Physical and Thermal Characteristics of Samples of Basalt, Thermal Insulation, Lining Materials

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ABSTRACT

The purpose of these studies is to determine the main regularities and optimal parameters of the processes of dry processing of mineral raw materials for the production of products for various purposes, to develop technologies for dry processing of kaolin, chamotte and basalt, to improve the design of low-power metal melting furnaces.

The results of the research are of theoretical interest and are of a purely practical nature. On their basis, it is planned to develop designs of low-power metal-melting furnaces for a new class with reduced energy consumption (gas and electricity) of technological costs.

KEYWORDS: *basalt, resource, material, rocks, mineralogical composition, degree of hardness, chemical properties, stratifications, raw material reserve, mineral, construction, structural feature, liquid basalt, quality, research, melting, furnace, casting, mold, flask, laboratory installation.*

1.1 Introduce the Problem

In the modern industry, production products such as lining heat-insulating bricks (FTC) are in great demand from manufacturers of refractory materials. This is due to the high cost of existing lining materials-especially imported ones and the lack of technology for the production of such bricks from local raw materials.

Because domestic entrepreneurs today do not need more bulk metal-melting furnaces. They tend to use low-power metal-melting furnaces. Since it is very expensive for small enterprises to process ore and plan to get hundreds of tons of liquid metals.

Obviously, this leads to excessive costs of fuel and energy resources and creates the ground for the production of low-quality products. Table 1. presents the physical and mechanical characteristics, the classic and proposed compositions of materials, as well as information about the technological costs of the FTC.

Based on the above, this article discusses the solution of issues related to the raw material problem, with new currency - saving sources of raw materials, especially local ones, contributing to the creation of stable at high temperatures, having good porosity, convenient for processing raw materials and increasing the activity of interaction of the components of the mixture, provided that the sintering temperature of the composite decreases.

In addition, the article presents the results of physical and thermal studies of the proposed mineral raw materials, which are well recommended in their laboratory tests.

1.2 Explore Importance of the Problem

In accordance with the requirements of GOST 31359-2007, the thermal stability of a material is evaluated by the heat transmittance indicators per unit of time. According to GOST 31359-2007 thermal conductivity — the ability of material bodies to conduct energy from the more heated parts of the body to the less heated parts of the body by the chaotic movement of body particles. Such heat transfer can occur in any bodies with an inhomogeneous temperature distribution, but the mechanism of heat transfer will depend on the aggregate state of the substance.

In other technical sources or sources of the physics course, thermal conductivity is also called a quantitative characteristic of the body's ability to conduct heat. This characteristic is equal to the amount of heat passing through a homogeneous material sample of unit length and unit area per unit time at a unit temperature difference (1 K). Currently, in the International System of Units (SI), the unit of measurement for the thermal conductivity coefficient is Vt/(m·K). [1-4.].

Sources report that the transfer of thermal energy is associated with the flow of hypothetical calorific heat from one body to another. However, with the development of the molecular-kinetic theory, the phenomenon of thermal conductivity was explained on the basis of the interaction of matter particles. The materials ' constituent molecules in the warmer parts of the body move faster and transfer energy through collisions to the slower particles in the colder parts of the body. The thermal conductivity of basalt is 3÷5 Vt/(m·K). [5-7].

Product name	Samples	Characteristics of lining bricks			
		Permissible temperature	Average density, **Kg/m2**	Coefficient of thermal conductivity Vt/ (m·K).	**Color**
Fireclayliningbrickv.	№1	1350÷1400	2,53	0,5	brown
Redbrick	№2	1500÷1550	3,0	0,7	Grey
Clinker bricks	№3	1450÷1500	2,3	0,07	white
Basaltliningbrick	№4	1200÷1400	1,8	0,21	Burnt brown.

In practice, it is often observed with an increase in temperature, a decrease in the coefficient of thermal conductivity, for example, of a liquid, which decreases. But the value of thermal conductivity for water, aqueous solutions, and other substances increases with increasing temperature, not decreases. The influence of temperature is small, and simple liquids are more sensitive to temperature than complex ones.

According to the Fourier law, the thermal conductivity is closely related to the heat transfer coefficient. When analyzing and determining the thermal balance of operating equipment, estimating heat loss, and solving many other heat transfer problems, it is often necessary to determine the heat flow passing through a solid wall separating liquids or gases at different temperatures, which in the simplest case is calculated by the formula:

q = K× (Tf1 – Tf2); K heat transfer coefficient; Tf1, Tf2 – temperature of liquid or gas between which heat exchange takes place.

Materials and methods

In our case, not only the thermal conductivity of the FTM is of great practical importance, but also its thermal insulation capacity, the indicators of which, when lining the inner wall of the melting furnace, play an important technological solution protecting the wall from heat loss. According to the reference data, the thermal conductivity coefficient of basalts is equal to 1.8 Vt / mK, in this case, such an FTM indicator wakes up equal to 3.12 Vt / mK [8].

