Influence of aggressive environment on basalt fiber based microplastics

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Abstract. Physical and mechanical properties of basalt fibers and microplastics based on them have been investigated. Influence of various environments such as distilled and sea water, alkaline solutions, UV-radiation, on microplastics’ characteristics have been studied. Alkaline solutions of high concentration are shown to affect the most the characteristics of studied materials.

1. Introduction
Basalt is an igneous rock constituting 30% of the earth's crust. The mechanical properties of basalt fibers are comparable with glass fibers but have a higher chemical resistance [1-5]. Thus, basalt plastics successfully compete with metal products, surpassing them in corrosion, alkali- and acid- resistance and etc. Therefore, basalt fibers and based on them composites are widely studied throughout the world [6-12].

2. Experiment
In our study the strength of basalt harnesses and monofilaments and basalt microplastics’ resistance to water, alkaline solutions and UV-radiation has been investigated. Epoxy oligomer ARALDITE CY8615 + XB 5173 HARDENER (Huntsman) has been used as impregnation binder. Linear density of basalt fibers occurred to be 1200 tex.

Time of exposure of microplastics to both distilled and sea water as well as alkaline solutions (pH 12.5 – 14.1) was 0-60 days, to UV-radiation 0-21 days.

Samples of monofilaments, microplastics were tested for tensile, strength \( \sigma \) and elastic modulus \( E \). Samples for shear strength \( \tau \) determination have been obtained by pressing. The samples consisted of plates with asymmetric cuts (Fig. 1), which were tested by means of uniaxial tension [11], and the shear strength was calculated by formula (1)

\[
\tau = \frac{P}{b\cdot w}, \quad (1)
\]

where \( P \) is breaking load, \( b \) is the width of the sample, \( w \) is distance between the cuts.

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3. Results and discussion

Monofilaments microphotographs and distribution by diameter are presented in figure 2.

Based on microphotographs (an example is shown in Fig. 2a, the distribution curve of monofilaments by diameter (Fig. 2b) was constructed, showing that the average diameter of the basalt monofilament is 19 μm. Measurement of the monofilaments’ diameter in respect of the length of the bundle (Fig. 3c) showed the average diameter is also 19–20 μm.

The dependence of the monofilaments’ strength on the number of averaged values is shown on fig. 3a. The average strength of the monofilament varies insignificantly when considering over 30 values, i.e. you can talk about the well-established value of strength. With a smaller number of averages the strength of the monofilament can differ by 40%. Such a spread overlaps the spread of the obtained data. A similar trend is observed in determining the elastic modulus (Fig. 3b).
As a result, the average value of the strength of the monofilament is 2400 MPa, with the harness strength values being 1.5 times lower, 1600 MPa. Such a difference testifies to the diversity in tension and diversity in length of the fibers in the bundle.

The strength of the control samples of basalt-based microplastics is 1460 MPa, while the fiber content in the samples is 65-70 vol. %. Using the formula (2) for calculating the fiber realization coefficient of the fiber $k$ [12], we get the value $k$~0.87-0.93.

$$k = \frac{\sigma_{mp}}{\sigma_f w} \quad (2)$$

Where $\sigma_{mp}$ is strength of microplastic, $\sigma_f$ is strength of monofilament, $w$ is distance between cuts.

The results of determination the microplastics strength after exposure to various environments are shown in Fig. 4
Figure 4. The strength of microplastics after exposure to: a) distilled and sea water; b) alkaline solutions (pH is shown in the figure); c) ultraviolet radiation.

As can be seen from the figures, the strength of microplastic depends on the time of exposure to various environments. The increase in strength after exposure to water (Fig. 4a) is associated with leaching of residues of the uncured resin and improvement of contact at the matrix – fiber interface.

In case of alkali solutions (Fig. 4b) it is associated with healing of edge defects, which occurs more efficiently at high concentrations of alkali in solution with short exposure times (up to 5-10 days). Longer exposure to the solutions has a negative impact on the matrix and fiber.

Exposure to UV radiation (Fig. 4c) leads to the curing of the epoxy matrix, i.e. hardening of the interphase boundary, and hence the growth of strength characteristics of loaded sample.

When determining the modulus of elasticity (Fig. 5), the tendency of strength characteristic remains the same.
The mass loss of microplastics during their exposure to different conditions was measured. It was found that a noticeable change in mass occurs only when the microplastics are exposed to alkaline solutions (Fig. 6). There is a sharp decrease in the mass of the sample to 0.5-0.8% in first 5 days, then the mass loss rate reaches plateau and after a 60-day exposure is 1.3-1.8%.

Analysis of shear strength (Fig. 7) showed its significant dependence on the area of the sample’s working region.
The figure shows that as the distance between cuts increases, a monotonic drop in shear strength occurs. The values of $\tau$ fall from 58 MPa to 20 MPa when $w$ increases from 3 mm to 10 mm, which is associated with an increase in the flexural stress arising in the process of application of axial tensile forces with increasing distance between the cuts. The values obtained at $w = 3$ mm correspond to the previously obtained experimental data \[1\].

4. Conclusions

Thus, the work showed the promising use of basalt plastics, since they have physical and mechanical characteristics comparable to those of glass-reinforced plastics, but at the same time have a higher resistance to the action of the aqueous medium and alkali solution, as well as resistance to the action of ultraviolet radiation. At the same time, in some cases, the influence of aggressive media leads to an improvement in the characteristics of materials.

Acknowledgments

The work was supported by the Ministry of Education and Science of the Russian Federation: Contract No. 03.G25.31.0264

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