Study of Influence of Climatic Factors of North on Properties of Polymer Composite Textolites

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Abstract. Influence of a very cold climate on properties of basalt and glass textolites made by an infusion method by successively laying a reinforcing material on a mold and impregnating with a three-component epoxy binder is studied. Full-scale climatic tests at an open proving ground during 2 years led to a decrease of ultimate tensile strength by 14% and an increase of ultimate bending strength by 18% for the basalt textolite, the increase of the ultimate tensile strength by 9% and the ultimate bending strength by 22% for the glass textolite. Conducted studies of changes of surface relief showed insignificant variations of average amplitude of inhomogeneities up to 0.4 μm for the basalt textolite and up to 4 μm for the glass textolite. The conducted studies of these materials demonstrated their resistance to the climatic influences in a region of the very cold climates, which is confirmed by a high level of preservation of their strength parameters.

1. Introduction
In recent years, more and more attention has been paid to the basalt fibers as a replacement for glass fibers [1] due to their advantages, such as environmental costs and increased physical and chemical properties. In addition to presence of non-toxic, non-combustible characteristics, the basalt fibers have higher chemical stability and higher tensile strength than E-glass fibers [2].

In the past few years, the basalt fibers have been used as reinforcing additives for thermosetting plastics such as epoxy, polyester and vinyl ester resins for manufacture of composite structural parts. Among them, the epoxy resin is one of the most important matrices, which has found a special place for the thermosetting polymers due to its excellent mechanical properties associated with the chemical and corrosion resistance [3]. Lopresto et al. [4] studied the mechanical properties of the E-glass and
basalt fibers to evaluate the replacement of the glass fibers with the basalt ones. Experimental results showed that the basalt showed a higher elastic modulus, the compressive, bending and impact strengths, but the tensile strength was higher for the glass fibers [4]. Dorigato and Pegoretti [5] studied tensile and fatigue behavior of the epoxy resin reinforced with basalt, E-glass and carbon fiber fabrics. It has been discovered that the higher characteristics of the laminated plastic were obtained using the basalt fabrics in comparison with the fiberglass composite [5]. Wei et al. [6,7] demonstrated that the best acid resistance was achieved for the basalt composites when they were treated with hydrochloric acid solutions of sodium hydroxide at different times. Wei et al. [8] found that the anticorrosive properties of both the basalt and glass fiber composites were approximately the same. Carmisciano et al. [9] indicated that the higher bending modulus and interlayer shear strength were obtained for the composites based on the basalt fibers compared to the E-glass ones, but the lower bending strength was observed.

Generally accepted world practice of substantiating terms of safe operation of the polymer composites for an aircraft industry and various branches of mechanical engineering is to carry out a “climate qualification” [10], during which a set of physical and mechanical parameters is monitored during prolonged exposure in open typical climatic conditions of the globe.

2. Materials and study methods
An object of the study is specimens of the basalt and glass textolites made by the infusion method by successively laying the reinforcing material on the mold, impregnating with the three-component epoxy binder, consisting of ED-22, Iso-MTHPA, Agidol 53 and curing at a temperature of 160±2 °C during 4 hours. Table 1 shows the physical and mechanical characteristics of the initial specimens.

| Table 1. Physical and mechanical characteristics of initial specimens. |
|---------------------------------------------------------------|
| **Basalt textolite**                                          |
| Ultimate tensile strength, MPa                               | 503.05 |
| Ultimate bending strength, N/mm²                             | 20.37  |

| **Glass textolite**                                          |
| Ultimate tensile strength, MPa                               | 488.15 |
| Ultimate bending strength, N/mm²                             | 21.45  |

The full-scale climatic tests were carried out at an open area under the conditions of the very cold climates according to GOST 9.708-83 during 2 years. To determine the changes of the physical and mechanical properties of basalt and glass textolites, from plates 500x500x5 mm in size after the exposure the tensile specimens were prepared in accordance with GOST 32656-2014 and the bending ones according to the method of GOST 25.604-82. The obtained specimens were tested using a Zwick Roell Z600 tensile testing machine of a type BPC-F0600TN.R09, serial number: 160088-2008 (GOST 12004-81) on the basis of the Collective Use Center of the V.P. Larionov Institute of Physical-Technical Problems of the North of the Siberian Branch of the Russian Academy of Sciences. The studies of the changes of the surface relief were carried out with the use of a SurfTest-201P profilometer.