In this dissertation work, a basalt base is recommended as a FTK, consisting of a combination of materials, "basalt + kaolin + chamotte". The choice of the composition of the composite in this ratio is substantiated by the studied data and the analysis of materials from literary sources.

It has been established that the heat-insulating materials of the "Gavasai" and "Akhangaran" rocks have a thermal conductivity 2.74 times lower than that of glass wool and 4.35 times lower than that of asbestos wool; the basalts of these deposits melt easily. The material of the "Aydarkul" and "Asmansay" rock has a thermal conductivity on average 3.78 times lower than that of glass wool and 5.98 times lower than that of asbestos wool. The study shows that the basalts of Uzbekistan with such a composition are suitable for the manufacture of various competitive products. [1].

The choice of the ratio of kaolin and chamotte minerals is explained as follows. Kaolin - the use of kaolin in the composition has a positive effect on the distribution of grain dispersion and plays an important role in restructuring the composition of the mixture in further processing. Kaolin has a high refractoriness, low ductility and binding capacity. Natural kaolin is limitedly used for the production of chamotte, semi-acidic refractory bricks, building ceramics, and white cement. At one time, chamotte is a type of refractory clay, which is fired to a complete loss of plasticity, with a certain degree of sintering. During firing, the working composition is obtained by firing in a special rotary kiln at a temperature of 1300-1500 ° C. First, it is crushed in special mills to get ground chamotte, and then the rest of the mass is introduced. Broken refractory bricks with the same chemical composition are also used, which must be cleaned of mortar and have a low content of impurities, no more than 10%.

Chamotte refers to aluminosilicate refractories containing, in addition to SiO2, up to 45% Al2O3. It has a higher thermal stability (10-20 water thermal cycles), but low slag resistance. It is most widely used in rebuilding at temperatures up to 1350 ° C for the construction of walls, arches that are not in contact with metal oxides, for the low-temperature part of the regenerative packing. Does not withstand abrasion at high temperatures.

The grain size composition of the material has a huge impact on heat resistance, gas permeability, strength, slag resistance and porosity of products. The larger the fraction of grains, the more porous the product will be, which means it will be less durable. The chemical composition of chamotte includes the following elements: 42% – Al_2O_3, 0,5% – TiO_2, 0,15% –Na_2O, 1,0% – Fe_2O_3, 0,16% – CaO, 0,7% – K_2O.

The main advantages of fireclay products are heat resistance (up to 1800 ° C), durability, resistance to adverse weather conditions, strength, frost resistance. For example, a brick made of such a material is able to withstand 25-30 freeze-thaw cycles. Unlike gypsum or concrete, fireclay bricks do not fade.

The disadvantages include the fact that with very frequent heating and cooling, the products lose their strength. Also, in the production of fireclay, a large amount of dust is emitted and a special chemical resin is used, which, when fired, harms the environment.

Bulk and density of chamotte can be determined at ambient temperatures. These properties affect the performance of refractory materials when exposed to high temperatures.These are the most important quality indicators for refractory fireclay products. When it is required to reduce the overall weight of the structure or increase thermal insulation, lightweight fire-resistant solid materials are used. They include: lightweight chamotte, pure fatty clays, a mixture of sawdust, peat or other organic substances. In this regard, we made an attempt to develop and study the optimal compositions of heat-insulating masses selected, taking into account the specific properties of specific raw materials and in the interrelation of the dominant factors of each technological redistribution (molding, drying, firing).

On the basis of those presented in Table 2. Comparative characteristics of FTK-bricks are presented. Therefore, basalts of the Aydarkul deposit were chosen as the raw materials under study as the main refractory raw material, the melting temperature of which reaches 1550 ° C, kaolin from the Karnab deposit, which has a positive effect on the grain dispersion distribution, which plays an important role in the restructuring of the mixture composition and creates a strong bond between grains of composite materials, as well as playing the role of a catalyst in creating a heat-shielding material, chamotte is a unique material that creates a high degree of thermal stability (sometimes reaching up to 1800 ° C), durability, and resistance to high temperature environments.

Tab. 2. Comparison of indicators of the characteristics of lining bricks

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Name of products	**Preferredtemperature, ºC**	**FTK weight, kg**	**Coefficient thermal conductivity, Vt/(m^{2}К,**	**Siliconoxidecontent**	**Average density of the product**
Fireclayliningbrick	1400ºC	3,8	0,72	59,02	1,8
Redbrick	800ºC	3,2	0,4	57,3	1,6
Clinkerbrick.	800ºC	4	1,16	51,11	1,3
Basaltliningbrick	1400ºC	4,2	0,7	55÷63	2,53

Thus, the presented physical, thermal and other characteristic indicators of the proposed constituent components of the FTC show the acceptability of their use in the composition of the basalt composite: "basalt + kaolin + chamotte".

