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Production of modified basalt fibre for heat-insulating products manufacturing

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Abstract. As a result of the research flexible heat-insulating materials were developed based on basalt fiber with increased effectiveness, which can be achieved due to directed fiber microstructure forming through fusion modification. It is known that chemical composition of initial fusion not identically influences on physical and chemical and mechanical properties of basaltic fibres. Structural descriptions of fusion and basaltic fibre got from him appear main factors the nearer, than high speed of cooling. This index mainly depends on such constituents: a) ambient temperatures; b) coefficient of heat conducting; c) heat conducting of fusion; d) areas of surface. By researches influence of temperature of basaltic fusion was shown on the structure of fibres. Structural characteristics of the basalt fiber (number of active zones, coefficient of its distribution on the basalt fiber surface, as well as a correlation of three groups of active zones) depend on rheological properties of basal fusion, speed of drawing through the die plate and cooling speed.

1. Introduction

The relevance of research work is due to the forecast reduction of world resources of energy producing materials with simultaneous increase of their consumption and cost, that defined a tendency to the tighten requirements to the thermal insulation of buildings and energy efficiency of technological processes. Therefore, development of materials and production technologies of high-efficiency heat and sound insulating products on the basis of the environmentally clean mineral raw material is the priority direction of the research. Basalts and its structural analogues (gabro, syenites) belong to the raw materials that can be used for obtaining of various materials.

2. Analysis of the latest research works and publications

The research in this direction is covered in works performed in leading research laboratories and modern industrial enterprises “Kocyubinske” and “Slavuta”. Publications by Dzhigiris, Shabanova, Makhova, Aslanova, Mokhorta, Gotz are dedicated to the problems of obtaining and use of silicate fusions with the different functional applications; publications of Krivenko, Pushkareva, Koval'chuk describe the efficiency of heat insulation using these materials and underline the importance of production conditions and structuring process management. But with the increase of requirements to the heat and sound insulation the requirements to fibre properties also rise, this requires perfection of its structure and production technology.

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3. Definition of the goal and objective of the research

The goal and objective of the research is production of heat and sound insulating products with enhanced operating properties on the basis of the modified basalt fibre and development of its production technology [1-3].

In order to increase the reliability of the experiment results and observe the logical sequence of the set objectives, the research work has been divided into three stages: technological stage, modification of basalt fibre stage and production of flexible heat and sound insulating products stage.

As raw materials the rock formations such as basalts and their structural analogues were used. For the research works the rock formations of the following Ukrainian deposits were used: Yanova Dolyna, Usachkivske, Donetske (Table 1).

Table 1. Chemical composition of basalts of deposits of Ukraine.

Name of deposit	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	TiO_2	R_2O
Yanova Dolyna	50.6	16.0	14.8	8.1	5.1	9.8	0.9	3.2
Donetske	47.6	17.5	16.6	7.8	5.1	9.5	1.5	4.7
Usachkivske	48.7	15.9	13.5	7.3	5.4	12.9	0.8	3.5

Summarizing the experimental results of researches of previous works, it is possible to define the fixed fact of corrosion of different intensity of basalt fibre in a corrosive environment not depending on chemical composition and deposits, and to select three groups [4].The first group includes a basalt fibre that completely dissolves in etchant solution; second group covers the basalt fibre that partly dissolves with formation of basalt fibre fragments without the change of its structural properties; third group includes the basalt fibre that keeps the initial form with formation of surface micropore structure. Thus, divergence in interaction of basalt fibres with etchant solutionbecame a pre-condition for the necessity of research.

4. Basic part of the researches

As a result of determination of corrosive process intensity of basalt fibre in etchant solutions of chemical nature and of different chemical composition a certain consistent pattern in distributing of basalt fibre properties was revealed [5]. According to the conducted researches the most distinctive representative of the first group are basalts of deposit of Yanova Dolyna; basalts of deposits of Usachkivske make the second group, and basalts of the Donetsk deposit make the third group (Table 2).

