Refractory ceramics, which have a number of important physical properties, have long been the subject of attention in developing structural elements in various branches of technology. However, unsatisfactory resistance to thermal loadings limit their practical application.

To increase the working efficiency of these ceramics when exposed to heat, attempts have been made to use them as a basis for composite structures, employing refractory oxide single crystals and the like for reinforcement [1, 2]. Since materials produced by this method differ from ordinary refractories somewhat, it was decided to demonstrate the peculiarities of their behavior under loading and to find the most suitable approaches to assessing their heat resistance.

The testpieces were made by semidry pressing at 500 kgf/cm and were fired at 1660°C for 4 h. Alumina with a grain size of 2 μ containing 98.9% aluminum oxide was used as the initial raw material, with a 1% addition of titanium dioxide. The reinforcing agent was laminar crystals of corundum (α-Al₂O₃) 0.2-0.5 mm long and 20-25 μ wide [3], either in the form of monocrystal plates or microbundles formed from several plates grown together along the basal planes. After firing, the test pieces were machined to the prescribed dimensions using a diamond tool.

The subjects of examination in the present communication were Al₂O₃ + 1% TiO₂ (material 1) without addition of laminar crystals, Al₂O₃ + 1% TiO₂ + 7% laminar crystals of α-Al₂O₃ (material 3), and Al₂O₃ + 1% TiO₂ + 15% laminar crystals of α-Al₂O₃ (material 5).

Since these materials differ considerably in structure, in assessing their heat resistance it is essential (according to [4]) to take into account both the characteristics of the material ultimate state such as strength, ultimate strains, and the modulus of elasticity, and peculiarities in their mechanical behavior under load. The parameter "measure of brittleness" was proposed in [4] to define the latter; it is equal to the ratio of specific elastic energy accumulated in the material by the instant of fracture to the total energy expended on its deformation:

\[ \chi = \frac{\sigma^2 \varepsilon_{ult}}{2E \int_0^{\varepsilon_{ult}} \varepsilon de} \]  

(1)

where \( \sigma \) is the tensile strength; \( E \) is the modulus of elasticity; and \( \varepsilon_{ult} \) is the ultimate deformation of the material (the relationship between \( \sigma \) and \( \varepsilon \) included in the integral is expressed by the deformation curve for the material).

Due to the lack of accuracy resulting from technical difficulties in finding the strength characteristics in tension of refractories, which are not readily deformable (\( \varepsilon_{ult} < 0.5\% \)), the compositions studied were tested in pure bending. The results of tests on compositions 1, 3, and 5 in which the force applied to the testpiece and the deformation of its stretched and compressed surfaces were recorded [5] are given in Fig. 1a. The deformations on each of these surfaces were recorded by two resistance strain gauges; this
made it possible to raise the accuracy of measurement and to plot the deformation diagram even when a breaking crack appeared under one of the sensors. The difference in the deformation magnitudes recorded on one surface of the testpiece did not exceed 2-3%. Control tests on steel (St. 3) and on glass testpieces were carried out before the investigations on materials of composition 1, 3, and 5, to check the efficiency of the measurement system. The static modulus of elasticity values calculated from the data from these experiments coincided fairly well (divergence not more than 1%) with the dynamic moduli of elasticity of these materials as determined in transverse testpiece oscillations.

On analyzing the diagrams (Fig. 1a) we observe that material of composition 1 is linearly elastic, but the nonlinearity during its deformation increases in proportion to the addition of α-Al₂O₃ lamellar crystals to it and differences become apparent in its behavior in tension and in compression.

The testing of materials of compositions 3 and 5 and processing the results of the experiment according to GOST 4738-72 based on the concept that ceramic materials under load follow Hooke's law lead to substantial errors in determining their strength (for example, the data in [6]). Peculiarities in deformation were therefore taken into account in calculating the strength characteristics of materials 3 and 5. It was proposed in [7] in processing the results of bend tests that the deformation diagrams should be approximated by a power, parabolic, or polygonal relationship to allow for nonlinearity. The following expression was used in [6, 8]:

\[ \sigma_{av,b} = \frac{a}{bh^2} \left( P + \frac{\varepsilon_{av}}{2} \frac{dp}{d\varepsilon_{av}} \right), \]

which is similar to the Karman-Ludvik formula. However, these approaches cannot be used for processing the results, because the difference in the resistance of the materials to tension and compression was ignored in them. This difference was taken into account in communication [9], but the nonlinearity of deformation curves for ceramic materials was ignored.

Following [10], both the nonlinearity of the deformation diagram and the differences in material behavior in tension and compression can be taken into account and the following formulas obtained for calculating the deformation curves:

\[ \sigma_+ = \frac{a}{bh^2} \left( P + \frac{1}{2} \varepsilon_{av} \frac{\varepsilon_{+}}{\varepsilon_{av}} \right) \left( 1 + \frac{\varepsilon_{-}}{\varepsilon_{+}} \right); \]

\[ \sigma_- = \frac{a}{bh^2} \left( P + \frac{1}{2} \varepsilon_{av} \frac{\varepsilon_{-}}{\varepsilon_{av}} \right) \left( 1 + \frac{\varepsilon_{+}}{\varepsilon_{-}} \right); \]

these are more general than those in [2] and flow from the equilibrium equations for a beam (Fig. 2) in pure bending

\[ \int_{-x_p}^{x_p} \sigma(z) \, dz = 0; \quad \int_{-x_p}^{x_p} \sigma(z) \, bx \, dz = \frac{P a}{2} \]

and from the hypothesis of two-dimensional sections. Here \( \sigma_+ \) and \( \sigma_- \) are the stresses on the stretched and compressed surfaces, \( \varepsilon_+ \) and \( \varepsilon_- \) are the strains, \( \varepsilon_{av} = (\varepsilon_+ + \varepsilon_-)/2 \) is the testpiece average strain; \( P \) is