FAILURE OF THE MIL COMPOSITES UNDER SHOCK WAVE LOADING[1]

S.A. ZELEPUGIN, A.S. ZELEPUGIN, A.A. POPOV, D.V. YANOV

Tomsk Scientific Center SB RAS, 10/4 Akademicheskii Avenue, Tomsk, 634055, Russia, szel@yandex.ru, +7(3822)492294
National Research Tomsk State University, 36 Lenin Avenue, Tomsk, 634050, Russia, szel@dsm.tsc.ru, +7(3822)492294

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 metallic-intermetallic laminate (MIL) composites can have micro-, meso- and macrostructure. The superior specific properties of this class of composites make them attractive for high-performance ballistics applications [1, 2].

In this work 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. 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. 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.

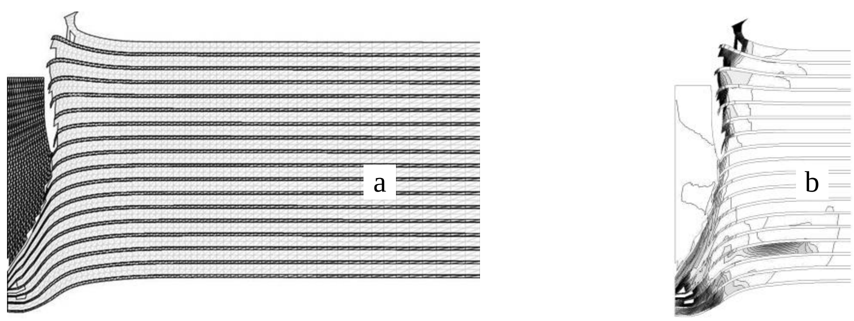

Fig. 1. Computer images with a radial section of the projectile/target assembly (a) and specific volume of microdamages (b) at 60 μs

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 93W-7FeCo rod with initial diameter of 6.15 mm and length of 23 mm. Initial impact velocity was of 900 m/s. Fig. 1 shows the configurations of the projectile and MIL composite target and the contours of the specific volume of microdamages at the time of 60 μs. Results of computations demonstrate that destruction of the intermetallic layer is brittle as against to plastic failure of the metal layer. The intermetallic layer provides the failure of the projectile and the metal layer terminates the propagation of damage. The results show that the depth of penetration depends on the thicknesses of intermetallic and titanium alloy layers. The composite target withstands the impact loading in the case of the ratio about 4/1 (Al_3Ti / Ti-6-4).

REFERENCES

[1] *Cao Y., Zhu S., Guo C., Vecchio K.S., Jiang F. // Applied Composite Materials. - 2015. - Vol. 22. - P. 437–456.*
[2] *Zelepugin S.A., Mali V.I., Zelepugin A.S., Ilina E.V. // Shock Compression of Condensed Matter. USA: American Institute of Physics. - 2012. - Vol. 1426. - P. 1101-1104.*

[1] This work was supported by the Russian Science Foundation (RSF), project no. 16-19-10264.