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JUSTIFICATION OF RATIONAL PARAMETERS FOR MANUFACTURING PUMP HOUSINGS MADE OF FIBROCONCRETE

Purpose. Establishment of patterns of influence of the main factors on the physicomechanical characteristics of fiber concrete, which is advisable to use for the manufacture of pump housings operating in adverse conditions.

Methodology. The work uses theoretical analysis of fiber concrete application in various industries, analysis of factors affecting fiber concrete strength; laboratory experiments are conducted to confirm theoretical results and identify regularities allowing recommending rational parameters of production of pump casings from fiber concrete.

Findings. The work attempts to offer technological solutions for the use of fiber concrete in a new field – mechanical engineering – in the manufacture of pump housings operating in the mining and metallurgical industry in unfavorable conditions such as pumping of aggressive liquids, highly abrasive pulp, high ambient temperature, dust, and others. The obtained results allow developing centrifugal pump housing casting technology without additional mechanical treatment and with high physical and mechanical characteristics as well as recommending rational composition of the fiber concrete mixture, meeting requirements to centrifugal pump housings according to strength conditions, manufacturability and economy.

Originality. The regularities of the effect on the strength of fiber concrete of the optimal content of steel fiber in the composition of the mixture as well as rational modes of mixing components are established experimentally. They are rotational speed of a mixer working part and mixing time of the components. The obtained regularities confirm theoretical studies and provide obtaining of the fiber concrete mixture with uniform distribution of all components in its volume as well as isotropic characteristics of solidified fiber concrete.

Practical value. The obtained results, presented in graphs and calculation formulas, make it possible to reasonably design composition of the fiber concrete mixture and to develop the technology of making centrifugal pump housings from it by a casting method without additional mechanical treatment. At the same time fiber concrete has density of 2200–2300 kg/m^3 versus 7500–7800 kg/m^3 of metal bodies, compression strength of 230–240 MPa, bending strength of 80–100 MPa. All these allow reducing thickness of a pump housing wall by 15–20 %.

Keywords: *pumps, fiber concrete, granite crushed stone, quartz sand, quartz flour, steel fiber*

Introduction. The main goal of mechanical engineering in the period of "Industry 4.0" is the development and introduction of new materials and technologies that improve the quality of products and reduce their cost, contribute to the creation of effective competitive equipment and do not require large investments.

Manufacturability is one of the most important elements of the manufacturing process of mechanical engineering products, which requires the use of the most advanced materials, effective methods and means to guarantee the achievement of specified quality indicators with minimal material and labor costs.

The manufacture of centrifugal pump housings for the mining and metallurgical industry from a new material – fiber-reinforced concrete – is a promising direction in realizing the objectives of the "Industry 4.0" program.

Modern production for the manufacture of body parts for pumping equipment is inextricably linked with tasks related to improving production efficiency, reducing production costs and the complexity of technological processes, as well as reducing material and energy costs, the use of new innovative materials. Currently, the casing parts of pumps used in mining and metallurgical production, depending on the pumped medium, are made mainly of cast iron, steel and aluminum alloys.

In the mining and metallurgical industry, a large number of centrifugal pumps operating under adverse conditions are being exploited. These are pumps that pump aggressive and hot liquids, abrasive pulps, and so on. For these reasons, their manufacture requires an increase in the thickness of the body, which in turn leads to their rise in price. In addition, adverse operating conditions lead to rapid wear of the casings and impellers, unplanned downtime and costly repairs.

One of the ways to reduce operating costs is to use construction materials with a low cost, yet meeting the requirements of the characteristics of pumping equipment. These materials include dispersed-reinforced concrete, which is one of the varieties of an extensive class of composite materials. Reinforcement of concrete is carried out with filament-fibers, evenly dispersed in the volume of the concrete matrix.

Fiber concrete is used for the manufacture of various structures for their intended purpose and each of them has its own specific requirements. The mechanical properties of fiber-reinforced composites depend on the number of fibers, type, and size.