Basaltic rocks with fibers forming a micropore structure after etching are available in an insignificant volume in Ukraine. Therefore, in order to obtain micropore structure of basalt fibre influence of correlation between oxides of raw material (basaltic rocks) and the ones of chemical modifiers on structure formation processes of the treated basaltic fibre were studies. At the first stage, obtaining of low temperature basaltic fusion with the extended range of working viscosity was studied, as well as determination of consistent patterns of conditions and methods of modified basaltic rocks obtaining with usage of accessible raw material [6]. The fibreglass of experimental composition was used in order to identify general consistent patterns of modified basalt fibre production process, with the purpose of cost reduction of the technological process a certain composition of raw material generated from the basalts of deposits of Ukraine (adjusted composition) was used (Figure 1, Table 2).

Table 2. Chemical composition of basaltic fibre after etching.

Nature of corrosive environment	Name of deposit	Content of oxides, %							
		SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	TiO_2	R_2O
Acid	Yanova Dolyna	-	-	-	-	-	-	-	-
	Donetske	64.8	16.0	10.3	3.1	2.8	2.3	0.4	0.3
	Usachkivske	49.9	11.0	14.5	6.3	4.4	10.9	0.5	2.5
Alkaline	Yanova Dolyna	-	-	-	-	-	-	-	-
	Donetske	71.4	14.0	10.2	1.5	0.5	2.2	0.1	0.1
	Usachkivske	58.6	14.7	11.4	6.9	1.2	5.5	0.9	0.8

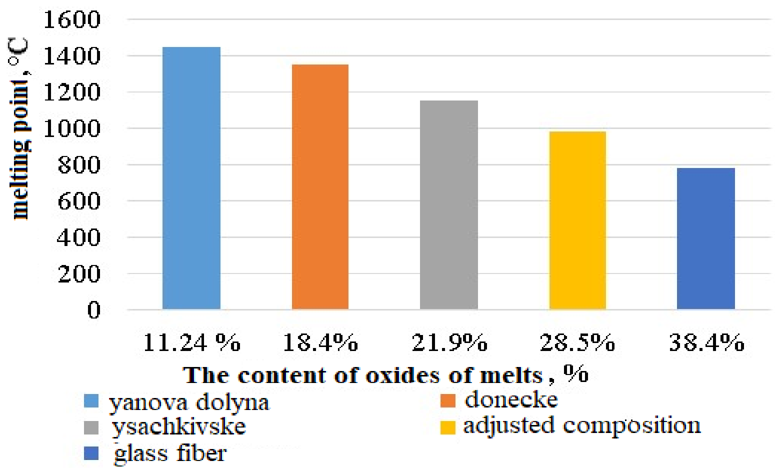

Figure 1. Influence of oxides of melt material coming from natural raw material on the melting temperature of basaltic charge.

The diagram shows the consistent pattern of properties changes of basaltic fusion using the correspondent deposits, namely decrease of melting temperature from 1420°C (Yanova Dolyna) down to 790°C (fibreglass); the melting temperature of the adjusted composition equals to 860°C. The same tendency is observed in dependences of cooling speed and thermal inertia from chemical and mineral composition of raw material.

The set target can be reached due to introduction of additives and modifiers together with the charge: compounds of iron in an oxidizing and protoxide form, for the decrease of melting temperature of basaltic fusion; compounds of alkaline metals of lithium, sodium, and potassium with the purpose of expansion of working viscosity range and stability of technological equipment operation, compound of MnO for the increase of working temperature.