3. Results of study and discussion of them
The long-term exposure to various media and temperatures significantly affects the properties of the materials. The study of a process of changing the properties of the composite materials under the action of climatic effects allows evaluating its operational characteristics and determining its purpose.

Table 2 shows the test results of the specimens of the basalt and glass textolites before and after the exposure.
Table 2. Physical and mechanical characteristics of specimens before and after exposure.

|                     | Initial state | Open area | Level of preservation of properties, % (relative to initial one) |
|---------------------|---------------|-----------|---------------------------------------------------------------|
| **Basalt textolite**|               |           |                                                               |
| Ultimate tensile strength, MPa | 503.05       | 431.81    | 86                                                            |
| Ultimate bending strength, N/mm² | 20.37        | 24.12    | 118                                                          |
| **Glass textolite** |               |           |                                                               |
| Ultimate tensile strength, MPa | 488.15       | 534.61    | 109                                                          |
| Ultimate bending strength, N/mm² | 21.45        | 26.18    | 122                                                          |

The climatic tests of the basalt textolite under the natural conditions led to the decrease of values of the ultimate tensile strength by 14% and the increase of ones of the ultimate bending strength by 18%.

The values of the strength properties of the glass textolite increased by 9% for the tension and 22% for the bending.

The studied surface reliefs in a direction perpendicular to an arrangement of the fibers show that the basalt fibers in the initial state are densely and uniformly located on the surface and grooves of a surface layer and on an inverse (sunny) side do not exceed 2 μm. Table 3 shows the average values of the parameters of the surface relief of the basalt and glass textolites before and after 24 months of the exposure. After the climatic tests, it is observed the increase of the average amplitude of the surface inhomogeneities (Ra) of the basalt textolite on the sunny side up to 0.48 μm (the initial value is 0.70 μm, after the exposure 1.18 μm), on the shadow side the average roughness decreases by 0.28 μm (the initial value is 9.98 μm, after the exposure 9.70 μm). On the both sides of the glass textolite, the parameters of the average roughness increase after the exposure: by a factor of 4 on the sunny side (the initial value is 1.03 μm, after the exposure 4.08 μm) and on the shadow side by 0.14 μm (the initial value is 5.50 μm, after the exposure 5.64 μm). The average values of the relief parameters are presented in Table 3.

Table 3. Average values of parameters of surface relief of basalt and glass textolites.

| PCM Brand          | State* | Average amplitude of surface inhomogeneities, μm** |
|--------------------|--------|--------------------------------------------------|
|                    |        | Value (Ra) | Standard deviation (Rq) |
| Basalt textolite   | I      | 9.98/0.70 | 12.79/1.06 |
|                    | F      | 9.70/1.18 | 11.1/1.9  |
| Glass textolite    | I      | 5.50/1.03 | 6.67/1.7  |
|                    | F      | 5.64/4.08 | 6.65/4.52 |

*I stands for the initial state, F means after 24 months of exposure.

**The numerator is the front (shadow) side, the denominator is the inverse (sunny) one of the exposed specimens of the polymer composite materials (PCM).

The conducted studies show that over 24 months of the exposure, the surface relief increases in the glass textolite, where partial destruction and removal of the binder from the surface of the material occurs. In this case, an average degree of a scatter of the values does not exceed 1.38 μm in the sunny side of the exposed materials, showing good reproducibility of measurements.
The destructive processes affected less than 4 μm (0.2% of thickness of the exposed plates), which confirms general regularity of the high resistance of the PCM to the action of the climatic factors [11,12].

4. Conclusion
1. The full-scale climatic tests of the basalt and glass textolites in the region of the very cold climate demonstrated their resistance to the climatic influences, which is confirmed by the high level of the preservation of their strength parameters.
2. The tests of basalt textolite under the full-scale conditions led to the slight decrease of the values of the ultimate tensile strength up to 14% and the increase of the values of the ultimate bending strength up to 18%. The values of the strength properties of glass textolite increased by 9% for the tension and 22% for the bending.
3. The destructive processes affected up to 0.2% of the thickness of the exposed plates, which confirms the general regularity of the high resistance of the PCM to the action of the climatic factors at the initial stage of aging.

5. References
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