Currently, all research work on the study of fiber concrete is associated with building structures. There are practically no works related to fiber-reinforced concrete in the field of mechanical engineering. In this regard, in this paper, an experimental study is conducted on the influence of various factors on the characteristics of fiber concrete, which can be used in mechanical engineering. The tested fiber concrete was a fine-grained concrete with the introduction of steel fiber from a wire into its matrix. Rational choice of sizes and fiber content, as well as technological modes of preparing a fiber-concrete mixture, make it possible to obtain cost-effective materials with improved strength characteristics, which can be effectively used, for example, for the manufacture of pump housings.

The research made it possible to manufacture and test the housing for a single-stage centrifugal pump made of fiber concrete with improved characteristics and to prove the possibility and prospects of fiber concrete for replacing expensive metals.

Literature review. Fiber concrete as a structural material is widely used in many areas of construction and is successfully used in foreign countries such as Germany, Japan, the USA, South Africa, and others. In Kazakhstan, little attention is paid to fiber concrete.

The advantages of materials using fiberglass as a reinforcing material are considered in many works. The author of the work [1] states that to obtain high-quality fiber concrete, the following conditions must be met: compatibility of concrete matrices and fibers; compliance with the required ratio of concrete mortar and fiber; uniform distribution of fiber fibers in the solution. The economic efficiency of the use of fiber-concrete structures, which can be achieved by reducing the complexity of their manufacture, increasing durability and reducing operating costs, was also noted.

Physical and mechanical properties of fiber-reinforced concrete have been studied for a long time and a lot of works are devoted to the study of this problem. In work [2], the results of studies on the physical and mechanical characteristics of fiber concrete are presented. The authors of this work believe that the characteristics of fiber concrete and structures based on it, among other factors, depend on the quantity and quality of steel fiber. The results of experimental studies show that the correctly calculated ratio of the amount of steel fiber in the concrete solution provides high physical and mechanical characteristics of the fiber concrete.

The dependence of the strength characteristics of fiber-reinforced concrete on the properties of dispersed reinforcement fibers (basalt, polypropylene, steel) and reinforcement parameters (volumetric dosage, binder content in the composite) are presented in the results of a comprehensive study [3]. In studies [4], the author proposes a new approach to the optimal reinforcement of fiber-reinforced concrete structures to determine the strength of the material. The influence of the bond between the fiber and the matrix on the tensile strength in bending has been established. The results of the study showed that an increase in the bond between the fiber and the concrete matrix, leading to a decrease in the ultimate strain energy, can cause a decrease in the tensile strength in bending. In other sources, for example, the author of [5] believes that by adjusting the structure of fiber concrete in accordance with the stress-strain state of the structure, it is possible to obtain fiber concrete with specified characteristics, which are determined by the operational requirements imposed on the latter.

The authors of the article [6] considered the study on the influence of various types of fibers on the physical and mechanical properties of centrifuged concrete. It was found that as a result of the introduction of various types of fibers, the indicators of the average density and parameters of the pore structure of concrete change. According to the results of the study, it is concluded that the introduction of fiber leads to a change in part of the volume of capillary pores, which reduces the apparent porosity and average size of the pores, while increasing their uniformity in size.

The use of reinforced concrete with dispersed fibers in the production of reinforced concrete structures, road coatings and cladding elements of buildings simplifies its manufacturing technology and reduces its complexity. As a result of studying the influence of various types of fiber fibers on the physicomechanical properties of centrifuged concrete, it was found that the introduction of various types of fibers changes the average density and the pore structure of concrete. The introduction of fiber leads to a change in part of the volume of capillary pores, which results in a decrease in the apparent porosity and average pore size, while increasing their uniformity in size [7].

One of the disadvantages of concrete products is the fragility of destruction, which occurs as a result of rapid crack propagation after minor plastic deformation. As a rule, crack resistance is numerically characterized by a critical stress intensity factor. Existing methods for the experimental determination of this characteristic contain their advantages and disadvantages. Therefore, a number of works are devoted to the determination of crack resistance of fiber-reinforced concrete. It should be noted that the crack resistance significantly depends on the degree of dispersion of the reinforcement, due to the size of the diameter of the fibers used. The authors of [8] developed a device that allowed us to determine the strength and energy characteristics of the crack resistance of fiber concrete, as well as to determine the degree of influence of fiber consumption on these characteristics and the tensile strength during bending. With the help of the developed device, it is possible to conduct research on the characteristics and properties of fiber concrete with other types of fibers to obtain reliable statistical data.