Research of materials and components of FTK. The study of materials and components of basalt silicate samples was carried out experimentally in two places:

1) in laboratory conditions of research and development center "STROM" at the Academy of Sciences of the Republic of Uzbekistan;
2) in laboratory conditions "Bekabad Refractory"

- Under laboratory conditions, the Research and Development Center "STROM" at the Academy of Sciences of the Republic of Uzbekistan prepared 4 mixtures of basalts with kaolin and chamotte, 2 mixtures of diabase with kaolin and chamotte and determined their softening temperatures. “They were carried out to determine the refractoriness of mixtures of various compositions of the materials used, for which 4 geological samples of raw materials were delivered.
- According to scientific and technical literature, the melting point of the above samples has the following values, presented in tables 3 and 4.
- Visual, characteristic of the presented raw materials:
- sample of kaolin - compacted pressed, clayey rock of dark gray color, with white blotches;
- a sample of basalt - a rock, a natural compacted raw material of magmatic origin, which is

formed during volcanic eruptions, during which enrichment, melting and homogenization occurs, has a black, smoky, yellow, brown, white dark gray or greenish-black color, etc. ... colors.

- Sample diabase - igneous rock, has black and dark gray colors.

Tab. 3.Name of the submitted samples of raw materials

№1	Fieldname
Sample №1	Kaolin of the Angrenfield.
Sample №2	KaolinofKarnabfield
Sample №3	Kaolin of the "Alyans" field
Sample №4	Basalt of the Aydarkul field
Sample №5	DiabaseKarnabfield

Table 4

№2	Name of the deposit of raw materials	Meltingpoint, ° C
Sample №1	Kaolin of the Angren field	1750-1800°C
Sample №2	KaolinofKarnabfield	1750-1800°C.
Sample №3	Kaolin of the "Alyans" field	1750-1800°C
Sample №4	Basalt of the Aydarkul field	1500-1550°C
Sample №5	DiabaseKarnabfield	1400-1450°C

Melting point of the above sample

The melting points of the samples are given from the literature data *.

Formation of the composition of mixtures and determination of their refractoriness. From finely ground samples of kaolin, basalt and diabase and chamotte, mixtures were formed and masses were prepared with the following ratios of components, which are presented in table. 5.

Test ratios of FTM components

№	Name of the deposit of raw materials	Meltingpoint, ° C
Sample №1	Basalt 60% (Aydarkul) + Kaolin 40% (Angren)	1200-1250°C
Sample №2	Basalt 60% (Aydarkul) + Kaolin 40% (Karnab)	1200-1250°C.
Sample	Basalt 60% (Asmansoy) + Kaolin 40%	1200-1250°C

№3	(Angren)	
Sample №4	Basalt 60% (Asmansoy) + Kaolin 40% (Karnab))	1200-1250°C
Sample №5	Diabase 60% (Karnab) + Kaolin 40% (Angren)	1400-1450°C
Sample №6	Basalt 60% (Karnab) + Kaolin 40% (Karnab) + fireclay	1400-1415°C

Tab. 6. Indicators of thermal insulation displaced masses (indicators of SRI "STROM").

Nameofmixedmasses		Refractoriness
Sample No. 1	Basalt 60% (Aydarkul) + Kaolin 10% (Angren) + fireclay 30%	1350°C.
Sample No. 2	Basalt 50% (Aidarkul) + Kaolin 25% (Carnab) + Fireclay 25%	1380°C
Sample No. 3	Basalt 50% (Aidarkul) + Kaolin 20% (Karnab) + Fireclay 30%	1415°C.

Determination of heat resistance of masses in laboratory conditions by pyrometric method. For this, according to the well-known method of studying the heat resistance of materials by a pyrometric method, pyroscopes - cones were made from the prepared mixtures of FTK components, which were fired in high-temperature electric furnaces with sieve rods.

In this case, the temperature of the fall of the cones made of the test material was recorded. According to the table, masses No. 1,2,3,4 have identical melting points, their refractoriness is characterized by a temperature of 1250 ° C. Masses No. 5 and 6 are characterized by a higher refractory temperature - 1380 ° C and 1415 ° C.

The reliability of the findings was verified empirically in the Central Research Laboratory of the State Enterprise Navoi Mining and Metallurgical Combine and received positive results. For this purpose, in accordance with the "Program and methodology for research and experimental-industrial work to determine the thermal insulation when laying the proposed basalt lining bricks on the inner surface of a low-power metal melting furnace, pilot tests of basalt FTM were carried out in industrial conditions. The experimental results are presented in Tables 4 ÷ 6.

