. 2. - The dependence of the strength of fine-grained concrete from the parameters of activation

The optimal nature of the effect of concentration is due to the fact that when the concentration of the activated cement slurry is too low, insufficient amount of activated cement particles gets into the concrete, and at a high concentration of the cement slurry, the activation efficiency decreases due to an increase in viscosity of the system. The high viscosity of the cement slurry prevents the development of cavitation nuclei, and also contributes to the rapid deterioration of the working parts of the apparatus and the increase in power consumption. However, in the case of using more powerful industrial dispersants, it is possible to use higher concentrations of cement slurry, as well as a reduction in the processing time of the material.

The total 28-day strength of concrete activated with optimal concrete parameters is 47% higher than the strength of non-activated concrete of the same composition (30,2 MPa versus 20,6 MPa). The effect of increasing durability during activation should be used in the manufacture of reinforced concrete products, since it can make it possible to refuse heat treatment of products or lower the steaming temperature. This conclusion can be made by analyzing Figure 3, which presents a graph of the change in the strength of activated concrete, expressed in % of the 28-day strength of non-activated concrete of the same composition.

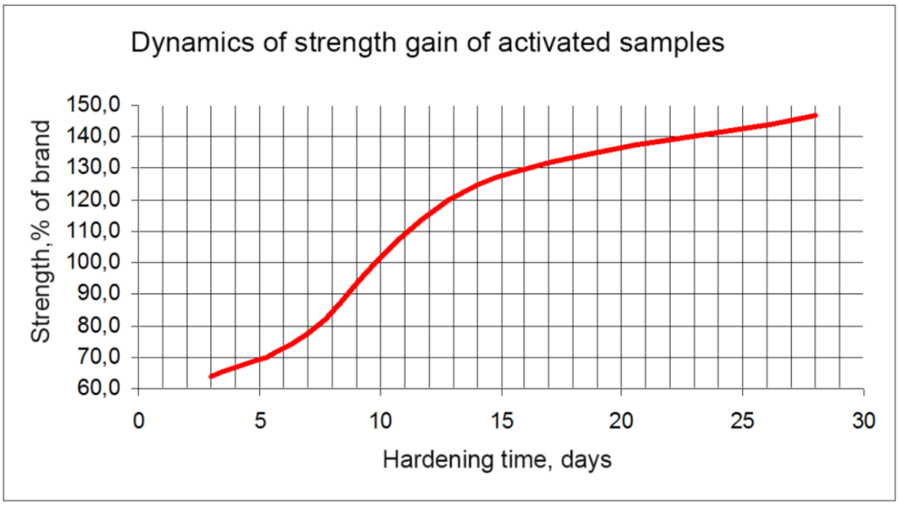


Fig. 3. - Kinetics of curing samples

Fine-grained concrete on activated cement showed increased resistance in aggressive environments. Concrete samples (100x100x100 mm) on activated and non-activated cements were tested in sewers in Novosibirsk for 1 year. As a result of inspection of the samples after testing, it was noted that the destruction of all samples of standard concrete occurred to a depth of 10 mm. At the same time, the samples on the activated cement collapsed to a depth of 5 mm (upper and lower surfaces), the vertical surfaces of the samples from which the aggressive liquids flowed easily, were almost not destroyed.

Studies of fine-grained concrete show that cavitational processing of Portland cement is an effective method of intensifying the technology of reinforced concrete products and improving product quality, as it can significantly improve the properties of concrete on Portland cement. Cavitational equipment is compact and high-performance, on the shaft of a single 30 kW motor, 3-5 stages of cavitation processing can be realized; the mass of such an installation without an engine does not exceed 200 kg. The device covers an area of no more than 2-3 m^2 and can be easily integrated into a standard concrete mixing plant.

4. Conclusions

Cavitational activation of Portland cement seems to be a promising method for improving the quality of structures for road construction from heavy and lightweight concrete. As a result of the activation of cement binders, the strength of concrete can be increased up to 1,5-2 times. An additional increase in the durability of concrete in aggressive operating environments (the action of groundwater and wastewater) is provided.

5. References

[1] Sovalov I.G. Methods of activation of cement and the impact of activation on the properties of concrete. - M.: TsBTI NIIOMTP, 1963. - 41 p.

[2] Lamekin N.S. Cavitation: Theory and Application / Gos. nat rus academy. - M.: Rusaki, 2000. - 246 p.

[3] Zibnitskaya N.E. Prospects for activating cement binders in concrete technology / N.E. Zibnitskaya, D.I. Zhivetyev, A.N. Mashkin // Proceedings of NGASU, 2005, V. 8, No. 2 (32). - P. 87-91.

[4] Berdov G.I., Mashkin N.A. Prospective directions for improving the composition and technology of building materials based on mineral binders //University news. Building, - № 4, 2015. - P.45-57.

Analyzing the Technology of Manufacturing Thin-Walled Castings with the Use of Cold-Hardening Mixtures

Kulikov V.Yu.[1], Кvon S.S.[2], Кovalev P.V.[3], Alina A.A.[4]
[1,2,4]Karaganda Technical University, Kazakhstan;
[3]Peter the Great Saint-Petersburg Polytechnic University,
Russian Federation

Abstract. This article deals with the topic of manufacturing thin-walled castings with the use of the molds made of cold-hardening mixture. The authors of the article consider the types of binders, curing methods, curing cycle times and the rheological properties of the mixture.
To confirm their positions, the authors describe the inorganic type of a binder (liquid glass and epoxy resin), the results of studying the liquid glass form.
Based on observations, it was concluded that the results obtained can serve as the basis for the technical specifications of manufacturing cold-hardening mixtures with the use of inorganic binders.

Keywords: cold-hardening mixture, clay, resin, liquid glass, mold, casting, binder.

1. Introduction

Cold-hardening mixtures (CHM) are mixtures that become hard and durable without exposure to high temperatures, that is, they self-harden. Currently, there are several formulations of cold-hardening mixtures for making molds. They can be classified by the type of the binder, by the method of curing, by the duration of the curing cycle and by the rheological properties of the mixture. There are three types of binders: organic, inorganic and combined.

In present day foundry, the following CHMs of this type are used:

1) CHM with polyurethane compositions cured with tertiary amine vapors: Cold-box-amine process;

2) CHM based on a special phenolic binder with methyl formate (MF) vapor purging: MF process or Beta-set process;

3) CHM with an epoxy-acrylate or furan binder, cured by silicon oxide (SO) blowing: Epoxy-SO-process or Furan-SO-process;

4) CHM based on a special phenolic binder with carbon dioxide purging: Resol-CO-process;

5) Classic CHM with liquid glass: CO-process.

In practice, an inorganic type of a binder is often used, that is, these are liquid glass mixtures. To ensure the hardening of mixtures with liquid glass, CO_2 blowing, introducing dicalcium silicates, liquid ethers, ferrosilicon into the mixture, and exposing to the air are used [1].

2. Experimental laboratory studies of the properties of CHM samples obtained by different methods

CHMs with liquid glass are non-toxic and have good pliability. On steel casting, when applied, an easily removable burn-in is obtained, even without painting the mold. The disadvantages of these mixtures should be attributed to their poor knockout and difficult regeneration. The compositions and properties of typical liquid glass mixtures are given in Table 1 [2].

The technology of making castings by casting into molds with the use of cold-hardening mixtures (CHM) is similar to the technology of casting into sandy-clay molds. Cold-hardening mixtures allow making molds without using heat. The resins as a binder are used. Curing of the mixture is achieved by using catalysts, for example by blowing with tertiary amines (carbon dioxide). As a result, the mixture self-hardens in the air within 10-15 minutes.

