THE INFLUENCE OF TECHNOLOGICAL FACTORS ON THE PROPERTIES OF BASALT FIBER WHEN USED IN THE MANUFACTURE OF FLEXIBLE HEAT AND SOUND INSULATING PRODUCTS

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Abstract: Analysis of energy efficiency and operational safety of technological equipment of industrial enterprises, engineering networks, buildings and structures, building structures in many sectors of the economy, including the housing and industrial sectors, causes interest in the use of high-tech, environmentally friendly heat and sound insulation materials with enhanced performance properties. One of the relevant representatives of these materials is basalt fibers and their use as raw materials in the production of flexible heat and sound insulating products.
It is known that the chemical composition of the initial melt equally affects the physicochemical and mechanical properties of basalt fibers. The main influence factors, including the chemical composition, are the thermal past of the melt, the method for producing basalt fiber and the conditions for the formation of its structure. These factors determine the structural characteristics of the fiber and, as a consequence, its physicochemical characteristics. The degree of fiber strength is directly determined by its chemical composition and production method. The greatest strength of the fiber is obtained by ensuring the perfect fiber structure in the absence of ruptures of siliceous chains.
Keywords: microporous basalt fiber, modification, basalt melt, low-temperature basalt melt.

1. Introduction

The priority area of scientific research is the development of materials and technologies for the production of highly effective heat and sound insulation products based on environmentally friendly mineral raw materials. One of the representatives of these materials is basalts and their structural analogues (gabbro, syenites) with the production of various materials when using them as raw materials.

The aim of research is obtaining microporous basalt fiber with enhanced performance properties based on modified basalt fiber.

To increase the reliability of the experimental results and the logical sequence of the tasks, the study is divided into three stages: technological, modification of basalt fiber and the production of flexible heat and sound insulating products.

2. Methods

The raw materials used are igneous rocks – basalts and their structural analogues.

Summarizing the experimental results of previous studies, it is possible to determine the fact of corrosion of different intensities of basalt fiber in a corrosive medium, regardless of chemical composition and deposits, and to distinguish three groups. The first group is basalt fiber as a result of interaction with etching solutions completely dissolves. The second group is partially dissolved with the formation of fragments of basalt fiber without changing its structural characteristics. The third group retains its original shape with the formation of a surface microporous structure. Thus, a prerequisite for research is the discrepancy in the nature of the interaction of basalt fibers with etching solutions (**Fig. 1**).

As a result of determining the intensity of the corrosion process of basalt fiber in etching solutions of a chemical nature and various chemical composition, certain patterns in the distribution of the properties of basalt fiber are revealed [1, 2]. According to the studies, the most characteristic representative of the first group is the basalts of the Yanova Dolyna deposit, the second group of basalts from the Usachkiv deposits, the third group of basalts from the Donetsk deposit. The chemical composition and sensitivity of representatives of these groups are given in **Table 1** and in **Fig. 2.**

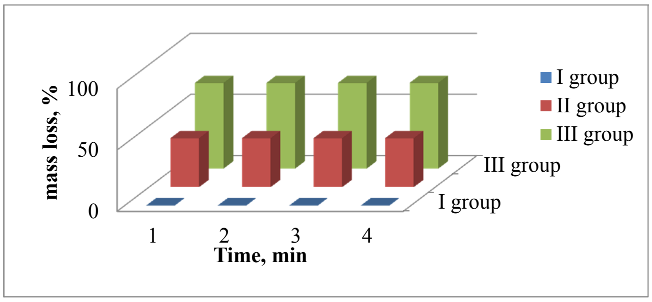

Fig. 1. The nature of the interaction of basalt fiber, various groups, in etching solutions

Table 1
The chemical composition of basalt fiber after etching

The nature of the corrosive environment	Deposits	Oxide content, %							
		SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	TiO_2	R_2O
Acidic	Yanova Dolyna	–	–	–	–	–	–	–	–
	Donetsk	64.8	16	10.3	3.1	2.8	2.3	0.4	0.3
	Usachkiv	49.9	11	14.5	6.3	4.4	10.9	0.5	2.5
Alkaline	Yanova Dolyna	–	–	–	–	–	–	–	–
	Donetsk	71.4	14	10.2	1.5	0.5	2.2	0.1	0.1
	Usachkiv	58.6	14.7	11.4	6.9	1.2	5.5	0.9	0.8

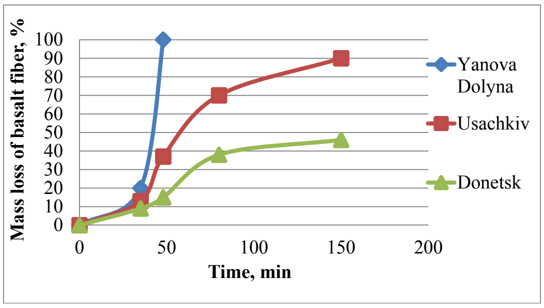

Fig. 2. The total mass loss of basalt fiber in etching solutions

3. Results

Basalt rocks, the fibers of which, during digestion, form a microporous structure in Ukraine are represented in very small amounts. Therefore, to obtain microporous structure of basalt fiber, studies were conducted on the effect of the ratio of oxides of the feedstock (basalt rocks) and chemical modifiers on the structure formation processes of the processed basalt fiber [3-6]. At the first stage – low-temperature basaltic melt with an extended range of working viscosity, as well as the determination of the patterns of conditions for obtaining modified basaltic rocks using available raw materials. On glass fiber of experimental composition, the general laws of the process for producing modified basalt fiber are established, in order to reduce the cost of the technological process, the composition of the starting materials from basalt deposits of Ukraine is determined (adjusted composition).