A particularly high temperature holding was recorded at 1415 ° C, where 30% chamotte from the total mass of raw materials was added to the composite. Thus, it was revealed that the presence of chamotte in the composition of the mixture of components contributes to an increase in the holding temperature, up to 1415 ° C, which proves the possibility of using chamotte in the composition of the proposed components of uasalt FTC.

Consequently, in the conclusion of the research and development center "STROM" at the Academy of Sciences of the Republic of Uzbekistan, it was recommended to use a mixture of materials "basalt + kaolin + chamotte" in the form of a lining heat-insulating brick for low-power metal-melting furnaces operating at temperatures up to 1400 ° C.

Figure 1 shows a histogram of the FTC consisting of basalt + kaolin + chamotte with a holding temperature of 1400 ° C.

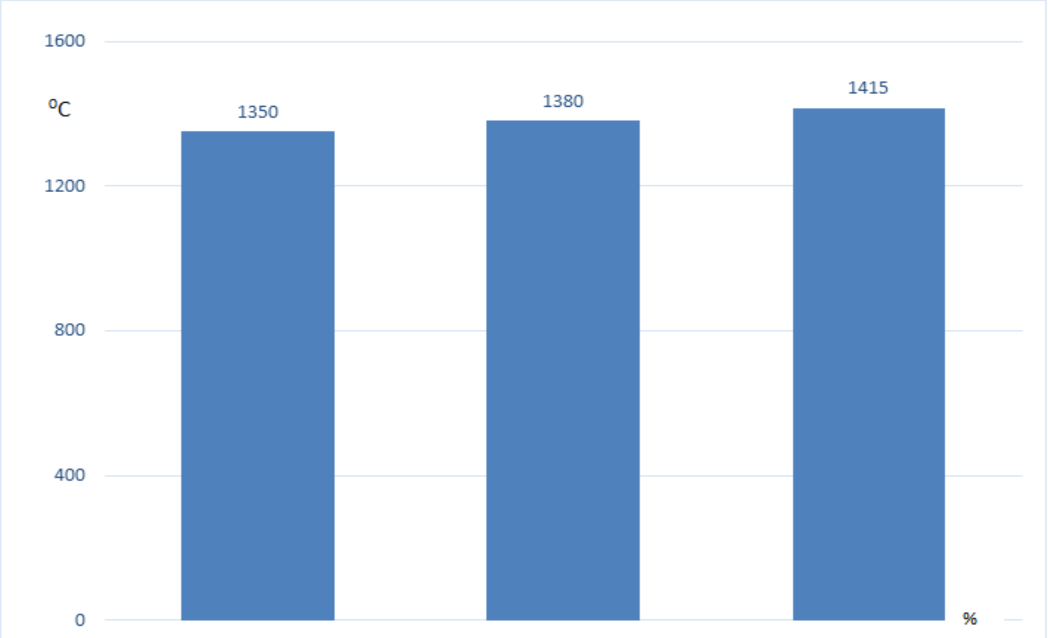
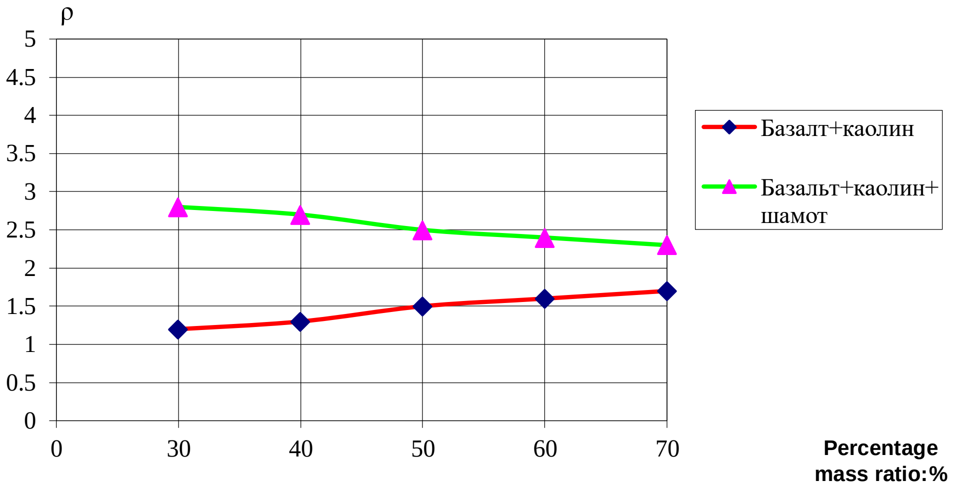


Fig. 1. Thermal insulation indicators of displaced masses: a) Basalt (60%) + kaolin (10%) + chamotte (30%); b) Basalt (50%) + kaolin (25%) + chamotte (25%) and c) Basalt (50%) + kaolin (20%) + chamotte (30%)

In order to give preference to the FTK consisting of basalt + kaolin + chamotte components, it is necessary to study the dependence of the density of the finished product on the percentage ratio of the components of the masses proposed for the FTK. It is known from technical sources that heat resistance depends primarily on the inherent characteristics of the materials.