Currently, more than 100 cold-hardening mixtures for manufacturing molds and rods have been developed.

The disadvantages of such mixtures include a high cost of the binder and difficult regeneration of the mixture, as a result of which they are rarely used in production. It is advisable to use these mixtures for manufacturing molds and rods, when it is necessary to obtain an impression in high-precision castings with high requirements for surface roughness.

The technology of casting in CHM ensures a high quality of the casting surface, the absence of gas pockets and inclusions of molding sand in case of the mold or rod collapse [3].

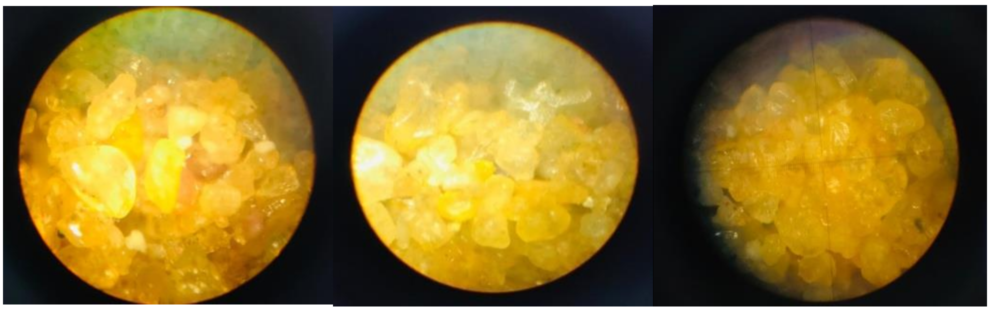
In recent years, the industry has developed plastic and liquid molding mixtures capable of spontaneous chemical hardening. Self-hardening plastic mixtures (SPM) provide the mold hardening in the workshop atmosphere within 5-15 minutes after its manufacturing; this is due to the fact that they contain liquid glass as a binder (about 5 %) and a hardener, ferrochrome slag (2-3 %).

Table 1 – Compositions and properties of quick-hardening mixtures on liquid glass

Mixture number	Mass fraction of the components, %					Properties and purpose of the mixture			
	Quartz sand	Heap sand	Liquid glass	Caustic soda solution	Others	Gas permeability, m^2	Humidity, g/m^3	Strength, Pa	Purpose
1	95.0-94.7	-	4.0-3.3	0.5-1.5	0.5 fuel oil	120.0	3.0	(4.0-7.0) /(980.0-1470.0)	For rods made by mechanized method
2	90.5-85.0	3.0-6.0	4.5-6.0	0.5-1.5	1.5 wood wool	80.0	3.0 - 4.5	(11.0-24.0) /(784.0-1176.0)	For rods that require increased flexibility
3	88.5-84.5	3.0-7.0	4.5	1.0	3 bauxite	800	3.3 - 4.2	(5.0-8.0) /(490.0)	For rods with easy knockout from castings
4	85.0-80.0	5.0-10.0	5.0	-	5 asbestos	120.0	2.8 - 3.0	(10.0-15.0) /(49.0-784.0)	
	70.5-50.0	24.0-43.0	5.0	0.5-1.5	0.5 fuel oil	80.0	3.5 - 4.5	(11.0-24.0) /(784.0-980.0)	The same

The use of plastic self-hardening mixtures makes it possible to abandon drying and using carbon dioxide for strengthening molds. But all this does not exclude the laborious processes of compaction of mixtures when obtaining molds. This drawback is eliminated by using liquid self-hardening mixtures (LSM), which were developed for the first time in our country by scientists from the TsNIITmash together with employees of the Moscow plant "Stankolit". The fluidity of such mixtures is conditioned by the fact that they include foaming additives, and self-harden by interaction of liquid glass and a hardener, ferrochrome slag. The technological process using LSM does not require highly qualified workers, reduces the labor intensity of molding by 3-5 times, allows increasing the production of castings on the existing areas, improves the quality of castings and the sanitary and hygienic working conditions of foundry workers [4].

The present studies have been carried out in the laboratory conditions to assess the effect of the height of filling CHM in the flask on the strength of the samples obtained (Figure 1).

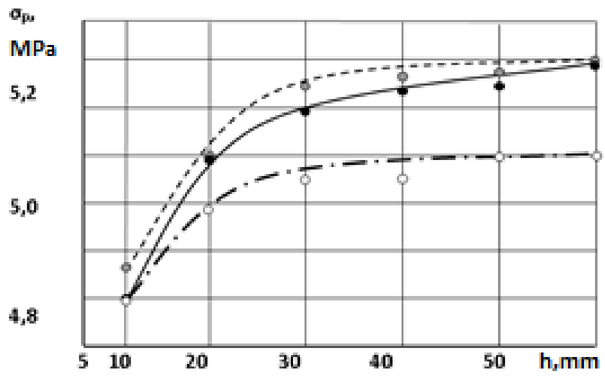


a) b) c)

a) 50g of quartz sand + 5g of liquid glass; b) 50 g of quartz sand + 5 g of liquid glass + 5 g of clay; c) 50g quartz sand + 5g liquid glass + 10g clay

Fig. 1. – The samples of CHM

The mixtures of the following content have been used: refractory filler - quartz sand 89 %, clay 2 %; resin 7-8 %, hardener 1 %, glycerin 0.03%. It was experimentally determined that the filling height does not have a significant effect on the properties of the CHM-form due to the small height of the column of the CH-mixture. The filling height with the mixture has been determined by the highest point of the match board. The dependence of the strength of the CHM-mold on the height of filling the mixture in the flask is shown in Figure 2.

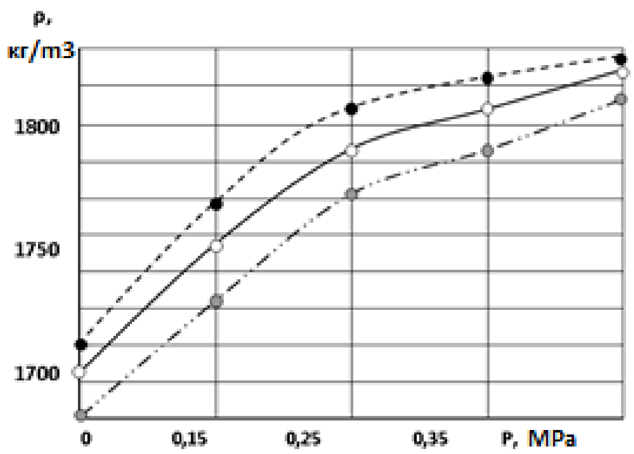


dashed line – 100 %; solid line – 1K0315 – 70 % + 1K02 – 30 %;
dotted line – 1K016 – 100 %

Fig. 2. – CHM-mold strength dependence on the height of filling in the flask

The density of the mold changes depending on the pressure value during the formation of the mold. The results of this series of experiments are shown in Figure 3. When carrying out studies, different fractions of the refractory filler (quartz sand) have been used. The studies have shown that increasing the pressure value increases the density of the CHM-mold. The difference in the initial bulk density of the mixture remains at any pressure.

Studies evaluating the effect of pressure applied to the mixture on the mold density have shown that initially the mold density increases significantly. This phenomenon arises due to the removal of interstitial air from the volume of the mixture and more compact packing of sand grains and particles of clay and resin under the action of the applied load. Later on, no significant increasing the density has been observed.

