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FAILURE OF MULTILAYER COMPOSITES UNDER DYNAMIC LOADING

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The field of material microstructure design targeted for a specific set of structural and functional properties is now a recognized field of focus in materials science and engineering. A new class of structural materials called metal-intermetallic laminate (MIL) composites can have micro-, meso- and macrostructure [1, 2]. The superior specific properties of this class of composites makes them attractive for high-performance aerospace applications, and the fabrication method for creating MIL composites allows new embedded technologies to be incorporated into the materials, enhancing their functionality and utility.

In this work numerical investigations have been done. The processes of high-velocity interaction of a projectile with a multilayer MIL composite target were numerically investigated in axisymmetric geometry using the finite element method. The set of equations for describing unsteady adiabatic motion of an elastoplastic medium, including nucleation and accumulation of microdamages and temperature effects, consists of the equations of continuity, motion, and energy [3].

To numerically simulate the failure of the material under high velocity impact, we applied the active-type kinetic model determining the growth of microdamages, which continuously changes the properties of the material and induce the relaxation of stresses. The strength characteristics of the medium (shear modulus and dynamic yield strength) depended on temperature and the current level of damage taking into account probabilistic approach to numerical simulation of fracture. The critical specific energy of shear deformations was used as a criterion of the erosion failure of the material that occurs in the region of intense interaction and deformation of contacting bodies. To simulate the brittle-like failure of the intermetallic material under high velocity impact, we modified the kinetic model of failure and included the possibility of failure above Hugoniot elastic limit (HEL) in the shock wave and sharp drop in strength characteristics if the failure begins.

In the computations, the target consisting from 17 composite intermetallic Al_3Ti - titanium alloy Ti-6-4 layers has been used. Total thickness of the target was 19.89 mm. Thicknesses of intermetallic layer and a layer of titanium alloy were varied. The penetrator used was a tungsten heavy alloy rod with initial diameter of 6.15 mm and length of 23 mm. Initial impact velocity was of 900 m/s.

The computations demonstrate the fact that the MIL composite target withstands the impact loading. The low level of microdamage in layers of titanium alloy shows the termination of propagation of brittle damage taking place in intermetallic layers. The results show that the depth of penetration depends on the thicknesses of intermetallic and titanium alloy layers. The MIL composite target withstands the impact loading in the case of 0.94 mm Al_3Ti / 0.23 mm Ti-6-4 (the ratio is about 4:1). In this case the intermetallic layer provides the failure of the projectile and the metal layer terminates the propagation of damage.

Results of computations demonstrate that the optimal composite target has higher ballistic resistance in comparison with a uniform target either Al_3Ti or Ti-6-4. Optimum construction of the composite target should include metal layer of sufficient thickness, which should provide the termination of propagation of brittle damage.

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