At the second stage influence of mechanical and rheological properties of basaltic fusion was examined, as well as influence of parameters of technological process, while it's passing through an orifice plate in the process of formation of primary fibre, which substantially influences forming of basaltic fibre surface structure. It was defined that at the temperature of 960-1180°C and viscosity of 3.19 to 4.08 Pa/s the adjustable speed of primary fibrepassing through an orifice plate is reached in the basaltic fusion; this allows obtaining of calculated durability of primary basaltic fibre with the certain structural properties of its surface [7-10]. In case of the use of the adjusted composition of basaltic fusion with the optimum value of working viscosity and temperature, characteristics stability is reached in 10-15 minutes and remains stable, this provides stabilizing of the technological process for obtaining of basalt fibre, which is more effective, than basaltic fusions of other composition with the range of optimum values within the limits of 25-40 minutes. It provides possibility to fix the glass-like state of the fibre material with formation of active zones on its surface with basalt fibre passing through an orifice plate with the speed of 36.0-38.5 m/min and cooling speed within the limits of 1840-1960°C/min. The surface of basalt fibre, formed with the observance of determined parameters of technological process, differs sufficiently from the surface of basalt fibre, formed according to the traditional technology.

As it can be seen from the picture, the surface of basalt fibre, formed according to the standard technology, has a smooth even surface with permanent curvature. The curvature of fibre surface takes place, whereas the first active area is a curvature of surface with negative value, the so-called cracks and cavities, the second area is a curvature of surface with a positive value, the third area has a prolonged form of a furrow and combines properties of the first and second areas, which provides concentration of electrostatic potential in these areas, unlike a basalt fibre, obtained using traditional technology, in which electrostatic potential is evenly distributed on the material surface. It provides the change of chemical corrosion, which takes place in a basalt fibre obtained using traditional technology, to electrochemical corrosion taking place in a basalt fibre obtained using adjusted technology; due to this change corrosion is limited by active areas (figure 2).

(a) (b)

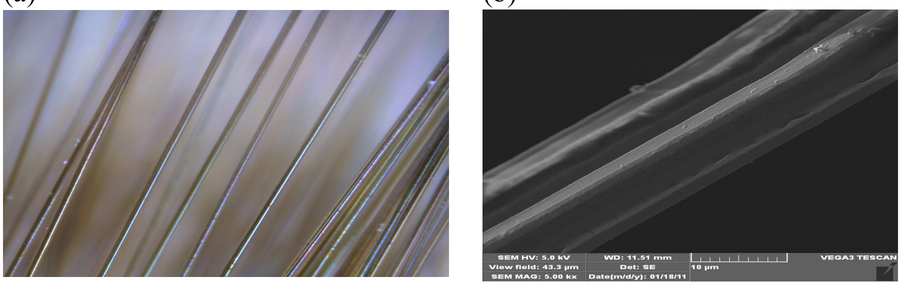

Figure 2. Basalt fibre obtained using: a - traditional technology, b - adjusted technology.

At the third stage of the study the process of interaction of basaltic fibre and etching solution was studied with the purpose of correction of chemical composition for obtaining the maximal content of silica, aluminium and titan. The choice of acid solution and establishment of optimum values of their characteristics is based on the analysis of properties of components of basaltic fibre material. This process under conditions of 3.25 etchant solution concentration, 50°C solution temperature and 60-65 min exposure time resulted in diminishing of etchant products concentration of basaltic fibre in the superficial layer of the solution, and consequently in displacement of ion-exchange processes into depth first fibre and acceleration of this process.

In this article the mechanism of micropore structure formation is also proposed. It is based on suggestion that during interaction of basaltic fibre with the acid solution, a material with overwhelming content of oxides of SiO_2, Al_2O_3, TiO_2, is formed; such material gains quartz glass characteristics after the thermal stabilization, as described in the works by the academician Grebenschikov.

The result of etching process development of basalt fibre is shown in the picture, which demonstrates that corrosive processes develop not evenly on the surface, only in active areas, unlike the ordinary fibres (Figure 3).

In a basaltic fibre the surface tension forces result in decrease of interpore partitions thickness from 30-45 mic down to 4-12 mic and increase of pore diameter from 18-28 mic up to 44-62 mic. Formation of pore structure takes place in the area of local offset of basalt fibre elements keeping micropore partitions and formation of capillary and submicro cappilary pores (Figure 4). Results of the etching process of the adjusted basalt fibre with volume micropore structure are shown in Tables 3-4.