The histogram shows the effect of the ratio of the masses of the FTM materials on the holding temperatures of the lining material. As a result of the experiments, it was revealed that an increase in the mass of chamotte in the composition of FTC leads to premature destruction, which occurs due to a decrease in the strength of the joint. An increase in the mass of kaolin contributes to a decrease in the holding temperature and the performance of the linking unit.



It is known from technical sources that heat resistance depends primarily on the inherent characteristics of the materials. When it comes to the physical characteristics of materials, pay attention to the density of the constituent material of the object. Therefore, in our case, an important role can be played by the ratio of the masses of the constituent components of the FTM, on which the density of the lining brick and the heat resistance of its material, which determine the holding temperatures, depend.

It should be noted that the successful implementation of the proposed mixture of components and FTC as a whole, it is necessary to ensure the quality of the products, as described in the previous paragraphs of this dissertation. The quality of the proposed mixture of the constituent components of the FTC is determined after the application of the FTC. In this case, two options for the fired product were considered. Figure 2 shows the dependence of the FTC density on the percentage of the constituent masses, which is also related to the percentage of the constituent components.

The figure shows that the minerals used for the manufacture of the proposed FTK: basalt, kaolin and chamotte have different degrees of density and strength. Therefore, by calculation, we determine the loose density of minerals after grinding. This conclusion is justified by the fact that the grinding process of semi-finished products is carried out simultaneously, regardless of the duration of grinding time, as evidenced by the obtained curves. In fact, grinding will continue until we get a fraction of 0.74 mm. The graphs showing the size class in the figure are obtained by separately grinding each mineral.

However, it should be taken into account that the proposed minerals for obtaining FTC have different degrees of hardness. According to the literature data, the density of basalts on the Maus scale is close to 3000 ÷ 5000 kgN / sm3 and the ultimate compressive strength reaches 2900 ÷ 3300 kgN / sm3.

In the first version, the dependence of the density of the constituent masses, "basalt + kaolin", and in the second version, "basal + kaolin + chamotte" were studied. The data presented in Fig. 2 shows that the density of the fired mass, consisting of the components "basalt + kaolin" at a mass ratio (%): 70 + 30 reaches up to 1.7 g / sm3. In turn, the density of the fired mass, consisting of the components "basalt + kaolin + chamotte" at a mass ratio (%): 50 + 20 + 30, reached a value of 2.8 g / sm3. This factor proves that the characteristic characteristics of chamotte, after adding the components "basalt + kaolin" to the mixture, contributed to a change in the physicochemical properties of FTC, improved its technological characteristics and thereby led to an increase in the density value. It was revealed that the percentage of the mass of the FTC equal to 50 ÷ 20 ÷ 30 is the most optimal option for creating a mixture for the manufacture of heat-resistant lining material.

In the environment of the preparatory processes of mineral raw materials for the manufacture of the proposed FTC, the time of grinding the constituent materials can play an important role. Therefore, to clarify the prevailing picture, an experiment was carried out to determine the size class of raw materials in the ratio of the masses used. The experiment was carried out using a ball mill, where crushed minerals were subjected to grinding. For this, 10 kg of each mineral, basalt-kaolin-chamotte, were randomly ground, which were alternately subjected to grinding. The grind in gresultsare shown in Fig. 3.