In work [9], the influence of the shape of thin plates of amorphous metal fibers on the mechanical properties of composites compared to fiber-reinforced concrete from steel fibers with hook ends was considered. It was found that amorphous metal fiber-reinforced concrete loses a significant part of its fluidity as a result of mixing in comparison with reinforced concrete with a hook end. The impact strength of a composite with an amorphous metal fiber proved to be more effective in resisting cracking than reinforced concrete with a hook end. Therefore, amorphous metal fiber is suitable for use in fiber-reinforced cement composite materials and structures, for structural materials and for protective panels.

Dynamic strength is an important criterion for evaluation of fiber-reinforced concrete, for use at variable loads. This characteristic is especially important for structures of protective structures, bridges, runways, pile supports, and so on. In work [10], the dynamic strength of fiber concrete was investigated, and factors affecting the microstructure of concrete and, as a result, its physical and mechanical properties were identified. An empirical formula is proposed that gives adequate results for calculating the coefficient of dynamic strengthening of fiber-reinforced concrete. The conditions and factors determining the positive effect of fiber-reinforced concrete matrix both at the stage of structure formation and at the loading stage are identified.

The analysis shows that almost all studies on fiber-reinforced concrete are devoted to building structures. The analysis of modern scientific achievements in the field of manufacturing machine-building parts from non-metallic materials is considered in [11]. The author of this work conducted a patent and literature review, where the use of composite materials reinforced with carbon fibers, depending on the type of matrix, is divided into reinforced plastics and reinforced metals. The materials introduced in the work cover the details of gears.

Based on the research, the authors of [12] have developed modern composite materials that can effectively replace steel parts in mechanical engineering. The composite material is prepared by joint grinding of cement (55 %), ash (40 %) and limestone (5 %). However, there is no data on the physical and mechanical characteristics of the proposed material.

The current trend is the combination of metal and composite parts of machine parts. Therefore, studies on the influence of various factors on the physical and mechanical characteristics of fiber concrete in relation to machine-building products, especially to pump body parts, are relevant.

Fiber concrete is one of the varieties of polymer concrete. Polymer concrete is a new effective chemically resistant materials in which the degree of filling with mineral fillers and aggregates reaches 90–95 % of the total mass. These new materials are unrivaled in comparison with other filled polymer compositions in terms of binder consumption, which is only 5–10 % of the total mass of polymer concrete. Naturally, the cost of such material is kept to a minimum.

The main properties of polymer concrete are determined by the chemical nature of the synthetic resin, the type and content of the fine fraction of fillers. Large fractions of aggregates, performing mainly the role of the skeleton, affect the physical and mechanical characteristics of polymer concrete-strength, viscosity, workability to a lesser extent.

High mechanical strength and wear resistance is characteristic of a variety of polymer concrete-fiber concrete, when special fibers are added to the polymer concrete mixture, which play the role of a reinforcing element.

The use of fiber allows increasing the resistance of the new composite material to deformation. During the curing of the fiber-reinforced concrete mixture, the probability of cracking is very small. If the cracks, nevertheless, appeared as a result of the shrinkage of the mixture, the fiber helps to connect their edges, which reduces the likelihood of fault zones.

Chaotic arrangement of fiber in the volume of fiber concrete has its advantages. In this case, when changing the direction of the acting forces, they will be perceived equally in the product.

The above allows us to highlight the main advantages of fiber concrete: high strength; low mass per unit volume; high impact resistance; elasticity; sufficiently high plasticity; chemical resistance; no reaction to temperature and humidity; fast solidification (curing of the mixture); dense and smooth surface of the product.

Thus, we can draw a conclusion about the prospects of using fiber concrete in mechanical engineering, in particular for the manufacture of centrifugal pump housings.

Purpose. The aim of the study is to establish the laws of the influence of the main factors on the physicomechanical characteristics of fiber concrete which can be used for the manufacture of pump body parts.

