Research Article

Mechanical tests of highly porous heat-protecting composite material

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Abstract. The paper considers the experimental problem of determining the physical and mechanical properties and stress-strain state of plates made of heat-shielding highly porous fibrous materials made of quartz fibers and differing in their structural structure (and, accordingly, in the properties of thermal conductivity, rigidity, strength). The modulus of elasticity and ultimate strength of the samples cut from the heat-shielding plate are determined, stress-strain diagrams are constructed.

Keywords: composite material, thermal protection, fibrous heat-shielding tiles, modulus of elasticity, tensile strength.

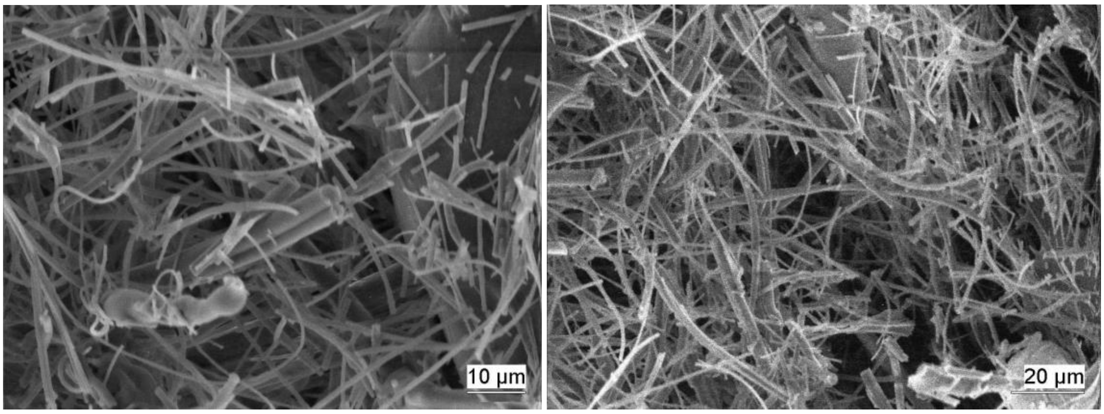
1. Introduction

At present, in the design of high-speed aircraft, one of the most important factors is the design of the thermal protection of the aircraft.

In the tile heat-shielding coating of high-speed aircraft, the main structural element is the heat-shielding element, which consists of fibrous heat-shielding tiles, erosion-resistant and varnished coatings, a damping pad and an adhesive that connects the damping substrate to the tile and the heat shield as a whole with the aircraft body. The main role in this is assigned to the heat-shielding tile. It is made of fibrous heat-shielding material and is a rigid spatial frame made of inorganic high-temperature fibers [1-17].

It is important to note that the mechanical and thermal properties of the heat-shielding material determine the fibers - their composition, structure, morphological features, etc. Undoubtedly, no matter how strong the fibers are, they must be sintered with each other and a strong bond must form between them in the places of their contact.

Plates made of fibrous composite material are used as a heat-shielding coating on modern aircraft. Their thickness is usually 4-10 cm. The coating is made of tiles measuring, for example, 20x20 cm. Such a coating was made for thermal protection of reusable space vehicles. Currently, new highly porous fibrous materials are being developed for the implementation of thermal protection of high-speed aircraft, and, in particular, hypersonic unmanned aerial vehicles.



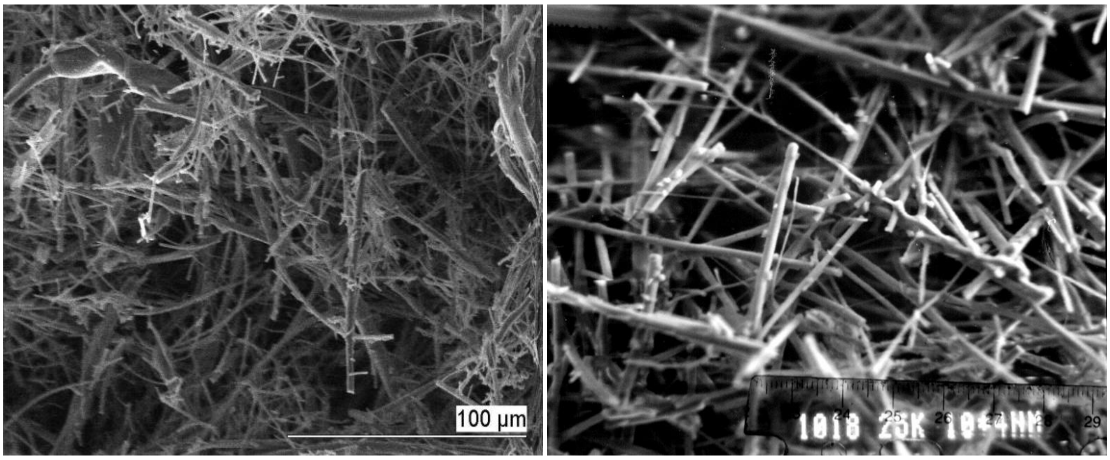


Fig. 1. Fibrous heat-shielding materials with a chaotic structure of fiber orientation.