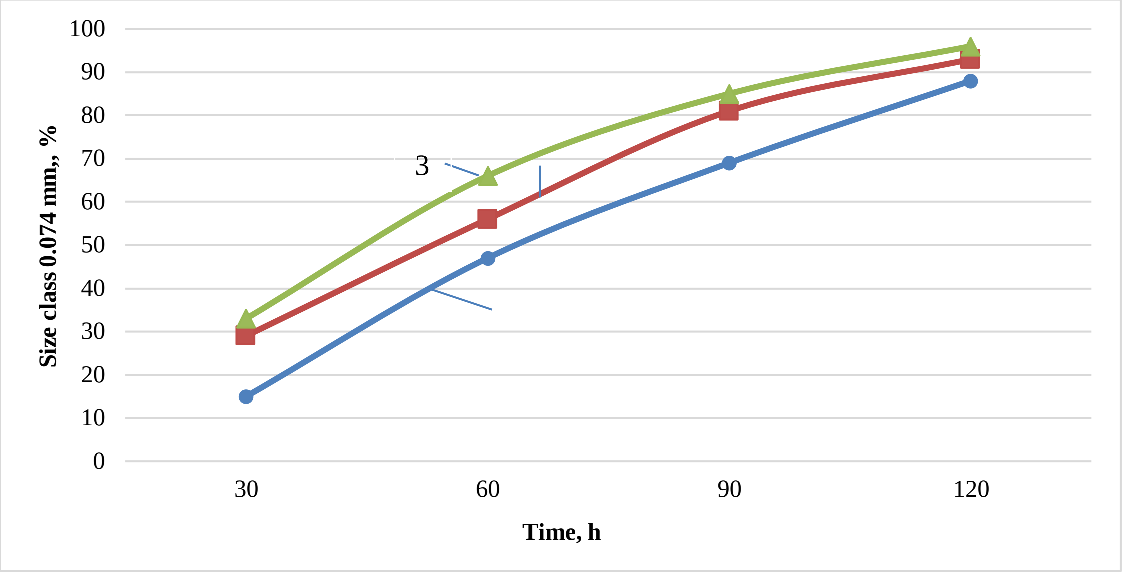


Fig. 3. Dependence size class 0.074 mm grinding of the constituent minerals of basalt FTM: 1-curve of basalt; 2-curve kaolin; 3-curve chamotte mineral.

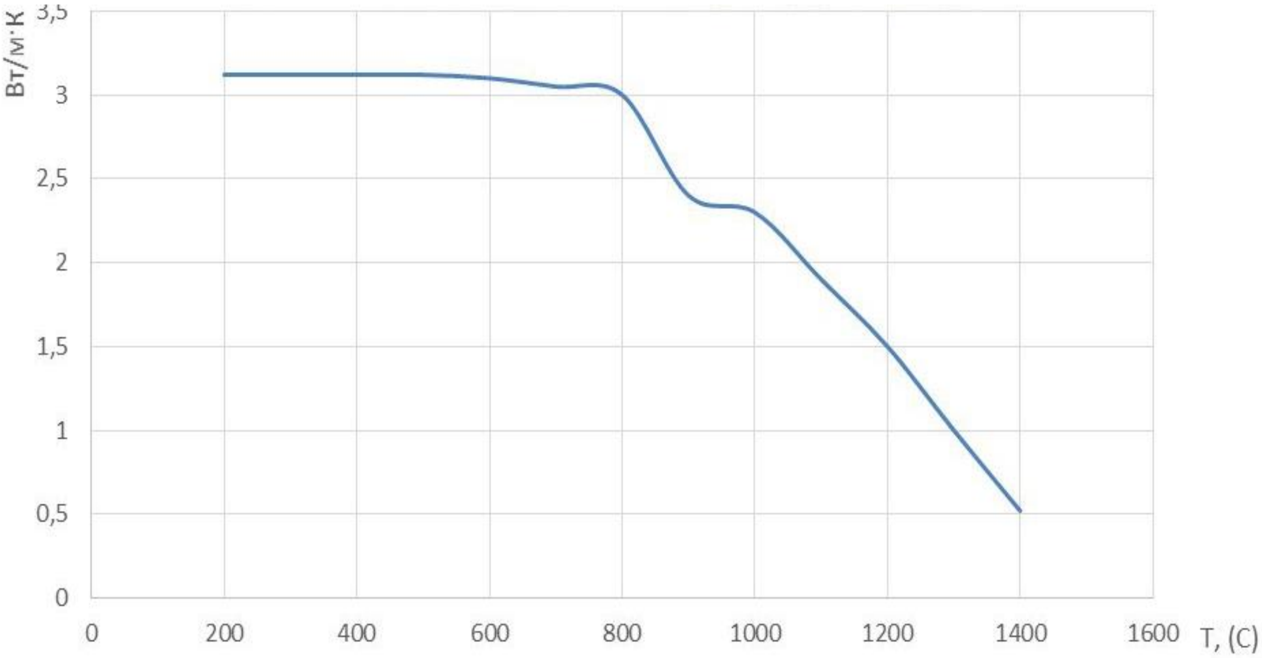
It was found that in order to obtain the required size class after grinding, the raw materials proposed in the thesis, it is necessary to carry out a combined method of grinding minerals.

For experimental-industrial work, heat-insulating brick products made in accordance with GOST 4069-69 (ST SEV 979-78) "Refractories and refractory raw materials" were specially and arbitrarily chosen. Methods for determining thermal insulation (with Amendments N 1, 2). “Interstate standard for refractories and refractory raw materials. Methods for determining refractoriness ".

Refractory bricks materials were made in the laboratory conditions of the Techno-Park NGGI, from the following constituent components. “Basalt + kaolin + chamotte”, in proportions: 50 ÷ 20 ÷ 30, 60 ÷ 20 ÷ 20 and 70 ÷ 10 ÷ 20, the total number of bricks was 50 pcs.