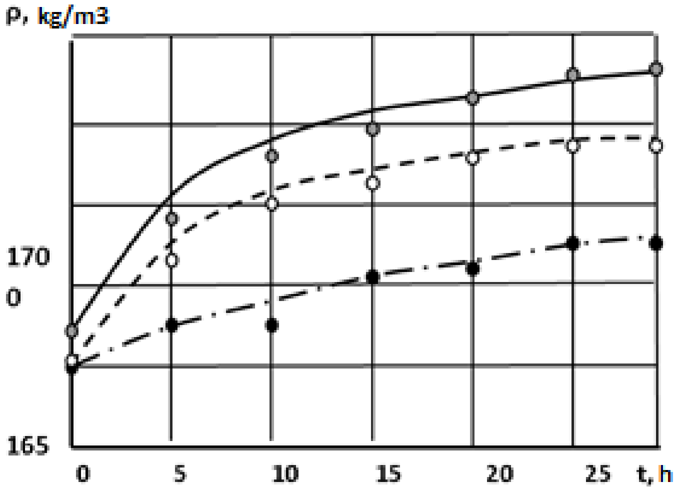


dashed line – 1K0315 – 100 %; solid line – 1K0315 – 70 % + 1K02 – 30 %;
dotted line – 1K016 – 100 %

Fig. 3. – The applied pressure value effect on the CHM-mold density

Long-term air drying of the mold leads to loosening over time. Similar distribution of density over time is observed at any pressure values used in the studies. At the same time, the higher the pressure on the mixture, the denser the mixture at the initial moment of hardening due to the most complete removal of interstitial air from the mixture, and thus the bulk density of the mixture approaches the specific gravity. A slight increase in pressing on the CHM within the initial curing period also leads to increasing the density of the mold. The effect of pressure and aging time on the mold density is shown in Figure 4.

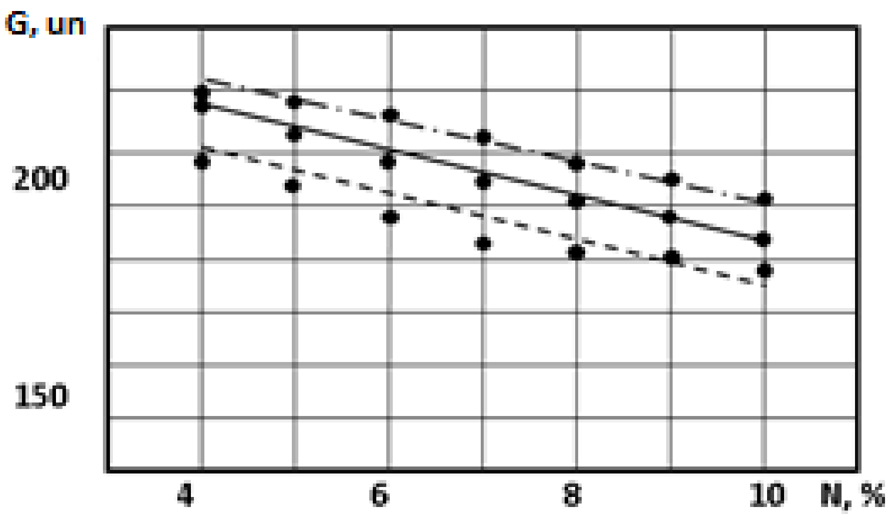
Studying the surface roughness of the mold have shown that increasing the magnitude of compaction of the CHM improves the cleanliness of the mold surface and, as a consequence, reduces the roughness of the casting surface. The production of cast billets with a high surface finish is achieved not only by using a certain mold manufacturing mode (compaction, drying) but also by using the optimal mixture composition. In addition, the composition of the mixture largely determines the cost of the mold.



solid line – 0.3 MPa; dashed line – 0.2 MPa; dotted – 0.1 MPa

Fig. 4. – Pressure and aging time effect on the mold density

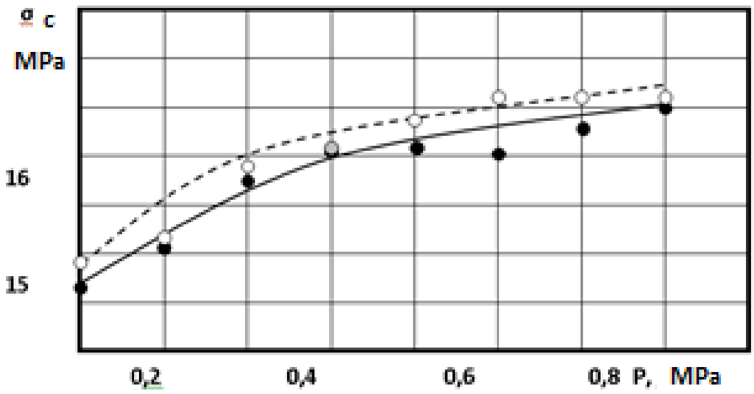
The effect of the resin content on gas permeability has been determined under conditions of various pressures on the mixture during mold hardening. It has been determined that gas permeability decreases with increasing the content of resin in the mixture at any pressure value or its complete absence during mold hardening. The resin occupies the space between the grains of quartz sand, thereby deteriorating gas permeability of the mixture. However, when using up to 10 % resin, the mixture has technologically needed gas permeability. Changing gas permeability with varying the resin content occurs almost linearly. In the experiments, we used quartz sand of fractions 1K0315 - 65 % + 1K02 - 35 %. It is obvious that increasing the content of fine fractions in the sand mixture leads to decreasing gas permeability of the CHM-molds. The resin content and applied pressure effect on gas permeability of the CHM-mold is shown in Figure 5.



dashed line – 0.4 MPa; solid line – 0.2 MPa; dotted line – no pressure

Fig. 5. – Resin content and applied pressure effect on the CHM-mold gas permeability

The compressive strength of the cured samples made of CHM has been studied at various values of pressing. The data obtained are presented in the form of the dependence in Figure 5. It has been determined that with increasing the value of pressing, the compressive strength of the CHM-mold increases. But strength increases significantly only at the initial stages of pressing; in the future, pressure does not render a large effect on the cured CHM-mold strength.



solid line – 1K0315 – 70 % +1K02 – 30 %; dashed line – 1K0315 – 100 %

Fig. 5 – Pressing value effect on the CHM-mold compressive strength

3. Conclusions

Based on the results of primary laboratory studies, the optimal composition of the cold-hardening mixture for making molds to manufacture thin-walled steel castings was determined: a refractory filler, quartz sand 89 % (in the proportion 1K0315 – 65 % + 1K02 – 35 %), clay 2 %; resin 7-8 %, hardener consumption 1 % , glycerin 0.03 %). The study showed that the use of clay along with urea resin allows to reduce the prime cost of the casting mold, while the strength of the mold, its gas permeability and surface cleanliness remain within the range of technologically necessary indicators.

4. References

[1] Issagulov A.Z., Ibatov M.K., Kulikov V.Yu., Kvon S.S., Shcherbakova E.P., Kovaleva T.V. Developing a mathematical model of the parameters of sand-resin molds. University Proceedings. 2018. No. 1 (70). - P. 33-35.

[2] Kovaleva T.V., Yeremin E.N., Kvon S.S., Kulikov V.Yu. Studying porosity of sand-resin molds made using unsteady pressure. In the collection: Innovative technologies in foundry. Proceedings of the International Scientific and Technical Conference dedicated to the 150th anniversary of the Faculty of Mechanical Engineering Technologies and the Department of Materials Processing Technologies! MSTU n.a. N.E. Bauman. Edited by K.A. Batyshev, K.G. Semenov, 2019. - P. 260-263.

[3] Kulikov V.Yu., Kvon S.S., Kovaleva T.V., Yeremin E.N. Studying the effect of pressing modes on the parameters of the porous structure of the mold. Foundry Worker of Russia. 2018. No. 8. - P. 9-14.

[4] Issagulov A.Z., Kulikov V.Yu., Tverdokhlebov Sh., Sidyakin A.V., Matveyev A.S. Analyzing the current state and methods of knocking out liquid glass mixtures. University Proceedings. 2015. No. 1 (58). - P. 41-43.

