

GLASS FOR CONTINUOUS FIBER BASED ON COMPOSITIONS BASALT-MODIFIER

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Rocks of volcanic origin, such as basalts, basaltic andesites, etc., are widely used in the production of thermal insulation materials based on mineral wool. At present, the most promising material obtained from such rocks is continuous fibre. Wide prospects for application of continuous basalt fibre are attributable to the abundance of the raw materials in the nature, the environmental friendliness of the production and high level of strength, thermal resistance and chemical resistance of the materials based on it. In particular, basalt continuous fiber is an effective reinforcement material in the production of composites that are characterized by high level of strength and resistance to alternating loads [1, 2]. However, there are a number of technological problems in the production of continuous fibre due to the instability of the chemical and mineral composition of basalt, the high absorption ability of iron-containing melt and the enhanced crystallization ability [2, 3].

Basalt continuous fiber produced directly from natural basalt rarely has good technological characteristics. Consequently, there are ongoing activities aimed at modifying the composition of basalts by way of introduction of additional components [4–7].

Optimization of basaltic glass composition is a topical direction of the technological innovations in the field of continuous basalt fiber production.

Basaltic andesites from Podgornyyanskoye deposit were used for basaltic glass production. According to the results of analysis of chemical composition of basalts conducted by atomic emission spectroscopy method with a laser analyzer LEA-S500, average composition of basalts includes, wt.%: SiO₂ 52.90; Al₂O₃ 16.18; Fe₂O₃ 12.88; CaO 8.36; MgO 4.31; R₂O 4.16; TiO₂ 1.21.

Basalt mineral composition includes plagioclases, which are anortite-based (CaAl₂Si₂O₈) and albite-based (NaAlSi₃O₈) solid solutions, pyroxene which is diopside-based (CaMgSi₂O₆) solid solution, and magnetite (Fe₃O₄). Basalt glasses were synthesized based on compositions basalt – modifier. The following materials were introduced as modifying materials: disthene-sillimanite concentrate (disthene), alumina, colemanite and boric acid.

The content of oxides in compositions varies within the following limits, wt.%: SiO₂ 47.33–52.90; Al₂O₃ 15.08–21.24; Fe₂O₃ 11.43–13.09; CaO 8.0–10.63; MgO 3.95–4.31; R₂O 3.67–4.16.

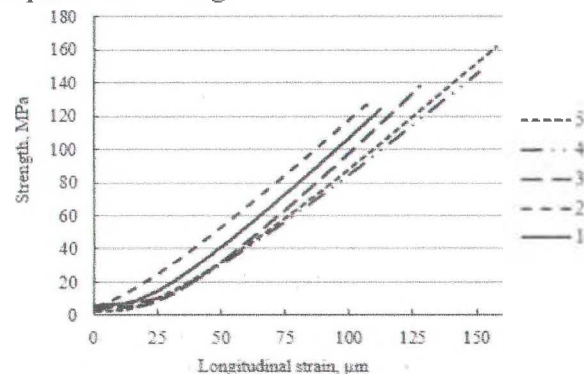
The melting of basalts and basalt-based compositions was performed the traditional way at the maximum temperature of 1500±10 °C in a gas furnace. The temperature rise in the furnace was carried out at a rate of 250 °C/h, gaseous atmosphere is oxidative; air excess factor is 1.08–1.13.

In order to identify the peculiarities of the process of melting basalt-modifier raw material compositions positional heat treatment was performed in gas furnace at 1250 and 1350 °C. The product of heat treatment of basalt at a temperature of 1250°C is a vitrified mass containing crystalline inclusions ranging in size from 10 to 300 microns. The introduction of alumina and disthene into the composition causes an increase in the volume fraction of the crystalline phase. According to X-ray diffraction measurements using diffractometer D8 Advance with CuK α radiation source, the crystalline phase is represented by relic plagioclase (labradorite). The increased crystallization ability of the glass associated with high content of iron oxides, leads to release of magnetite Fe₃O₄. Introduction of boron-containing components into the composition causes the melt to occur at lower temperatures. B₂O₃ significantly reduces the viscosity and the surface tension of the melt, which accelerates the process of dissolution of the crystals of the mineral part of basalt.

The products of heat treatment at temperature of 1350°C are a glassy material containing gaseous inclusions. Homogeneous samples of basalt glasses were obtained at 1500 °C.

Basalt glasses crystallizability has been evaluated by means of a complex method based on

the results of gradient crystallization and differential scanning calorimetry data using unit DSC 404 F3 Pegasus. The upper crystallization temperature (liquidus temperature) of the basalt glass is 1280 °C. It rises to 1310 °C by the increase of Al₂O₃ content in the basalt glass composition. Glass synthesized based on boron-containing compositions has the lowest values of crystallization ability. The temperature of the liquidus is reduced by 30–50 °C, which allows to decrease the fiber molding temperature. The main performance characteristic of continuous fibre is its strength. There is a direct correlation between the strength of the glass and the strength of fibre produced from it. Strain diagrams of basalt glass samples obtained using the universal electromechanical testing machine Galdabini Quasar 100 presented in Fig.



1 – Basalt glass; 2–5 – Glass of modified compositions

Fig. Strain diagrams of basalt glass

The ultimate flexural strength and, accordingly, the ultimate tensile strength of the glass obtained by melting basalt is 124 MPa. Close values are typical for the glass obtained from basalt-colemanite compositions (sample 2 in strain diagram). The use of basalt-disthene compositions in glass production leads to a significant increase in strength – up to 164 MPa (sample 5 in strain diagram).

Considering the totality of technological and mechanical properties, introduction of complex aluminum- and boron-containing modifiers is the optimal solution. When basalt-disthene-colemanite compositions were used, samples of basaltic glass with the strength values of 137–148 MPa were obtained. The increase of the strength of basaltic glass will ensure obtaining high-strength basalt fiber, which is highly demanded in production.

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