There are many works on the identification of thermophysical and mechanical properties by methods of mathematical modeling. [18-26]. In works [26-39] the problems of thermal loading of the nose parts of high-speed aircraft with a coating of composite heat-shielding materials in a high-speed aerogasdynamic flow are solved. In [40-66] the problems of determining the mechanical properties of heat-shielding materials as well as obtaining of composite materials are solved.

This paper considers the experimental problem of determining the physical and mechanical properties and stress-strain state of plates made of heat-shielding highly porous fibrous materials made of quartz fibers and differing in their structural structure (and, accordingly, in the properties of thermal conductivity, stiffness, strength). The material TZMK-10 is considered as the initial material on the basis of which the model parameters are identified. For this material, all experimental studies were also carried out - the elastic modulus and ultimate strength of the samples cut from the heat-shielding plate were determined.

2. Test procedure

The main purpose of the test was to study the material of the plate of heat-shielding material (Figures 2 a), 2 b)) under axial compression and to determine its mechanical characteristics. During the test, nine samples were made.


Fig. 2 a) Sample of heat-shielding tiles.

Fig. 2 b) Sample of heat-shielding tiles.

Test procedure:

1. Sample preparation. Geometric measurements were taken with an electronic caliper.
2. Input of initial data in the Instron program, construction of the test method.
3. Balancing loads.
4. Calibration of the video extensometer.
5. Conducting compression tests at a speed of 0,8 mm/min.

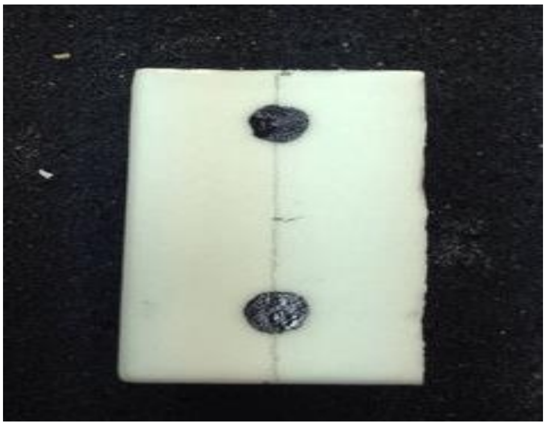


Fig. 3. Applied marks on samples.