To achieve this goal, the following tasks were set:

- to prove the technical feasibility and economic feasibility of using fiber-reinforced concrete for the manufacture of centrifugal pump housings;
- to select rational starting materials for the preparation of fiber-reinforced concrete mix with specified physical and mechanical characteristics;
- to determine the factors that most affect the mechanical characteristics of fiber-reinforced concrete;
- to develop the composition and technology for the preparation of fiber-reinforced concrete mix for the manufacture of pump housings;
- to determine the influence of the main factors on the strength characteristics of fiber-reinforced concrete.

Methods. The methodology for conducting research on the influence of the main factors on the physical and mechanical characteristics of fiber-reinforced concrete.

The casing (cochlea) of a centrifugal pump experiences various loads from the effects of fluid flow or pumped pulp. This flow coming out of the impeller interacts with the casing; in this case, shock loads occur, friction forces arise, and a significant pressure of the fluid flow is 5–15 MPa on the casing. In addition, when working in an area close to cavitation, vibration of the housing may also occur. Therefore, the material – fiber-reinforced concrete, from which it is proposed to manufacture centrifugal pump housings, is subject to quite serious requirements for strength, rigidity and abrasion.

Taking into account the novelty of the issue under study, a comprehensive research method was used, including theoretical studies on the rational structure of the fiber-concrete mixture, laboratory experiments to establish a rational technology for its preparation, including the selection of components (filler, aggregate, fiber, binder and hardener), design work on the production of matrices for casting the casing of a centrifugal pump, and, finally, bench tests of a prototype pump with a body made of fiber concrete.

As a result of theoretical studies, it was found that the most rational is the fiber-reinforced concrete mixture with intermittent granulometry of the filler and aggregate. In this case, the voids in large fractions are filled with smaller particles, which allows one to get a mixture with a high density and provide higher strength of products made of fiber concrete in the future.

When choosing materials for the preparation of fiber-reinforced concrete, we analyzed a number of materials that are economically viable, due to their low cost, while their physical and mechanical characteristics can provide the specified characteristics of products made of them. Rubble, granite rubble (red and gray granite), quartz sand as a fine aggregate, quartz flour and chalk were studied as a large aggregate. As a binder, the epoxy resin ED MN-20 was selected.

The analysis showed that the best mixture is prepared on crushed granite and quartz sand. Crushed stone and sand do not absorb the resin and it is spent only on enveloping their particles. This allows one to get more strength products from fiber concrete.

Theoretical studies and calculations established that it is most efficient to use a three-fraction mixture in which the coarse and fine aggregate, as well as the filler, differ in size from each other by an order of magnitude. This allows us to propose a method for choosing the size of the filler and aggregate.

The choice of the size of the fraction should begin with the largest one. The upper limit of the grain size is governed by the thickness of the product. For the best filling of forms and casting of the product, the size of the largest granules should not exceed 1/3 of the wall thickness of the product – in our case, the thickness of the casing of the centrifugal pump. For example, if the thickness of the pump casing is 10 mm, the maximum fraction of coarse aggregate should not exceed 3 mm. However, pouring practice has shown that such large granules give large and not always desirable shagreen on the surface of the gel coated product. Studies have also shown that when coated with a normal gelcoat layer of 0.5 mm in size, granules up to 1.2 mm in size do not give strong shagreen. Thus, the recommended largest fraction of aggregate should be 1.0–1.2 mm. The next fraction of the filler for the most complete filling of voids in the coarse fraction should be 0.1–0.2 mm, and the smallest – filler – 0–0.02 mm. Such a mixture will be optimal and most economical.

Based on these data, the basic composition of the fiber concrete mix was selected: granite crushed stone – 50 %, quartz sand – 25 %, quartz flour – 11 %, steel fiber – 2 %, resin – 10 %, hardener – 2 %.

To conduct experimental studies, a number of influencing factors were analyzed and the degree of their influence on the final result was evaluated, which was taken as the most objective indicator of the strength of fiber concrete.

The selection of optimization factors and parameters is a very important step in preparing an experiment. When solving the optimization problem, the Box-Wilson method gives good results. In our research, quite a lot of factors affect the mechanical characteristics of fiber concrete. Therefore, the most significant factors were identified in the research process. This allowed us to plan a rational number of experiments to achieve the optimal area in the shortest possible way.