[5] Boldin A.N., Davydov N.I., Zhukovsky S.S., et al. Foundry molding materials. Molding, core mixtures and coatings: Handbook. M.: Mechanical Engineering, 2006. – P. 155-161.

[6] Kulikov V.Yu., Aubakirov D.R., Kvon S.S., Dostayeva A.M., Shcherbakova E.P. The use of wear-resistant materials in the metallurgical industry of the Republic of Kazakhstan. Metallurgist. 2018. No. 10. - P. 80-83.

Quality Assessment of Recovery and Repair of Front Loaders

Zharkevich O.M., Nurzhanova O.A., Zhukova A.V., Mateshov A.K.
Karaganda Technical University, Karaganda, Kazakhstan

Abstract: The article describes the structure of quality indicators of repair for front loaders. Statistical data on the mean time between failures of front loaders are presented. The reasons for the failure of the loaders are presented. The weight coefficients and averaged actual values of the repair quality indicators of the front loaders have been determined. Based on the method of principal components, a factorial model of the signs of the quality of repair is obtained. Dependences of technological and organizational factors are obtained.
Key words: repair, quality, indicator, expert assessment, goal tree, weight coefficient.

1. Introduction

Quality is the degree to which a set of intrinsic characteristics meets the requirements [1].

At the time of detection, quality indicators can be pre-repair and post-repair. At the same time, a number of indicators characterizing quarry special equipment during the repair process and in the initial period of operation are direct, and indicators characterizing the technological process and production resources are indirect, with the help of which it seems possible to predict the quality of repair.

Indicators have varying degrees of informational content and can give an assessment when used together. Pre-repair indicators provide only partial information, therefore, for a more complete quality assessment, a post-repair reliability assessment or the use of predictive models is necessary. The structure of repair quality indicators is presented in the form of a tree of properties, starting with simpler ones, relatively easily estimated by consumers, and ending with generalized ones that characterize complex properties. [2].

The purpose of the study was to develop a methodology for assessing the repair quality of quarry special equipment, taking into account the dependencies for technological and organizational factors, including consumer requirements.

For this, a choice of indicators of the repair quality for the quarry special equipment was made.

The choice of indicators and their hierarchy are based on the structure of customer requirements (Table 1).

Table 1 - Structure of quality indicators of repair of quarry special equipment

<table>
<tr><td colspan="4">Goal tree levels</td></tr>
<tr><td>0</td><td>1</td><td>2</td><td>3</td></tr>
<tr><td rowspan="9">Integrated indicator of the quality of repair</td><td rowspan="8">Comprehensive indicator of the quality of repair</td><td rowspan="3">Technological indicators of the repair quality</td><td>1. Convenience of delivery for repair and receipt of quarry special equipment</td></tr>
<tr><td>2. Repair duration</td></tr>
<tr><td>3. Repair cost</td></tr>
<tr><td rowspan="5">Organizational indicators of the repair quality</td><td>4. Technical indicators of the repaired quarry special equipment</td></tr>
<tr><td>5. Appearance of the repaired quarry special equipment</td></tr>
<tr><td>6. Degree of post-repair fitness for quarrying</td></tr>
<tr><td>7. Reliability</td></tr>
<tr><td>8. Durability</td></tr>
<tr><td colspan="3">Economical use of repaired quarry special equipment</td></tr>
</table>

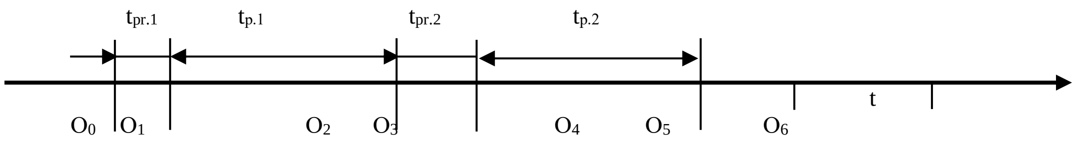
The quality of repair of quarry special equipment, in this case, front loaders (loaders), includes technological (appearance, reliability, etc.) and organizational (cost and duration of repair, etc.) factors. The most difficult thing in assessing quality is to determine the reliability indicators, which are realized after a relatively long period of use of the machine, therefore, the information obtained by traditional observation methods loses its relevance.

Consumers are largely interested in a complex integral indicator reflecting the ratio of the economic effect from the use of a machine to the cost of its repair and operation. Assessment of the quality of repair and, especially, forecasting the reliability of the work of the working bodies of special equipment is possible in the process of quality control of spare parts, repair of parts, when defects in previous operations of manufacturing and repairing parts are identified and eliminated and parameters characterizing the quality of mates, assemblies and parts are stabilized.

In the process of acceptance tests of the repaired machine (unit), the external condition (painting, fasteners)and the compliance of the main technical indicators (power, productivity) with the standard values are assessed

2. Results and discussion

Insufficient quality of repair for quarry special equipment is manifested by low operating time of special equipment to the first failure, which characterizes the degree of post-repair serviceability of special equipment. The flow diagram of failures and restoration of quarry special equipment is shown in Figure 1.



O_0, O_2 - moments of failure of quarry special equipment; O_1, O_3 - moments of restoration of special equipment; $t_{p.1}$, $t_{p.2}$ – working hours of special equipment; $t_{pr.1}$, $t_{pr.2}$ - restoration time of special equipment

Fig.1. - The flow of failures and restorations of quarry special equipment

The data on the mean time between failures of the repaired quarry special equipment in the quarries of the Karaganda and Pavlodar regions in 2019 are presented in Table 2.

Table 2 – Mean time between failures of repaired quarry special equipment in 2019

Name of quarry special equipment	Mean time between failures, h
Front loader Белаз-78250	12450
Front loader Sandvik LH-21	13560
Front loader Cat 980H	13800
Front loader Hitachi ZW 310	12940
Front loader JSB 456	13770

A significant number of resource failures are caused by crushing, wear, or cracks, and in some quarry special equipment (for example, loaders) this is manifested in the initial period of operation (Fig. 2).

a)

b)

c)

d)

e)

a) cracking in the bucket seat of the loader Sandvik; b) flaring the bucket eye of the loader Hitachi; c) a crack in the boom of the loader Hitachi; d) lateral surface crack of the loader Sandvik; e) deep scratches on the cylinder rod of the loader Cat

Fig. 2. - Reasons for failures in the work of quarry special equipment

To manage the repair quality of quarry special equipment, it is necessary to provide prompt feedback of the technological process with the results of using the repaired equipment. Thus, an express assessment of the repair quality is needed.

There can be two directions here [3]:

- development of a methodology for predicting the quality of repairs based on the actual level of the technologist;

- obtaining expert assessments by surveying customers.

In practice, it is insufficiently used to assess the quality of repair of special equipment, the defectiveness of parts, interfaces and assemblies detected in the process of repair, running in, especially in the initial period of operation of quarry special equipment.

The proposed methodological approach has been implemented and experimentally tested to assess the repair quality of quarry special equipment at Trubodetal LLP. First, a group of experts identified complex and unit factors and stages of unit factors, i.e. established a cause-and-effect relationship between the technological process of restoration and repair with single indicators of repaired special equipment, and developed the appropriate survey forms.

The quality of repair services is presented in the form of a multilevel structure of the goal tree [4]. The goal tree cannot absolutely adequately reflect the structure of object properties, but reflects only its basic properties.

A survey of experts from the main group and subsequent processing of the questionnaires established the values of the weight coefficients of complex and unit factors and their levels, as well as the standard deviation σ and the coefficient of variation v of random variables (Table 3).