The results of the analysis of these graphs show that the thermal conductivity of any material depends on the inherent and material indicators of raw materials. In this case, the technological characteristics of materials and their density are of great practical and scientific importance. This factor is also inherent in our case. As noted above, the denser the FTK material, the more heat-resistant it is.

a)


Вт/м·K
3,5
3
2,5
2
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1
0,5
0
0
200
400
600
800
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1400
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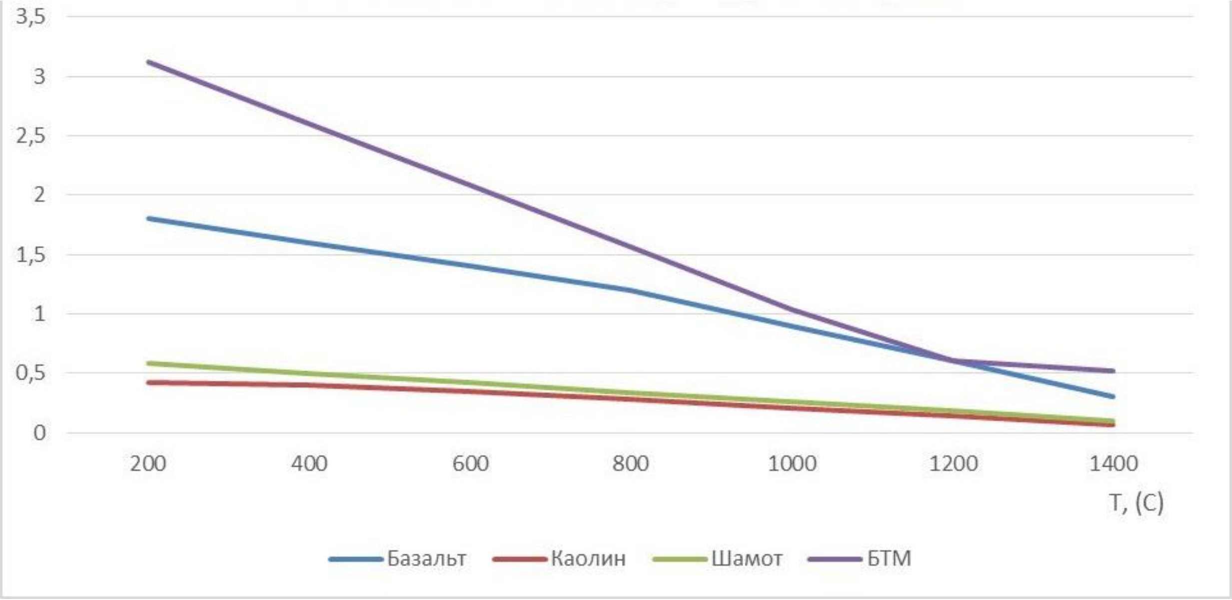
3,5
3
2,5
2
1,5
1
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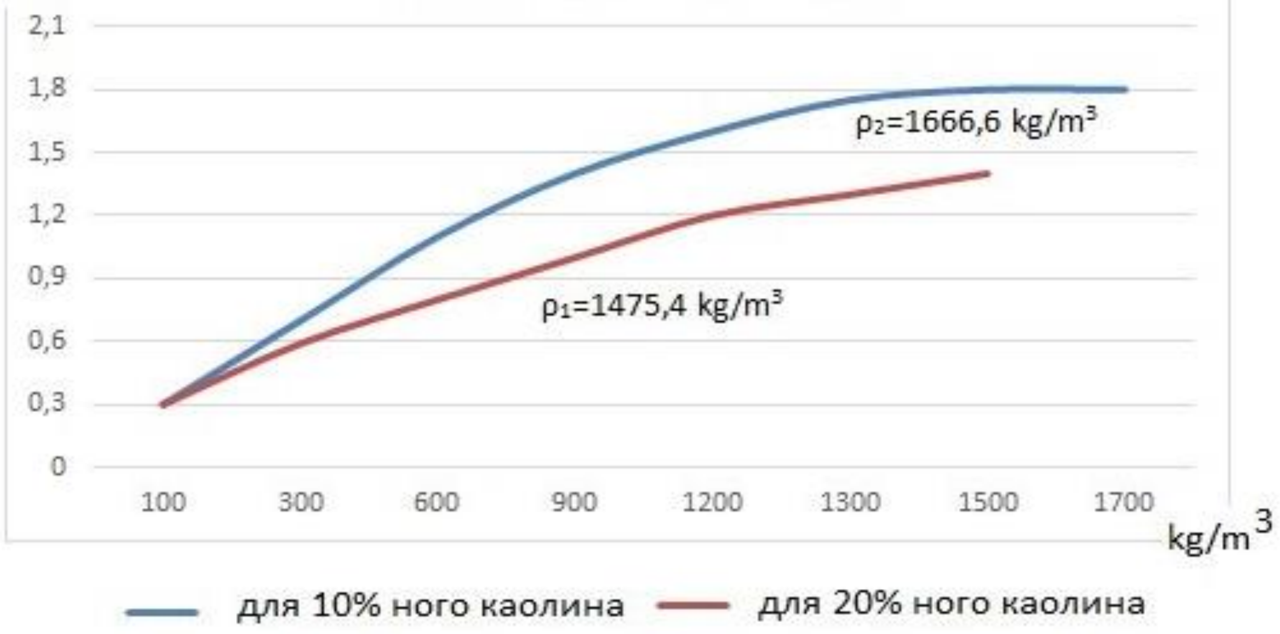