The analysis shows that the speed and mixing time, as well as the amount of fiber, should be considered the greatest influencing factors on the strength characteristics when preparing fiber concrete.

In order to minimize the number of experiments, a step was selected for each factor.

It was taken into account that small steps may not allow one to fix the change in the optimization parameter and lengthen the search, and the upper limit of the step is limited by the area of determining the factor. Movement was carried out from the center of the experiment (the main level) to the periphery (upper and lower levels).

Based on the above, a matrix of experiments was compiled, shown in Table 1.

Based on this matrix, the tested formulations presented in Table 2 were developed.

When conducting experimental studies, the main evaluation criterion for the quality of fiber concrete was the strength

Table 1

The matrix of experiments by the method of steep climbing

Indicators	Factor		
	f_1	f_2	f_3
Basic level	40	500	100(10)
The range of variation in	20	100	50(5)
High level	60	600	150(15)
Lower level	20	400	50(5)
Experience: 1	+	+	+
2	+	–	+
3	–	+	+

Note: f_1 – the influencing factor is the mixing time of the components, min; f_2 – the influencing factor is the speed mode of the mixer, min^{-1}; f_3 – the influencing factor is the amount of fiber, g (%)

Table 2

The compositions of the tested mixtures of fiber-reinforced concrete

Consumption of all components, the parameter	Experiences				
	1	2	3	4	5
Granite crushed stone, %	50	50	50	50	50
Quartz sand, %	25	25	25	25	25
Quartz flour, %	11	11	11	11	11
Steel fiber, %	2	3	4	5	6
Resin, %	10	10	10	10	10
Hardener, %	2	2	2	2	2
The frequency of rotation of the working body, Rev/min	200 400 600 800 1000	200 400 600 800 1000	200 400 600 800 1000	200 400 600 800 1000	200 400 600 800 1000
Mixing time, min	2 3 4 5 7	2 3 4 5 7	2 3 4 5 7	2 3 4 5 7	2 3 4 5 7

of the hardened material for compression and bending. The experiments were conducted using the following method. To determine the strength characteristics of the tested compositions, samples-beams size 40 × 40 × 160 mm were made in accordance with the requirements of "GOST 10180-2012 Concrete. Methods for determining the strength of control samples". From the prepared composition of the fiber-concrete mixture, three samples were prepared by filling a mixture of special metal forms.

After complete solidification, the samples were removed from the molds, subjected to external inspection and tested for strength by crushing on a hydraulic press PGM-50MG4 in compliance with the requirements of GOST. Initially, the beam samples were tested for bending when the load increased at a speed of (0.15±0.05) MPa/s.

The ultimate bending strength was calculated using the formula

$$\sigma_{bend} = \frac{M_{bend}}{\frac{c \cdot h^2}{6}} = \frac{P_{bend} \cdot l/2}{\frac{c \cdot h^2}{6}}, \qquad (1)$$

where σ bend is tensile strength in bending, Pa; c is width of the sample at the break point, m; h is height of the sample at the break point, m; P bend is bending load in the middle part of the sample, H; l is the distance between supports when placing the sample on the press, m.

The 6 halves of the rolls obtained after the bending test were immediately subjected to a compression test at an average load growth rate of (2 ± 0.5) MPa/s. The compressive strength was determined by the formula

$$\sigma_{bend} = \frac{P_{bend}}{S_{bend.}}, \qquad (2)$$

where P_{bend} is breaking load, Pa; S is the area of the sample affected by the load, m^2.

In accordance with GOST 10180-2012, the final determination of strength took into account the data of two samples with higher strength and determined its average value.

After the experiments, statistical processing of the research results was performed, which allowed us to obtain regularities of the influence of the studied factors on the strength characteristics of polymer concrete.

Experimental studies and their results. The conducted research has established the rational composition of fiber concrete, consisting of granite rubble, quartz sand, quartz flour with the addition of steel fiber. Epoxy resin is used as a binder. These components make it possible to obtain fiber concrete that fully meets the requirements for the material for the manufacture of centrifugal pump housings. These components make it possible to obtain fiber concrete that fully meets the material requirements for the manufacture of centrifugal pump housings.