Table 3 - Statistical values of the repair quality indicators of quarry special equipment

№	Indicators	Weight factor, Kbj	Customer satisfaction,%	Values of indicators	
				Standard deviation σ	The coefficient of variation v
1	Convenience of delivery for repair and receipt of special equipment (x_1)	K_{b1} = 0,056	70,0	0,277	0,38
2	Duration of repair (x_2)	K_{b2} = 0,055	60,3	0.315	0,75
3	Repair cost (x_3)	K_{b3} = 0,075	44,7	0,312	0,47
4	Technical indicators of the repaired special equipment (x_4)	K_{b4} = 0,170	45,0	0,231	0,52
5	The appearance of the repaired special equipment (x_5)	K_{b5} = 0,110	55,8	0,133	0,42
6	Degree of post-repair workability (x_6)	K_{b6} = 0,167	40,8	0,275	0,58
7	Reliability (x_7)	K_{b7} = 0,182	50,6	0,255	0,6
8	Durability (x_8)	K_{b8} = 0,185	42,8	0,238	0,45

In the questionnaires, the experts ranked the complex quality indicators, and also showed the weight of the subsequent ones in shares of the first indicator, taking into account the deviations in quality. For each indicator, the sum of direct and inverse ranks was found. The calculations of the weighting coefficients and the determination of the degree of confidence in the calculations were performed using the normalized matrix of ranks. The higher the value of the weighting factor, the more significant it is.

In the questionnaires developed on the basis of this table, customers (users of quarry special equipment) mark the actual level of each single indicator.

The value of the coefficient of the j-th indicator of the level of repair according to the data of the i-th customer is found by the formula [5]:

$$K_{py\ ij} = \sum W_{zj} \times K_{bj}, \qquad (1)$$

where $K_{bj,\ n}$ – the weight of the j-th indicator and their number;

W_{zj} - coefficient of the z-th actual level of the j-th indicator.

The average value of the repair rate is determined by the results of a survey of m customers [4]:

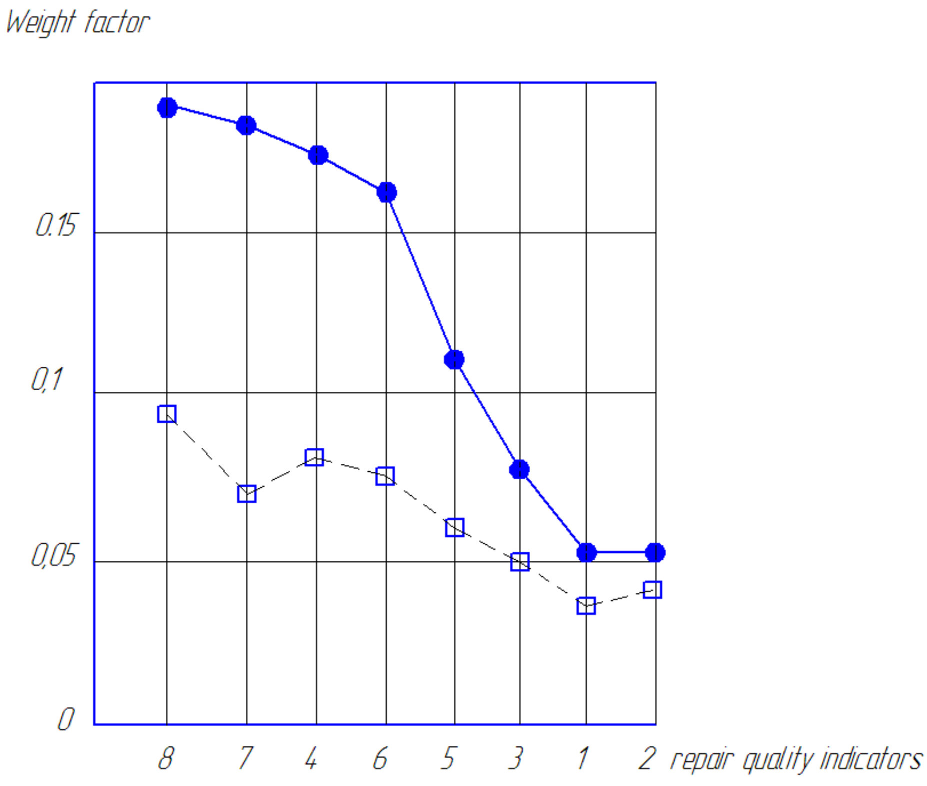
$$\bar{K}py = \frac{1}{m}\sum_{i=1}^{m} K_{pyi} \quad (2)$$

where K_{pyj} is the complex coefficient according to the i-th customer is the sum for all j generalized indicators.

Using formula (2), the average value of the repair rate was 0.07 in 2019.

To obtain information with a confidence level of at least 0.9 and a relative error of at least 10%, at least 20 specialists should be involved, and the maximum permissible for practical purposes with a degree of confidence in the calculations (0.8 and 20%, respectively), 10 specialists are enough.

According to the developed methodology, 100 customers were interviewed regarding the quality of repair of the company's special equipment. Table 2 and Figure 3 reflect the actual values, weight and distribution of indicators, as well as the degree of customer dissatisfaction.



1 – 8 - indicator numbers corresponding to tables 1, 2; - Kb j, - Kpyij

Fig. 3. - Diagram of the weight factor (Kbj) and averaged actual values of repair quality indicators (Kpyij) for the quarry special equipment of Trubodetal LLP for 2019

The greatest dissatisfaction with the quality of repair services and loss of quality is observed for more significant indicators: durability (10.5%), reliability (9.5%), usefulness (9.1%) and technical indicators (8.2%) as a percentage of other indicators, the sum of which is 100%.

To assess the initial obtained and refine the results of the expert ranking of the repair quality indicators, a multivariate factor analysis [6] of the initial indicators of the repair quality was carried out. By the method of principal components [7] and rotation, a factorial model of features was obtained (Figure 4).

Two factors are highlighted:

- technological factor f_1, formed by a large group of features (4,5,6,7 and 8);
- organizational factor f_2, formed by two features (1 and 2).

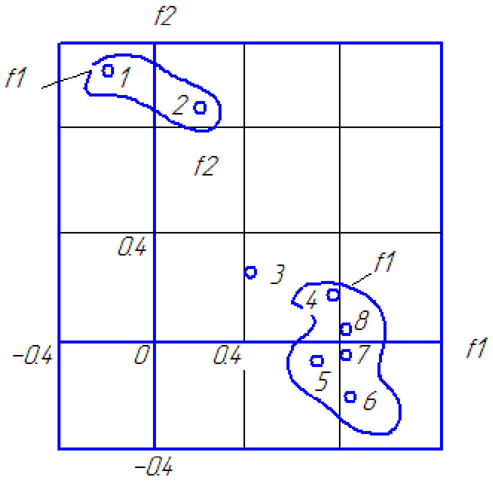
These two factors can be expressed by the following dependencies:

$$f_1 = 0,216x_4 + 0,220x_5 + 0,257x_6 + 0,215x_7 + 0,246x_8 \quad (4)$$

$$f_2 = 0,512x_1 + 0,501x_2. \quad (5)$$

The factor model shows that consumers are less worried about the duration and cost of repairs than technical indicators.

The expert structure of the goal tree and the factor model do not contradict each other. The advantage of the developed method is the efficiency of obtaining information and the possibility of improving the relationship between the customer and the repair department.



1 – 8 - indicator numbers corresponding to tables 1, 2; f1 - technological factor; f2 – organizational factor

Fig. 4. - Factor model of quality features of special equipment repair

This technique is applicable to assess the quality of repair of any mining special equipment and other technical machines.