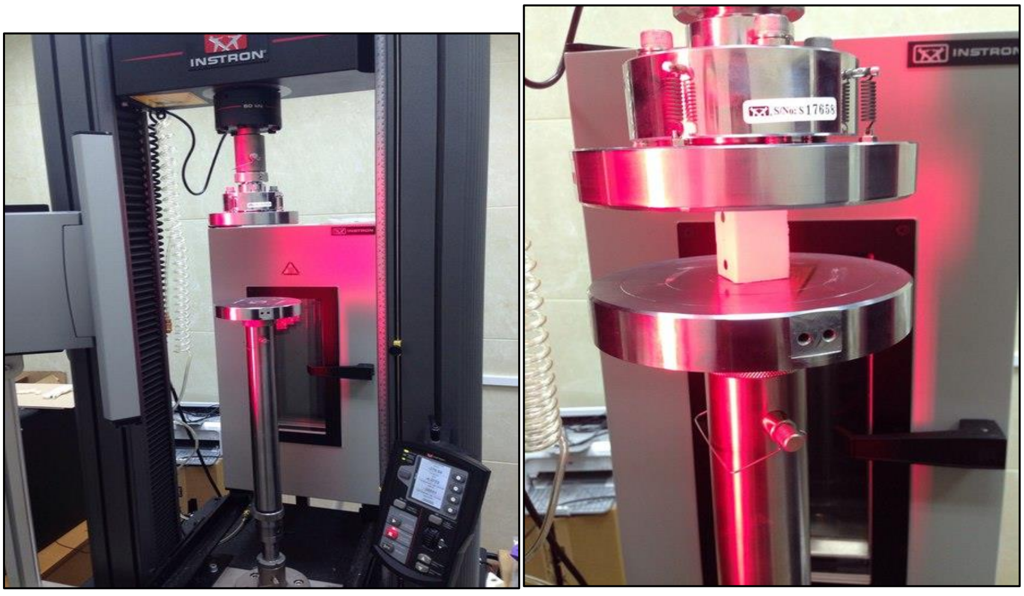


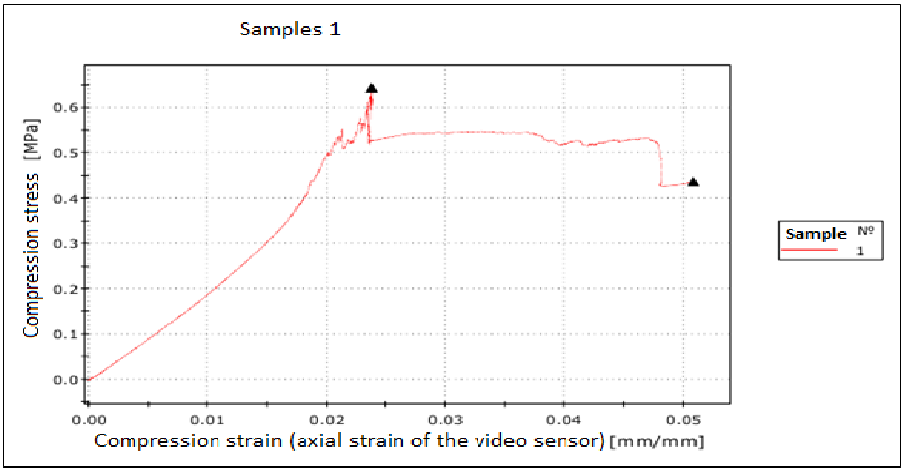
Fig. 4. Instron testing machine. Sample at the start of the test.

Fig. 5. Loss of stability of the sample. Sample destruction.

3. Mechanical test results

During the test, nine samples were made. To determine the required parameters, special marks were applied to the samples, Figure 2 b). Marks were placed on those surfaces of the samples, on which there was a thin coating, differing in properties from the material of the slab itself. These marks are required to measure material deformation under load using a video extensometer. Base (distance between marks) was 20 mm. As it turned out during the test, this was the wrong decision, out of nine tested samples, only one of them gave an acceptable result, and on its basis it was possible to obtain an acceptable stress-strain diagram, Figure 6. Further, in the process of searching for the cause of unsuccessful tests, it was decided to apply marks on other faces of the samples, free from the coating, that is, on the material of the plate itself. As it turned out, this solution yielded results, Figure 7.

Fig. 6. Stress-strain diagram for the sample 1.



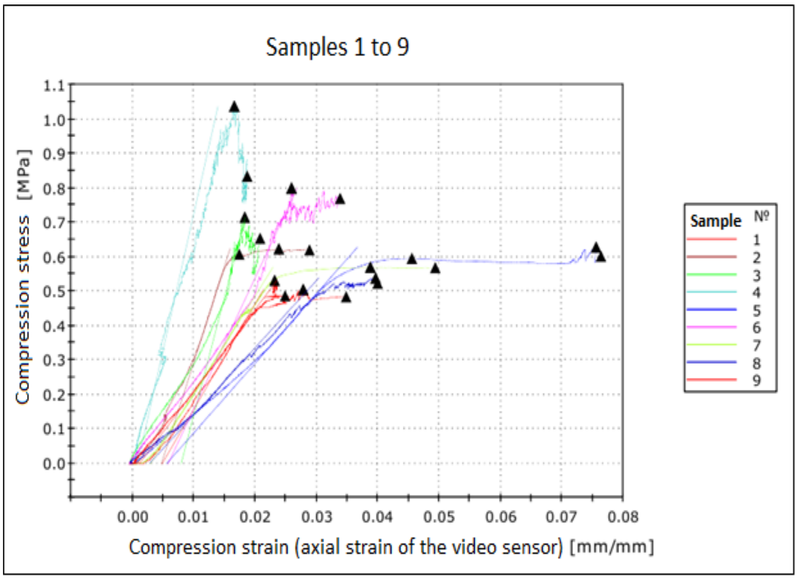


Fig. 7. Stress-strain diagram for repeated testing of samples 1-9.

Tab. 1. Mechanical characteristics of samples 1-9.

Sample №	Module, MPa	Maximum deformation	Tensile strength, MPa	Load, N
1	19,5	0,040	0,54	319
2	23,7	0,023	0,53	334
3	55,7	0,024	0,62	402
4	68,25	0,017	0,71	406
5	79,08	0,017	1,035	532
6	28,5	0,039	0,57	337
7	30,6	0,028	0,505	285
8	38	0,026	0,8	501,7
9	20	0,045	0,63	439

As a result of testing, the mechanical characteristics of the samples were obtained. The elastic moduli of sample №1 during the first test was 42 MPa, ultimate strength 0,64 MPa, deformation 0,024.

4. Conclusion

For a tile made of high-strength heat-shielding material, experimental studies were carried out - the elastic modulus and ultimate strength of the samples cut from the heat-shielding plate were determined, stress-strain diagrams were plotted.

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