Influence of steel fiber content on the strength of fiber concrete. The introduction of reinforcement into the mix significantly increases the physical and mechanical properties of fiber concrete. The analysis of characteristics and cost indicators allowed us to recommend steel fiber for the study of fiber concrete from the point of view of its application for the manufacture of centrifugal pump housings. It can be wave or anchor and is represented as straight or wave wire pieces with curved ends 10–50 mm long. The preliminary tests with steel wire, steel anchor and fiber-glass fiber allowed us to recommend steel fiber of the anchor type for further research, since fiber concrete samples from it showed the best strength results.

Steel fiber (Fig. 1) is a reinforcing element that improves the strength and other technical characteristics of fiber concrete. It improves its resistance to mechanical influences; its fibers have good adhesion, so they form a homogeneous mixture. Steel fiber filaments eliminate the occurrence of cracks, peeling of the surface or the occurrence of plastic deformations.

The experiments used steel fiber with the following characteristics: fiber length – 23.0 mm, diameter – 0.6 mm.

The fiber content in fiber concrete should be within certain limits, providing the specified characteristics of the products. The volume fraction of the fiber in the product should be large enough to ensure that the share of the load perceived by it is as

Fig. 1. Steel fiber

large as possible. However, if the fiber content in the material exceeds a certain level, this leads to deterioration in the properties of fiber concrete due to the fact that the mixture is not able to permeate all the fibers. As a result, the adhesion of fibers to the mixture deteriorates and voids may form in the product, reducing the strength of the material.

Special studies were conducted to determine the optimal content of fiber in the fiber concrete. Their results are shown in Table 3, and after statistical processing are presented graphically in Fig. 2.

The influence of the rotation speed of the working body of the mixer on the strength of fiber concrete. The new composite material – fiber concrete – will be competitive in comparison with metals if its physical and mechanical characteristics are stable and it will not have weakened zones. This can only be obtained if all the components are evenly distributed in the volume of the mixture during its preparation.

The components of the fiber-reinforced concrete mixture have different characteristics; therefore, to obtain a homogeneous mixture, a sufficiently high frequency of rotation of the working body of the mixer is necessary for uniform distribution of components in the entire mixture volume.

Only in this case, fiber concrete will have isotropic properties after hardening, which is very important when operating pump housings. Obtaining a uniform distribution of all components in the volume of fiber-reinforced concrete mixture is possible at a certain frequency of rotation of the working body of the mixer. However, keep in mind that an excessively high speed will lead to excessive drive power and increased power consumption.

The experiments made it possible to determine the rational rotation frequency of the working body of the mixer.

These data are shown in Table 4 and in Fig. 3 after statistical processing of experimental results.

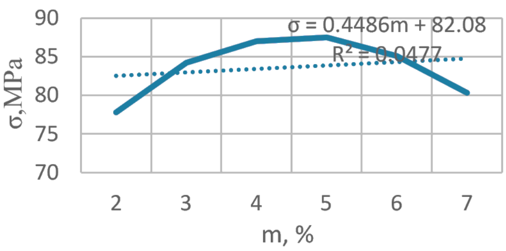
Influence of mixing time of components on the strength of fiber concrete. Another important parameter that ensures the uniform distribution of all components in the volume of the mixture and their uniform enveloping of the binder, which provides high strength characteristics of the fiber concrete is the duration of mixing of the components.

This parameter is important in terms of energy costs and, as a result, the cost of preparing the mixture. The results of experiments to optimize this parameter are shown in Table 5 and Fig. 4. The analysis of the presented schedule allows us to recommend a rational mixing time of the components tmin $\sigma = f(t)$

Table 3

Dependence of the strength of fiber concrete on the consumption of fiber

The fiber consumption m,	2	3	4	5	6	7
Strength σ, MPa	77.8	84.2	87	87.5	85.1	80.3



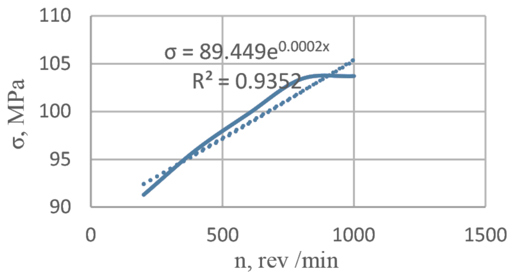
$\sigma = f(m)$

Fig. 2. Influence of fiber consumption on the strength of fiber concrete

Table 4

Dependence of the strength of fiber concrete on the speed of rotation of the working body of the mixer

