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Modification of basalt fibers by low-temperature plasma

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Abstract. In the article the characteristics of basalt fibers and threads are given, their advantages over other mineral fibers are considered. Materials and methods of research are described. The results of a study of the properties of filaments, such as the breaking load force of a basalt thread before and after its treatment in a low-temperature plasma are presented. The regime of plasma treatment is revealed at which the strength of the fibers of the basalt thread increases, it established that modification of low-temperature plasma allows increases the characteristics strength of basalt filaments and transforming the structure of their surfaces.

1. Introduction
In Russia and abroad, the production of fibrous materials based on mineral, glass, kaolin and other fibers is intensively developing. However, it’s also increases technical requirements for these materials, and as well as the shortage of raw materials restrains the growth of their production volumes.

In connection with this, the industrial production of basalt fibers and materials based on them has become widespread, where rock as a raw material - basalts, gabbro-debase porphyries and others - were used as an initial one-component raw material.

Basalt fibers have high heat, sound insulation and structural properties. In terms of temperature resistance, as well as in acid, alkali and vapor resistance, they go beyond mineral and glass ones.

The high physical and mechanical properties of basalt fibers determine the creation and growth of new high-efficiency construction, technical, heat-sound-insulating and as well other composite materials and products for various industries. The use of basalt fibers as raw materials makes it possible to produce materials that replace asbestos, metal, wood and others [1].

The aim of the research is to modify the basalt threads with a low-temperature plasma and to study its effect on fiber strength.

2. Materials and methods
The objective of the study selected basaltic twisted thread BS 10-68Z40-KV-12. The plasma treatment was carried out on an experimental high-frequency plasma plant of reduced pressure, described in [2], using as a plasma-forming gas, and a mixture of argon / propane-butane gases in a ratio of 70/30. Determination of the breaking load of the basalt thread was carried out on the Shimadzu AGS-X testing machine. The microstructure of the basalt fiber was examined by confocal laser microscopy using the Olympus LEXT 4000 microscope.

3. Results of experiments and discussion

Threads from basalt fibers are used for the production of various textiles. However, in the process of weaving products, the fibers of the yarns break due to various mechanical factors, which in turn leads to a deterioration in the quality of the finished product and difficulties in the production process.

Based on the previous work and their results in the study of the influence of low-temperature plasma on the properties of various types of fibers and filaments [3-6], studies of the effect of plasma basalt thread processing parameters on its strength are presented.

The processing of the basalt thread in a high-frequency plasma installation was carried out in two stages: with the voltage variation and the current intensity at the anode of the generator lamp; with a variation in processing time.

At the first stage of the studies, processing of the samples of the basaltic filament was performed in an industrial plasma installation with a plasma-forming gas argon / propane-butane in the ratio of 70/30. The value of plasma gas flow (G) was 0.04 g/s, a generator frequency (f) was 13.56 MHz, and pressure (P) in the vacuum chamber was 26.6 Pa, a processing time (t) 3 min. The voltage of the anode (Ua) varied from 4 to 7 kV, and the anode current (Ia) was from 0.5 A to 0.85 A. Based on the results of the treatments, the most optimal values of the voltage at the anode and the forces current at the anode, at which the best results for the force, applied load were achieved. The results of the studies presented in Table 1.

Table 1. Values of the maximum breaking load force of the basalt thread at the selected plasma processing parameters

| Voltage (Ua), kV | Current strength (Ia), A | Maximum breaking load force, N |
|------------------|--------------------------|-------------------------------|
| Control sample   | 30.07                    |
| 6.5              | 0.8                      | 36.05                         |

The maximum value of the breaking load force for the selected parameters is increased by 20% compared to the control sample.

At the second stage of the studies, the basalt fiber samples were processed in an experimental plasma installation with a plasma-forming gas flow rate G = 0.04 g/s, f = 13.56 MHz, P = 26.6 Pa, Ua = 6.5 kV, Ia = 0.8 A. The processing time (t) then ranged from 1 to 9 minutes. The results of the studies presented in Table 2.

Table 2. The dependence of the maximum breaking load force of the basalt thread on the plasma treatment regimes

| Voltage (Ua), kV | Current strength (Ia), A | Processing time (t), min | Maximum breaking load force, N |
|------------------|--------------------------|--------------------------|-------------------------------|
| Control sample   | 30.07                    |
| 6.5              | 0.8                      | 1                        | 33.21                         |
|                  |                          | 3                        | 36.05                         |
|                  |                          | 5                        | 38.36                         |
Based on the data in Table 2, it can be concluded that the modification of basalt fibers with a low-temperature plasma increases the maximum breaking load force, and the maximum value is achieved with a processing time of 9 minutes. The best mode of plasma treatment at which the maximum strength of the basalt thread is maximized, and the mode with parameters: $G = 0.04 \, g/s$, $f = 13.56 \, MHz$, $P = 26.6 \, Pa$, $U_a = 6.5 \, kV$, $I_a = 0.8 \, A$, $t = 9 \, min$, and the value of its maximum breaking load increases to 29%. A study of the dependence of the tensile strength on the duration of plasma treatment in the direction of increasing the latter is being carried out at the present time.

In Figure 1 are microphotographs of samples of fibers of a basaltic filament of a control and processed low-temperature plasma.

![Microphotographs of fibers of a basalt thread (x100): a – control sample; b – sample treated in argon/propane-butane gas (70/30).](image)

Figure 1. Microphotographs of fibers of a basalt thread (x100): a – control sample; b – sample treated in argon/propane-butane gas (70/30), $G = 0.04 \, g/s$, $f = 13.56 \, MHz$, $P = 26.6 \, Pa$, $U_a = 6.5 \, kV$, $I_a = 0.8 \, A$, $t = 9 \, min$

The above diagram shows microphotographs of a sample that has undergone plasma treatment, more uniform structure of the fibers of the basalt thread and less irregular surface are observed in comparison with the untreated sample. Due to these changes in the surface of the fibers, an increase in the maximum bursting force of the basalt thread treated with low-temperature plasma is likely to occur as compared to the untreated yarn.

4. Conclusion

Thus, based on the results of study, it can be concluded that modification in conditions of low-temperature plasma is upcoming method of increasing the characteristics strength of basalt filaments and transforming the structure of their surfaces.

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