Fig. 3 shows the patterns of changes in the properties of basaltic melt when using appropriate deposits, namely, a decrease in the melting temperature from 1420 °C (Yanova Dolyna) to 790 °C (glass fiber), the melting temperature of the adjusted composition is 860 °C.

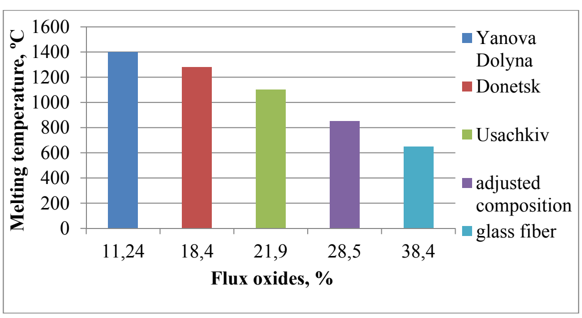

Fig. 3. The effect of the flux oxides that are part of natural raw materials on the melting temperature of the basalt charge

The aim is achieved by introducing additives with modifiers into the charge. Iron compounds in oxidizing and protoxide form, to reduce the melting point of basalt melt. Compounds of alkali metals of lithium, sodium, potassium in order to expand the range of working viscosity and stability of operation of technological equipment [7–9]. MnO compounds to increase operating temperature (**Fig. 4**).

At the second stage, the influence of the physicomechanical and rheological properties of the basaltic melt, and the process parameters during its passage through the spinneret plate during the formation of the primary fiber, which significantly affects the formation of the surface structure of the basaltic fiber, is considered [10–12]. It is established that in the temperature range of the basaltic melt 960...1180 °C and viscosity 3.19...4.08 Pa/s, an adjustable speed of drawing the primary fiber through the spinneret plate is ensured, it provides the calculated strength of the primary basalt fiber with a certain structural characteristic of its surface . In the case of using the corrected composition of the basaltic melt with the optimal value of the working viscosity and temperature, it is reached after 10–15 minutes and remains stable [13, 14]. This ensures stabilization of the process of obtaining basalt fiber, which is more effective than basalt melts of another warehouse, in which the zone of optimal values is within 25–40 minutes. At a broaching speed of 25...38.5 m/min of basalt fiber through the spin plate and a cooling rate in the range of 1840...1960 °C/min, fixation of the vitreous state of the fiber material with the formation of active zones on its surface [15, 16] (**Fig. 5, 6**).

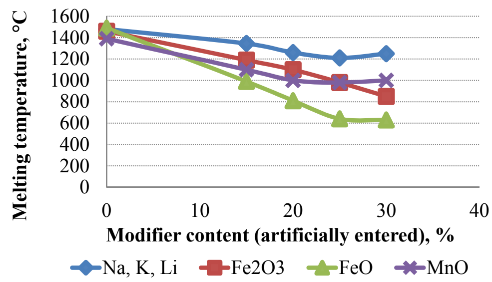

Fig. 4. The effect of modifiers on the melting temperature of the basalt charge

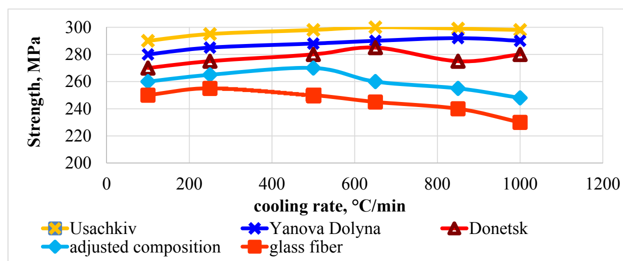

Fig. 5. The effect of the melt broaching speed on the strength of basalt fiber

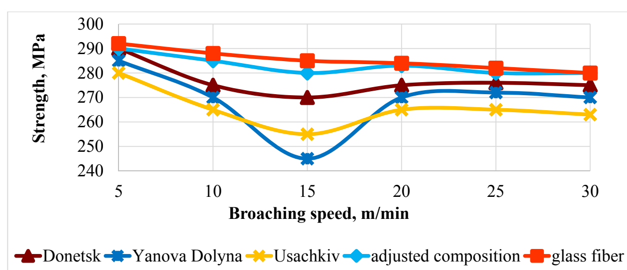

Fig. 6. The effect of melt cooling rate on the strength of basalt fiber

The surface of basalt fiber formed by standard technology has a smooth, uniform surface with constant curvature. Change in the magnitude of the curvature of the fiber surface (the first active zone – surface curvature is negative, the second zone – surface curvature is positive, and the third zone is characterized by advancement) [17]. This ensures that the electrostatic potential is concentrated in these zones, in contrast to the basalt fiber obtained by traditional technology, in which the electrostatic potential is uniformly distributed over the entire surface of the material. This process provides a change in chemical corrosion that occurs in the basalt fiber obtained by traditional technology to electrochemical in the case of using basalt fiber obtained by the adjusted technology that ensures the passage of corrosion within the active zones (**Fig. 7**).