Frequency of rotation of the working body. *n*, turnover/min	200	400	600	800	1000
Strength; σ, MPa	91.3	96.0	99.8	103.4	103.7



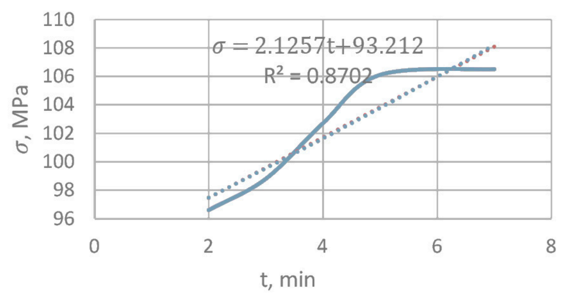
$\sigma = f(n)$

Fig. 3. Influence of the speed of rotation of the working body of the mixer on the strength of fiber concrete

Table 5

Dependence of the strength of fiber concrete on the mixing time of components

Mixing time, *t*, min	2	3	4	5	7
Strength, σ, MPa	96.6	98.8	102.7	106.1	106.5



$\sigma = f(t)$

Fig. 4. Effect of component mixing time on the strength of fiber concrete

Conclusions. Studies have shown that with an increase in the amount of steel fiber to a certain ratio, the strength of fiber concrete increases proportionally. The optimum is 4.5–5 % steel fiber of the total weight of the mixture. Further addition of fiber to the mixture makes it difficult to obtain a homogeneous mixture with a uniform distribution of fibers and constituent components in its volume, which negatively affects the strength characteristics of fiber concrete. It should also be noted that the addition of a reinforcing element to the fiber-reinforced concrete mixture helps to improve the conditions of structure formation. This ratio is confirmed by the results of determining the strength characteristics of fiber-reinforced concrete.

Analysis of the results of studies on the influence of other factors on the strength of fiber concrete has shown that the optimal mixing time of the components of the mixture on its strength is 5–6 minutes at a speed of rotation of the working body 800–1000 turnover/min.

Finished products made of fiber concrete must be dried for the final strength gain. Studies have shown that the drying temperature significantly affects the dynamics of strength gain.

Fig. 5. Ready-made housing

However, it should be noted that excessive drying temperature does not lead to a significant increase in strength. The drying temperature should be 90–100 °C.

According to the results of experiments, it was found that the following composition of fiber concrete is the most rational (by volume): granite crushed stone 50–52 %, quartz sand 25–26 %, quartz flour 11 %, steel fiber of anchor type 3–4 %, epoxy resin 10–11 %, hardener 2 %. Such a composition of fiber-reinforced concrete has a density of 2200–2300 kg/m^3, compressive strength of 230–240 MPa, bending 80–100 MPa.

The final stage of the research was the manufacture of the casing (cochlea) of a single-stage centrifugal pump from fiber concrete of the selected composition. Special equipment was developed for casting 2 snail halves. After casting them, they were glued together with epoxy glue thickened with andesite flour. The glued body was covered with gelcoat in two layers. A-prototype of the pump housing made of fiber concrete is shown in Fig. 5.

The tests carried out confirmed the technological capacity and feasibility of manufacturing centrifugal pump housings from fiber-reinforced concrete. They are much stronger than cases made of metal, which makes it possible to reduce the wall thickness of the case by 1.5 times, and, consequently, the mass of the case itself.

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Обґрунтування раціональних параметрів виготовлення корпусів насосів із фібробетону

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Мета. Встановлення закономірностей впливу основних факторів на фізико-механічні характеристики фібробетона, що доцільно використовувати для виготовлення корпусів насосів, які працюють у несприятливих умовах.

Методика. У роботі використано теоретичний аналіз застосування фібробетону в різних галузях промисловості, аналіз факторів, що впливають на міцність фібробетону, проведені лабораторні експерименти з метою підтвердження теоретичних результатів і встановлення закономірностей, що дозволяють рекомендувати раціональні параметри виготовлення корпусів насосів із фібробетону.