Fig. 4. Graph of dependences of parameters related to thermal conductivity: a) graph of the dependence of the thermal conductivity coefficient of thermally modified FTK on the final heating temperature; b) graph of the dependence of the thermal conductivity coefficient of FTK and raw materials on the final heating temperature and c) dependence of the thermal conductivity of FTK on its average density kg / m3 ...

The dependences presented in all figures show data on thermal conductivity and temperature. In this case, the most important result of the study is the selection of the appropriate components of the new FTC and its optimal composition. The obtained results of the study allow us to contribute to the manufacture of FTC in 1400 ° C temperature regime of raw materials, which showed low thermal conductivity and high heat protection from the outside world.

Based on the research results set out in this work, a mixture of components and the ratio of the mass of FTC are recommended, which ensures: preservation of working capacity (8 months longer than similar lining bricks used in practice), stable stability of the thermal regime, energy savings and a decrease in material costs.

Thus, it was revealed that the presence of chamotte in the composition of basalt FTM contributes to an increase in the heat resistance of bricks to 1415 ° C. This conclusion is confirmed by the results of approbation carried out at the Scientific Research Institute (SR and IC "STROM") at the Academy of Sciences of the Republic of Uzuekistan. It was recommended to use mixtures of components "basalt + kaolin + chamotte" as a material for facing bricks for lining the inner face surface of metal melting furnaces operating with a holding temperature of up to 1400 ° C.

For an effective full-scale comparison of the indicators of basalt heat-insulating bricks in the processes of smelting operations in furnaces with classical heat-insulating materials. New heaters have proven their efficiency and thermal insulation, temperature holding up to the maximum operating temperature of the melting furnace - 1400 ° C with a mass ratio of 50 ÷ 20 ÷ 30. When the ratio of the masses of the components used, "basalt + kaolin + chamotte": 60 ÷ 20 ÷ 20 and 70 ÷ 10 ÷ 20 did not achieve the final positive result. The tests continued until the furnace came to a complete stop.

During the period of using basalt heat-insulating bricks in the processes of metal-melting works in furnaces, new materials, consisting of the ratio of materials "basalt + kaolin + chamotte", differed in environmental friendliness, the absence of cracks, explosive flashes and other similar negative signs. Complete positive indicators of the "basalt + kaolin + chamotte" composite, recommended themselves as a stable heat-insulating material, efficient at a temperature of 1400 ° C, during the operation of the melting furnace.

The results of pilot tests after using basalt thermal insulation products with the composition of the mass ratio: 50 ÷ 20 ÷ 30 showed the absence of solubility of materials and granules of basalt, kaolin and chamotte. There was no distortion of the shape of bricks, a change in their surface color, a change in the standard dimensions of bricks with full compliance with standard quality indicators. According to the results of pilot tests, the dependences of thermal conductivity on temperature were constructed, which are presented in Figures 3: a, b and c. Conclusion

In general, the use of the proposed heat-insulating material, made on the basis of local basalts, kaolin and chamotte, instead of classic bricks, ensured the preservation of quality indicators, performance and improvement of technological parameters. As a result of using as a mixture of components of mixed masses consisting of mineral raw materials, it was found:

- FTM manufactured on the basis of local basalts, kaolin and chamotte can successfully compete with classical heat-insulating materials;
- lining heat-insulating bricks made from local minerals retained the full working capacity of the basalt insulation, according to preliminary forecasts, they extended their service life from 1.8 to 2.5 years;

Thus, the acceptability of the use of local basalts, kaolin and chamotte cleaned from slimes for the manufacture of lining heat-insulating bricks has been proved.

The samples, which were well recommended by the FTC, underwent laboratory testing under laboratory conditions "Bekabad Ogneupor". Based on the results of the laboratory test, a conclusion was obtained on the laboratory tests of the FTK samples, where the following was established:

1. At a temperature of 1280 ° C, slight traces of sample softening were observed.
2. The shrinkage of the samples was, on average, 1.5% versus 6%.
3. After firing, ceramic sintering began to appear in the sample.
4. The porous structure of the sample has been preserved, and accordingly its heat-insulating properties have been preserved.

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