3. Conclusions

1) The structure of indicators of the repair quality of quarry special equipment has been established.

2) Comprehensive repair quality factors have been determined according to the customer's data.

3) The factorial model of the signs of the repair quality for quarry special equipment based on the method of principal components was obtained;

4) Scientific and methodological foundations for assessing the quality of restoration and repair of parts have been developed with the establishment of a factor model of features of the quality of repair of special equipment and dependencies for technological and organizational factors.

4. References

[1] Lassaad Lakhal, Federico, Pasin Mohamed Limam. Quality management practices and their impact on performance // International Journal of Quality & Reliability Management 23(6). - P. 625-646.

[2] Grab V.P. Qualimetric approach to the assessment of product quality indicators // Proceedings of the International Symposium "Reliability and Quality", 2012. - T. 1. - P. 107-110.

[3] Kizim A.V., Chikov E.V., Melnik V.Yu. Problems of forecasting and planning for software and information support for maintenance and repair of equipment // Open Education, No. 2, 2011. - P. 224 – 227.

[4] Mohammad Modarresa, Se WooCheon. Function-centered modeling of engineering systems using the goal tree–success tree technique and functional primitives //Reliability Engineering & System Safety, Volume 64, Issue 2, May 1999. - P. 181-200.

[5] Martirosyan A.T. Efficiency indicator of equipment maintenance in the system of key performance indicators // Internet journal "Science Science", Volume 9, No. 6 (2017). - P.1-7.

[4] Korolev A.E. Sociological assessment of the quality of tractor repair // Collection of scientific papers of the 34th International Scientific Conference of the Eurasian Scientific Association (Moscow, December 2017). - Moscow: ENO, 2017. - P. 123-124.

[5] Vijayamohanan Pillai N. How Do You Interpret Your Regression Coefficients? MPRA Paper No. 76867, 2017. – P

[6] Horst Treiblmaier, Peter Filzmoser. Exploratory factor analysis revisited: How robust methods support the detection of hidden multivariate data structures in IS research // Information & Management,Volume 47, Issue 4, May 2010. - P. 197-207.

[7] Ian T. Jolliffe and Jorge Cadima Principal component analysis: a review and recent developments //Philosophical transactions of the royal society a mathematical, physical and engineering sciences. - P. 1-16.

Installation for Drying and Heat Treatment of Bulk Materials

Kipnis L. S., Malashkevichute – Brillant E.I., Medvedeva I.E., Tulegenova Sh.N., Musin K.A
Karaganda Technical University, Karaganda, Kazakhstan

Abstract. An installation was developed for drying and heat treatment of bulk ore concentrates of metallurgical production, made according to the scheme of a shaft furnace. The design of shaft furnaces, mainly for drying and heat treatment of dispersed materials, and can be used in metallurgical, construction and other industries. The technical result of the invention is to increase the productivity of the process, the efficiency of heat utilization and ensuring the stable operation of the furnace.

Key words. Shaft furnace, metallurgy, drying, lining, bulk materials, ore materials, refractories, metal powders, coolants

1. Introduction

For heat treatment of bulk materials in various industries are widely used mine installations of various designs [1].

It is advisable to use such installations for processing in a dense layer materials with a high density and high thermal conductivity, in particular, metal powders, concentrates of beneficial ores, refractories and others. Used for this in a number of industries drum, vibrating, conveyor installations, fluidized bed furnaces, etc. are not efficient enough, since their work is associated with energy consumption to set the material in motion. As practice shows, for such materials, vertical shaft-type apparatus can be most suitable. Since there are no moving parts in their design, this makes them easy to maintain and helps reduce operating costs [1].

Obtaining composite products by casting is one of the directions of resource saving, reducing material consumption and labor intensity in mechanical engineering.

Wherein machine parts can be synthesized from elements obtained by the most efficient methods and from optimal materials, depending on the requirements for individual parts of the part. The most promising materials include cast composite materials with an aluminum matrix, reinforced with refractory dispersed particles, due to their high mechanical characteristics, thermal conductivity, wear resistance, and relatively low cost.

The preparation of dispersed particles introduced into the matrix melt includes their heat treatment in order to remove moisture, degrease the surface and heat to the optimum temperature. A comparative analysis of existing methods and apparatus for heat treatment of bulk materials was carried out in order to assess their effectiveness for metal powders, polymetallic ores and other materials with high density and high thermal conductivity.

Rotary and vibrating installations, widely used in a number of industries, as well as fluidized bed furnaces, are not efficient enough in this case, since a large energy consumption is required to set the material in motion. The analysis showed that for such materials, vertical shaft-type apparatus, in the design of which there are no moving parts, can be most suitable, which makes them easy to maintain and reduces operating costs [8].

The process of drying and heat treatment of bulk materials of foundry and metallurgical production was studied in an installation made according to the scheme of a shaft furnace, the active part of which is a set of vertically arranged and interconnected cells with inclined walls through which the processed material passes. Heat supplied to the material through the walls of the cells, which are heated from the outside when flowing around them with a stream of hot air or gas.

As an object of research, we used concentrates of polymetallic ores, metal powders, as well as foundry sand.

On a cold physical model, the features of the movement of bulk materials with a moisture content of 0 to 10% in cells of circular, square and rectangular cross-sections were studied at various values of the speed of vertical movement (flow rate in the outlet section) of the material and the geometric parameters of the cells. The conditions for material hanging in the cells at constant and variable moisture content of the material over the cross section of the cells and their relative position are determined. It has been experimentally established that the least resistance to the movement of bulk material is provided when the wall of the cells is inclined to the vertical axis of 55-60 ° Data for optimization of cell geometry was obtained. Experiments were carried out on a laboratory setup, which consists of a shaft furnace itself, a system for supplying and removing a coolant heated by a burner device or an electric heater, nodes for loading and unloading material, sensors for controlling the filling of the loading bunker, and devices for manual control of the coolant supply.

The distribution of temperature and moisture content of the material over the section of the cell and the height of the mine in the stationary and moving layers at different temperature modes of operation, as well as the change in the temperature of the coolant along the height, were obtained using a laboratory setup, the dependences of these parameters on the speed of vertical movement of the material in the mine (drying capacity) and specific heat consumption. The proposed scheme can be used to create compact small-sized drying units.

On the base of laboratory experimental studies, the design of a small-sized shaft drying plant for metal bulk materials with a particle size of 0.5-2 mm and a moisture content of 6-12% has been developed.

The material processed is fed by the feeder to the furnace hopper, in which the material level sensors are installed. A constant level of material in the furnace is ensured by coordinating the operation of the units for loading and unloading material from the furnace.

The heat carrier is introduced into the lower part of the furnace tangentially and moves in countercurrent with the material descending during the drying process. Thermometers of the drying temperature control system are installed in the inlet pipe of the coolant and in the unloading funnel of the furnace, which ensures the stability of the coolant temperature and regulation of the furnace stroke according to the temperature of the material at the outlet, which can be automated. Exhaust gases having a temperature at the outlet of the furnace of 130-150 ° C must pass through a dust catcher, and then pass through the casing of the feed feeder of the processed material, which will allow their heat to be utilized.

2. Results and discussion

For drying and heat treatment of bulk ore concentrates of metallurgical production, an installation was developed, made according to the scheme of a shaft furnace (Fig. 1). The installation contains a cylindrical body lined with refractory or heat-insulating material, inside which there is an active part, which is a set of vertically arranged with a gap relative to each other on the support rods 9 in the form of truncated cones or pyramids [7].