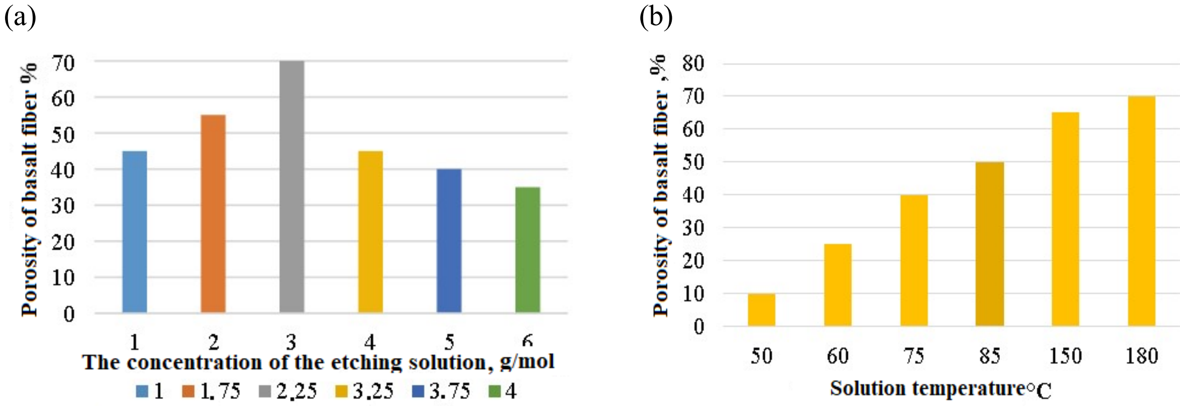

Figure 3. Influence of etchant solution on porosity of basaltic fibre: a-change of acid solution (HCl) concentration at T=50°C, t=180 min; b-change of acid solution (HCl) at 3.25 gr/mole concentration.

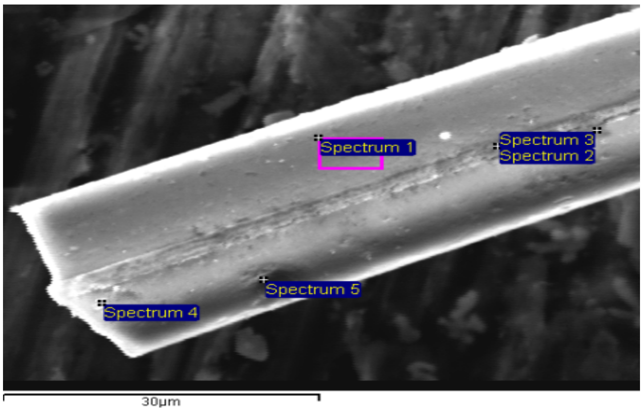

Figure 4. Etching process development in a basalt fibre.

Table 3. Structural characteristics of the modified basalt fibre.

Name of charge	Value of structural characteristics			
	General porosity, %	Diameter of pore, mic	Radius of pore, mic	Thickness of micropore partitions
Adjusted composition	68-84.6	44-62	<18-28	4-12
Donetsk deposit	<55	18-28	30-35	30-45

Table 4. Physical and mechanical characteristics of the modified basalt fibre.

Name of charge	Value of physical and mechanical characteristics				
	Middle density kg/m^3	R_p, MPa	Heat-transfer coefficient, W/(m^2•K)	Group of fibres	Length of fibre
Corrected composition	200-400	1.0-4.05	0.044-0.065	III	continuous

The next stage of the research work was determination of structural characteristics of the modified basalt fibre after thermal stabilization. The porosity of basalt fibre increases at the optimum temperature of thermal load of 1000-1060°C and time set at 45-55 minutes with rising temperature; it proves the structural transformations inside the fibre resulting in diminishing of micropore partitions (transformation of glasslike state into liquid) [6-9].

In accordance with the results of researches of thermal characteristics of the gained basalt fibre, the working temperature of the adjusted basalt fibre should be within the limits of 1000-1120°C.