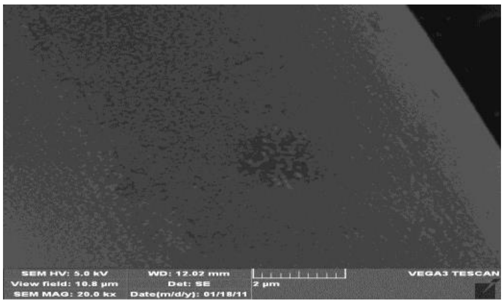

Fig. 7. The placement of active zones on the surface of basalt fiber

At the third stage of research, the interaction of basalt fiber with etching solutions is studied in order to adjust the chemical composition in the direction of obtaining the maximum content of silica, aluminum, and titanium. The choice of an acid solution and the establishment of optimal values of their characteristics is based on an analysis of the properties of the constituent parts of the basalt fiber material [18]. The concentration of the etching solution is 3.25 and the temperature of the solution is 50 °C, the exposure time is 60–65 minutes. A decrease in the concentration of digestion products of basalt fiber in the surface layer of the solution as a result, a shift in the ion exchange processes in the depth of the fiber and accelerate the speed of their passage.

4. Discussion and conclusions

In basalt fiber, due to surface tension forces, a decrease in the thickness of the inter-porous walls from 30...45 μm to 4...12 μm and an increase in pore diameter from 18...28 μm to 44...62 μm are provided. The formation of the porous structure is formed in the area of local removal of basalt fiber elements with the preservation of inter-porous septa in them and the formation of capillary and submicrocapillary pores. The results of the digestion process of the adjusted basalt fiber with a bulk microporous structure is shown in the figure. Physico-mechanical and structural characteristics are given in **Table 2.**

Table 2

Physico-mechanical characteristics of the modified basalt fiber

Charge name	The value of physical and mechanical characteristics					
	Average density, kg/m^3	R_p, MPa	Coefficient of thermal conductivity, W/(m^2·K)	Fiber diameter, microns	Fiber length	Fiber group
Adjusted composition	200–400	1.00–4.05	0.044–0.065	180–250	continuous	III

The next step in the work is determination of the structural characteristics of the modified basalt fiber after thermal stabilization. Where the optimum temperature of the thermal load is 1000–1060 °C and the time is 45–55 minutes. With increasing temperature, the porosity of basalt fibers increases, indicating structural transformations in the middle of the fiber, which leads to a decrease in inter-porous septa (transition of the vitreous to liquid state) (**Fig. 8, 9**).

According to the results of studies of the thermal characteristics of the obtained basalt fiber, it is found that the operating temperature of the adjusted basalt fiber is in the range of 1000–1120 °C, and the cyclic stability is increased in comparison with other deposits of Ukraine. The thermal conductivity coefficient and the stability of the modified basalt fiber under cyclic thermal load are more stable in comparison with ordinary basalt fiber.

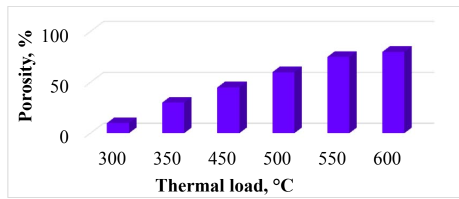

Fig. 8. The effect of thermal load on the total porosity of the modified basalt fiber (*t* – 60 min, Ø 180–250 μm)

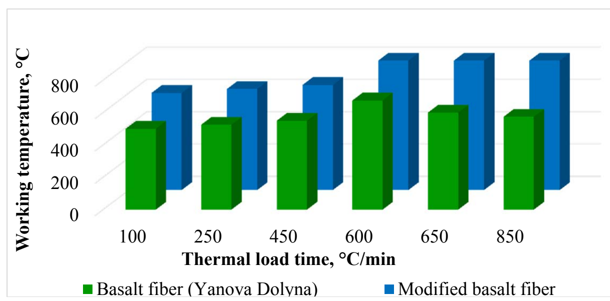

Fig. 9. Dependence of the working temperature of basalt fiber on the time of thermal load ($T_{t.l.}$ – 1060 °C, Ø 180–250 microns)

The performed studies of the development of the technology for the production of flexible heat and sound insulation products based on modified basalt fiber and the study of their operational characteristics allows to conclude that the properties of the fiber are improved when used in heat and sound insulation products (bundles). To obtain coarse basalt fibers, basalts are used, the melts of which, by their properties and other rheological characteristics, ensure the passage of the process in the steady state while ensuring the calculated temperature indicators.

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