The walls of the sections are made with an inclination to the horizontal plane 40-600, the size of the gap between the sections through which the processed material passes is (0.5 - 0.6) · (L - l), where L, l is the width of the cell, respectively, at the upper and lower levels. The height of each section is determined by the ratio:

$$H + [\frac{(L - l}{2}) \cdot tg\gamma]$$

where γ is the angle of inclination of the side wall of the section.

Heat is supplied to the material through the walls of the cells, which are heated from the outside when flowing around them with a stream of hot air or gas.

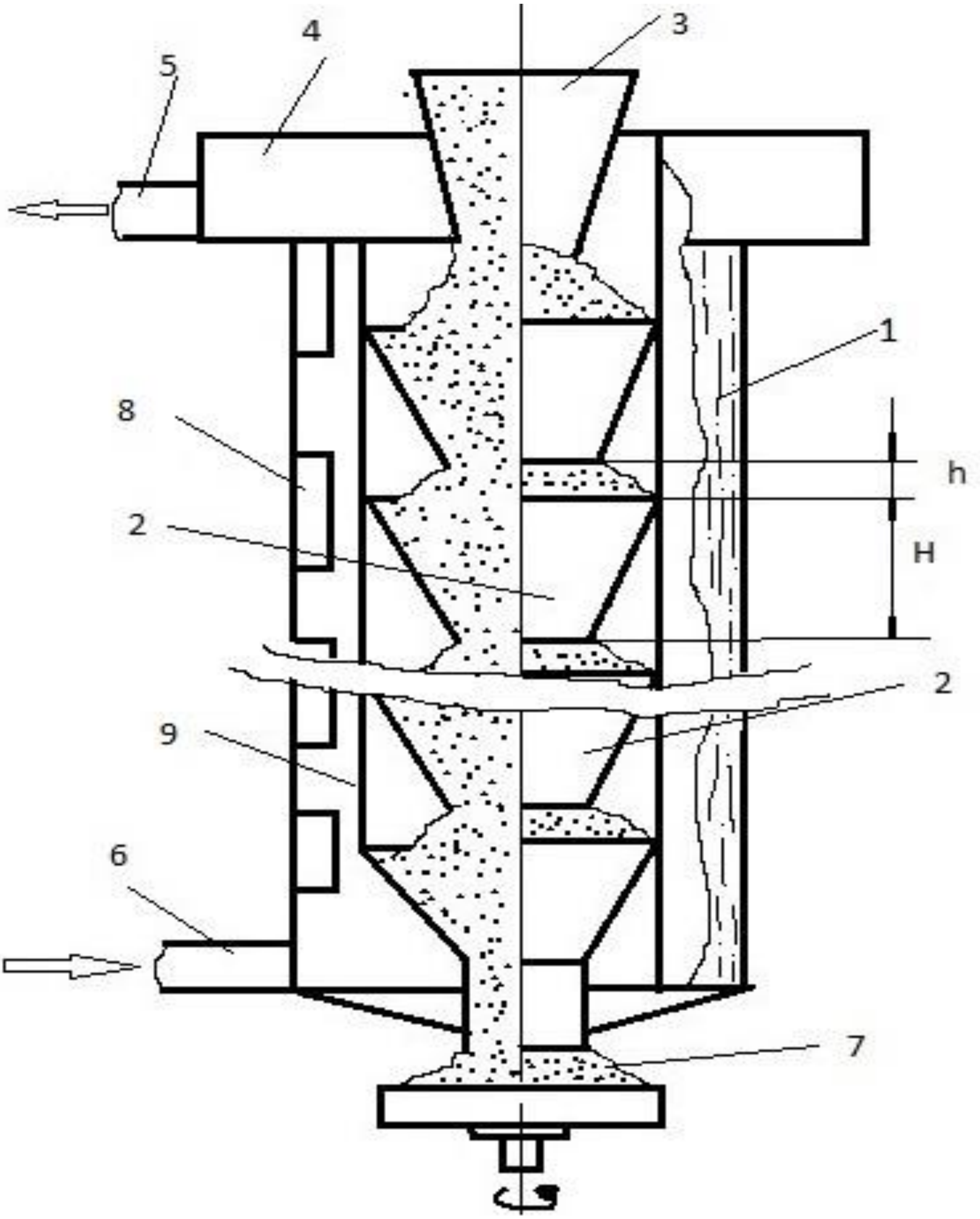
The installation as a whole consists of a shaft furnace itself, a heating medium supply and removal system, which is heated by a burner device or an electric heater, material loading and unloading units, sensors for controlling the filling of the loading bunker and devices for controlling the heating medium supply. The original wet material is fed into the hopper 3 by a feeder.

From the bottom of the hopper, the material starting to heat up, together with the heated moisture, is lowered into the drying sections2. The generated steam is released into the inner space of the shaft through the gaps between the sections. The coolant is fed tangentially into the lower part of the furnace body through the nozzle 6 and gradually rises to the upper level together with steam to the collector 4 and is removed from the furnace through the gas duct 5.

The installation was used to study the distribution of temperature and moisture content of the material over the section of the cell and the height of the mine in the stationary and moving layers at various operating temperatures, as well as the change in the temperature of the coolant along the height, the dependences of these parameters on the speed of vertical movement of the material in the mine (drying capacity) and specific heat consumption. The design of a small-sized shaft drying plant for metal bulk materials with a size of 0.5-2 mm and a moisture content of 6-12% has been developed.

Material level sensors can be installed in the furnace feed hopper. The constancy of the material level in the furnace is ensured by the coordination of the operation of the units for loading and unloading material from the furnace. The heat carrier is introduced into the lower part of the furnace tangentially and moves in counter current with the material descending during the drying process. Thermometers of the drying temperature control system are installed in the inlet pipe of the coolant and in the discharge hopper of the furnace, which ensures the stability of the coolant temperature and regulation of the furnace stroke according to the temperature of the material at the outlet, which can be automated.

Exhaust gases having a temperature at the outlet of the furnace of 130-150 ° C must pass through a dust catcher, and then pass through the casing of the feed feeder of the processed material, which makes it possible to utilize their heat. If more intensive heating of the walls of the sections is required, the furnace body can be equipped with resistance heaters located in the grooves of the lining.



1 - casing, 2 - drying sections, 3 - hopper, 4 - collector, furnaces 5 - gas outlet, 6 - branch pipe,7 - charge, 8-insert, 9 - support rods