The modified basalt fibre before and after thermal load has enhanced operating properties; thermal consistency and other operating properties of the modified basalt fibre increase comparing those of the ordinary basaltic fibre (Figure 5, 6).

(a) (b)

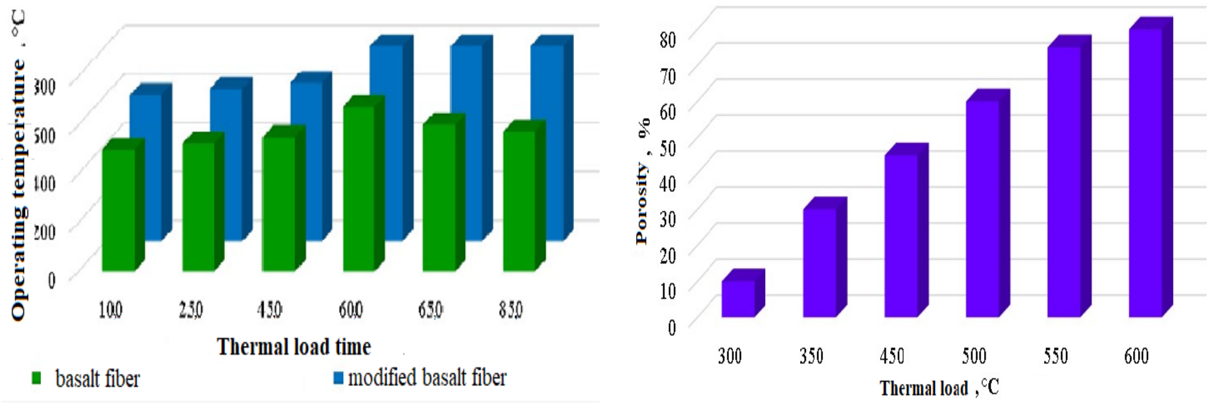

Figure 5. Structural properties of the modified basalt fibre after the thermal load: a - dependence of basalt fibre working temperature on thermal load duration (Tt.n.-1060°C, Ø180-250 mic); b - influence of the thermal load on general porosity of the modified basalt fibre (t=60 min Ø 180-250 mic).

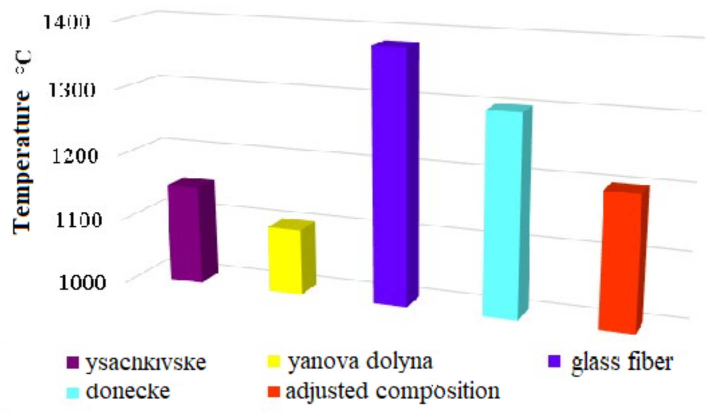

Figure 6. Working temperature of basalt fibre of different deposits of Ukraine.

5. Conclusions

Studies have shown the effect of basalt fusion temperature on the fiber structure. The lower the temperature of gaining the performance characteristics of the fusion (means the lower the temperature interval of melting) and the less time of temperature exposure, the larger is the degree of crystal-chemical structure restoration during fiber production. In the frames of the present study principles of fiber micropore structure gaining were developed and the mechanism of volumetric micropore fiber structure forming offered. The main physical and mechanical characteristics of the gained fiber and materials produced on its basis were determined. The developed heat and sound insulating products (plaits) can be used for heat-insulation of pipelines of thermal networks with the working temperature of 1420°C. While the working temperature of plaits produced on the basis of the not treated basalt fibre would make 840°C.

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