IMPROVEMENT OF THE MECHANICAL CHARACTERISTICS OF IMPACT-RESISTANT AND ULTRAHIGHTEMPERATURE BORIDE- AND CARBIDE-BASED CERAMIC COMPOSITES

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The mechanical characteristics of impact-resistant and ultrahigh-temperature ceramic composites based on borides and carbides (such as B_4C-SiC, AlB_{12}-TiC, HfB_2-SiC, HfC-$MoSi_2$, ZrB_2-SiC, and ZrB_2-SiC-ZrC) have been significantly improved through high (4.1 GPa) and moderate (30 MPa) pressure sintering and the formation of solid solutions. These materials are ideal for protective applications like body armor for special forces, VIPs, helicopter and airplane protection, as well as for abrasive nozzles, ceramic bearings, and structural ceramics in nuclear power plants.

Elemental interdiffusion was confirmed by EDX and Auger spectroscopy, even when X-ray diffraction could not definitively confirm it. Composites based on B_4C-SiC and $AlB_{12}C_2$-TiB showed better mechanical properties than those reported for similar materials in literature. The dynamic strength of the ceramics was found to be 2-5 times higher than under static loading. These results were integrated into computer models for simulating armor penetration, utilizing numerical methods for solid mechanics, geometric modeling, finite element analysis, and deformation/destruction modeling. It is known that the processes of dynamic deformation and destruction of materials are extremely complex. Therefore, the models that describe them are also complex. Phenomenological models have many empirical parameters.

To describe the deformation of plastic materials, the model of an isotropic plastic material with kinematic strengthening, the Johnson-Cook Strength model, is used for low-plastic ceramic materials – the Johnson-Holmquist JH-2 (Johnson-Holmquist Strength Segmented) model.

The computer simulation consisted of two parts. The first is a comparison of the results of test calculations with the experiment, and the second is the determination of the impact of various design solutions on the load-bearing capacity of armor protection elements. The main indicators of the effectiveness of protection were the change in the speed of the bullet in the process of penetration and the size of the destroyed part of the package.

The test consisted in the numerical solution of the problem of piercing a square plate with dimensions $l \times l \times h = 60 \times 60 \times 10$ mm with a steel bullet with a diameter of $\Phi = 7.62$ mm (bullet caliber 7.62). The initial speed of the ball $V\_0=940$ m/s. A direct central strike was considered. Based on calculations with successive changes in the thickness of the plate, the maximum thickness of its penetration was determined, h=4 mm. An irregular grid of 8-node finite elements is chosen for the plate model. Around the projected point of contact between the sphere and the plate, thickening of the mesh occurred. Boundary conditions - rigid fixation of the outer contour of the plate. The contact between the ball and the plate is friction with a coefficient of 0.1.

It was established that the plate does not break through under the test conditions. During the penetration, the total mechanical energy of the ball decreases, and the plate increases. The ball flattens almost completely. This is evidenced by changes over time in the speeds of its various sections. The deformation of the plate is localized in a circular area with a size of about 3 diameters of the sphere. Significant spatial and temporal heterogeneity of the parameters of the stress-deformed state of the plate and sphere is observed. According to the results of the test calculation, the plate with a thickness of h=10 mm meets the conditions of armor protection. This conclusion is confirmed by the results of bench tests. Ballistic studies of protective bonded with polyurethane and wrapped in Kevlar or fiberglass showed that the plates withstand the impact of a bullet with a kinetic energy of W=3.4-3.7kJ. Comparison of the results of the experiment and the test gave reason to consider the numerical modeling correct.