Fig. 1. - Shaft furnace

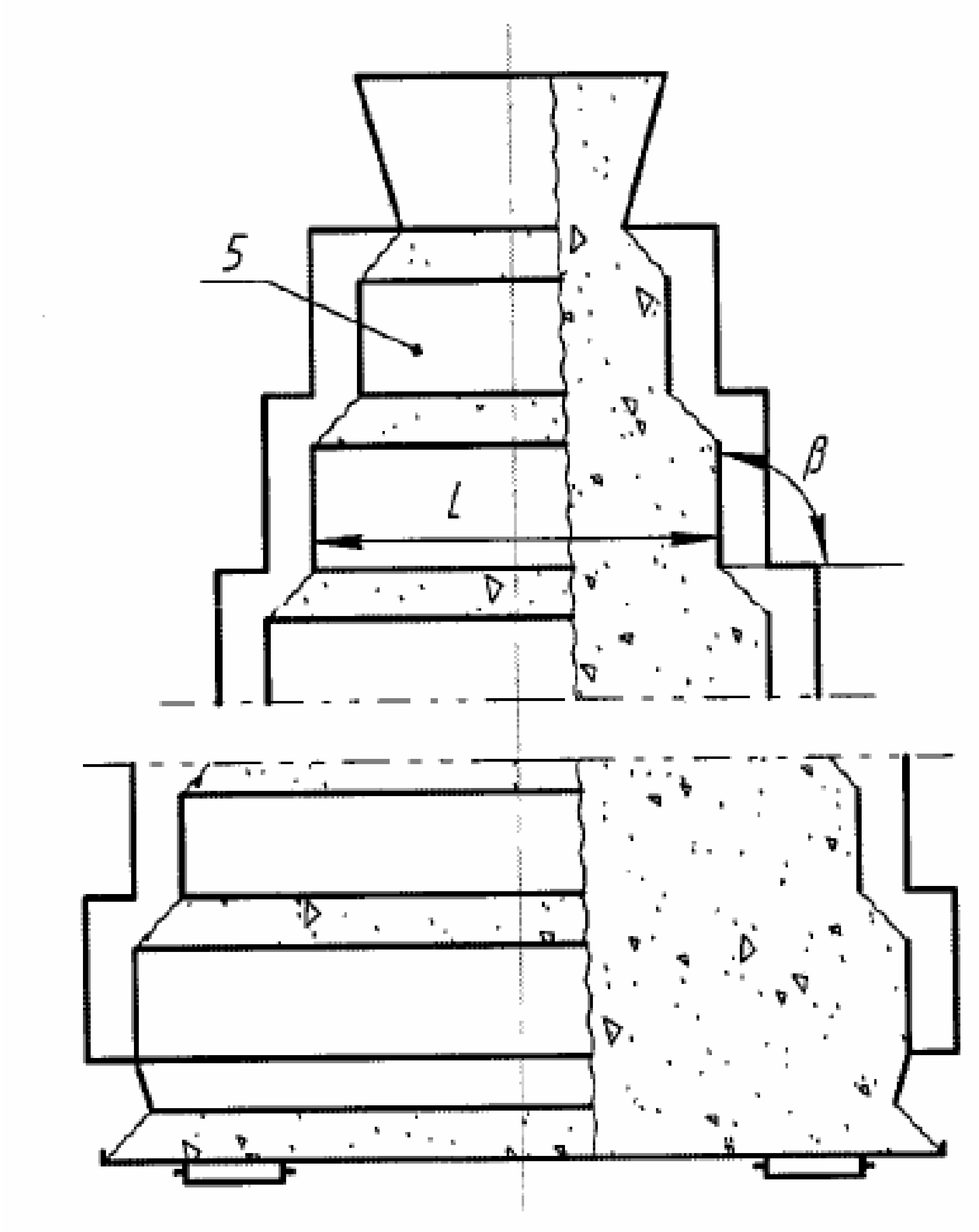


Fig. 2. - Shaft furnace 2

On a cold physical model, the features of the movement of bulk materials with a moisture content of 0 to 10% in cells of a circular, square and rectangular cross-section at various values of the speed of vertical movement (flow rate in the outlet section) of the material and geometric parameters of the cells are studied. To prevent material from hanging in the cells, the slope of their walls to the horizontal plane should be at least 55-600.

The inserts are made in the form of equal angles, while for the upper sections the shelves of the corners are facing down, and for the lower ones, in which the moisture content of the material is less, the shelves are facing up (position 8 in Fig. 1).

Flowing around the liners during vertical movement, the material deflects them to the side, which contributes to a more uniform removal of moisture from the material.

For materials in which the flow ability increases significantly with decreasing moisture content, a variant of the shaft furnace design is proposed, the sections of which are rectangular in plan are made with geometric parameters that consistently vary along the furnace height [4].

In the proposed design, the upper section is performed with a ratio of length to width from 1: 1 to 1: 2, for the sections located below, the width gradually decreases, and the length increases while maintaining the equality of the areas of the horizontal projections.

The geometric parameters of the sections are set according to the ratios:

$$L_{n-1} = L_n + \frac{2h}{tg\theta},$$

$$B_{n-1} = \frac{B_n L_n}{L_{n+1}},$$

$$\gamma = \theta + (2 \div 5)^0,$$

$$\gamma = 90 + 100^0,$$

where Ln-1, Ln, Bn-1, Bn - respectively the length and maximum width of the overlying and underlying adjacent sections,

θ is the angle of collapse of the processed material;

h is the height gap between adjacent sections;

β, γ - angles of inclination, respectively, of the longitudinal and end walls of the sections;

n is the serial number of the section from top to bottom.

The shaft body and lining are made with the same gaps between the shaft walls and sections [7].

3. Conclusions

The design of this furnace will increase the productivity of the process, the efficiency of heat use and ensure stable operation of the furnace.

An installation for drying and heat treatment of bulk ore concentrates of metallurgical production, made according to the scheme of a shaft furnace, has been developed. The design of shaft furnaces, mainly for drying and heat treatment of dispersed materials, and can be used in metallurgical, construction and other industries.

The technical result of the invention is to increase the productivity of the process, the efficiency of heat use and ensure the stable operation of the furnace. In order to increase the efficiency of heat exchange between the walls of the shaft and sections, a configuration of the shaft body is proposed, rectangular in plan, made stepped in the longitudinal direction with equal gaps between the end walls of the shaft and sections.

Installation contains a cylindrical body lined with refractory or heat-insulating material, inside of which there is an active part, which is a set of sections in the form of truncated cones or pyramids, located vertically with a gap relative to each other, fixed on support rods. The proposed configuration and the choice of the geometric parameters of the sections according to the proposed ratios improve the stability of the vertical movement of the processed material in the cells of the furnace core and its more intensive mixing, which accelerates the heating of the material and intensifies the release of moisture and vapors from it. Производительность данной печи повысилась на 20%.

References

[1] Bogdanov A. S. Tokarev A. V. Yudanov V. A. Continuous coking of coal in a shaft furnace //Bulletin of the Kyrgyz State Technical University I. Razzakova, No39, Volume 1, 2016. – P. 25-30

[2] Shubin, A.F. Direct-flow counter-current shaft furnace for the production of active lime //Steel, No5. 2001. – - P. 80-84

[3] Method and shaft furnace for firing bulk material Beyer K., Schaefer D. Patent for the invention RU 2507460 C2, 02.20.2014. Application No. 2011111275/02 of 08/12/2009.

[4] Matyukhin V. I., Yaroshenko Y. G., Matyukhin O. V. Improving the thermal conditions of shaft furnaces of non-ferrous metallurgy //University News. Non-ferrou s metallurgy, No. 3, 2010. – P. 25-30

[5] Fundamentals of metallurgical production: textbook / [Bigeyev V.A., Vdovin K.N., Kolokoltsev V.M., etc.]; ed. V.M. Kolokoltseva. - St. Petersburg [and others]: Lan, 2017. - 614 p.

[6] Borschev V.Ya. Equipment for grinding materials: crushers and mills. Textbook. - Tambov: Publishing House of the Tambov State Technical University, 2004. – 241 p.

[7] The method of roasting lumpy limestone in a shaft furnace and a shaft furnace for roasting lumpy materials Chaykin BS patent for invention No: RU 2426049 C1 Patent Office: Russia Publication Year: 2011 No Application: 2010117592/02 Registration Date: 04/05/2010 Publication Date: 08/10/2011 Patent Owners: Institute of Thermal

Metallurgical Aggregates and Technologies Limited Liability Company Steel project Open Joint-Stock Company Metallurgical Plant "”Electrostal”

[8] Kipnis L.A. Shaft furnace for drying and heat treatment of bulk materials. Patent of the Rep. Kazakhstan No. 77614 10/24/2011

[9] Modeling of the processes of heat treatment of bulk and sheet materials in order to increase their efficiency Volynsky V. Yu. Modeling of the processes of heat treatment of bulk and sheet materials in order to increase their efficiency: thesis Doctors of technical sciences: 05.17.08. - Ivanovo, 2006. - 394 pp., ill. RSL OD, 71 07-5 / 47