Результати. У роботі зроблена спроба запропонувати технологічні рішення із використання фібробетону в новій області – машинобудуванні при виготовленні корпусів насосів, що працюють у гірничо-металургійній галузі в несприятливих умовах: перекачування агресивних рідин, пульп із високою абразивністю, високою температурою навколишнього середовища, запиленістю й т.і. Отримані результати дозволяють розробити технологію виливки корпусів відцентрових насосів без їх додаткової механічної обробки з високими фізико-механічними характеристиками, й рекомендувати раціональний склад фібробетонної суміші, що задовольняє вимогам до корпусів відцентрових насосів за умовами міцності, технологічності та економічності.

Наукова новизна. Експериментально встановлені закономірності впливу на міцність фібробетону оптимального вмісту сталевої фібри у складі суміші, раціональні режими змішування компонентів: частота обертання робочого органу змішувача та час перемішування компонентів. Отримані закономірності підтверджують теоре-

тичні дослідження й забезпечують отримання фібробетонної суміші з рівномірним розподілом усіх компонентів у її об'ємі та ізотропні характеристики затверділого фібробетону.

Практична значимість. Отримані в роботі результати, представлені у вигляді графіків і розрахункових формул, дозволяють обґрунтовано проектувати склад фібробетонної суміші й розробляти технологію виготовлення з неї корпусів відцентрових насосів способом виливки без додаткової механічної обробки. При цьому фібробетон має щільність 2200–2300 кг/м^3 проти 7500–7800 кг/м^3 корпусів з металу, міцність на стиск 230–240 МПа, на вигин 80–100 МПа, що дозволяє знизити товщину стінки корпусу насоса на 15–20 %.

Ключові слова: *насоси, фібробетон, гранітний щебінь, кварцовий пісок, кварцове борошно, фібра сталева*

Обоснование рациональных параметров изготовления корпусов насосов из фибробетона

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Цель. Установление закономерностей влияния основных факторов на физико-механические характеристики фибробетона, который целесообразно использовать для изготовления корпусов насосов, работающих в неблагоприятных условиях.

Методика. В работе использован теоретический анализ применения фибробетона в различных отраслях промышленности, анализ факторов, влияющих на прочность фибробетона, проведены лабораторные эксперименты с целью подтверждения теоретических результатов и установления закономерностей, позволяющих рекомендовать рациональные параметры изготовления корпусов насосов из фибробетона.

Результаты. В работе сделана попытка предложить технологические решения по использованию фибробетона в новой области – машиностроении при изготовлении корпусов насосов, работающих в горно-металлургической отрасли в неблагоприятных условиях: перекачка агрессивных жидкостей, пульп с высокой абразивностью, высокой температурой окружающей среды, запыленностью и т. д. Полученные результаты позволяют разработать технологию отливки корпусов центробежных насосов без их дополнительной механической обработки с высокими физико-механическими характеристиками, и рекомендовать рациональный состав фибробетонной смеси, удовлетворяющий требованиям к корпусам центробежных насосов по условиям прочности, технологичности и экономичности.

Научная новизна. Экспериментально установлены закономерности влияния на прочность фибробетона оптимального содержания стальной фибры в составе смеси, рациональные режимы смешивания компонентов: частота вращения рабочего органа смесителя и время перемешивания компонентов. Полученные закономерности подтверждают теоретические исследования и обеспечивают получение фибробетонной смеси с равномерным распределением всех компонентов в ее объеме и изотропные характеристики затвердевшего фибробетона.

Практическая значимость. Полученные в работе результаты, представленные в виде графиков и расчетных формул, позволяют обоснованно проектировать состав фибробетонной смеси и разрабатывать технологию изготовления из нее корпусов центробежных насосов способом отливки без дополнительной механической обработки. При этом фибробетон имеет плотность 2200–2300 кг/м^3 против 7500–7800 кг/м^3 корпусов из металла, прочность на сжатие 230–240 МПа, на изгиб 80–100 МПа, что позволяет снизить толщину стенки корпуса насоса на 15–20 %.

Ключевые слова: *насосы, фибробетон, гранитный щебень, кварцевый песок, кварцевая мука, фибра стальная*

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