Development and Study of Laminated Aluminum-Ceramic Armor Materials

Ye. F. Kharchenko, I. A. Kurmashova,
Ye. A. Solovyova

TSNIISM JSC

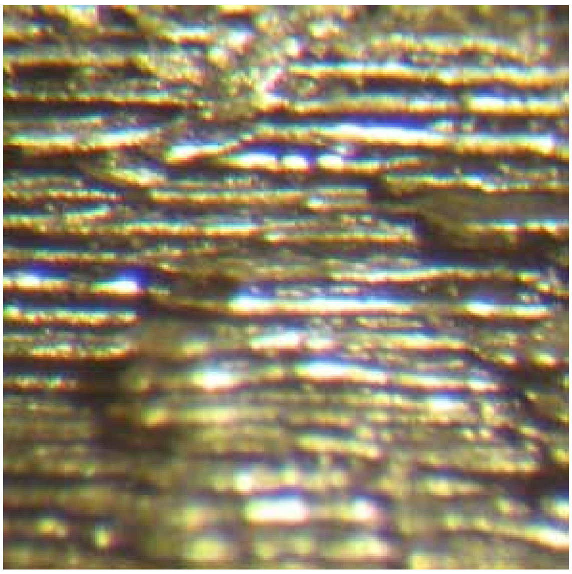
At present ceramic materials found a wide application in body armors. Physical and mechanical properties of ceramics are determined by chemical-bond character and crystalline structure. Chemical bond in ceramics is ionic or mixed ionic-covalent that explains its low plasticity, high rigidity and hardness and relatively high level of compression strength [1]. In particular, ceramics obtained by traditional hot pressure (powder baking) method has Vickers hardness of ~2000 MPa.

There are methods for obtaining ceramics by electrochemical anodization of aluminum in salt or acid solutions, for example, in sulfuric acid with concentration of 170 to 200 g/liter at current density of 1 to 2 A/dm^2 with a thickness up to 70 µm. In some other types of electrolytes and anodization methods, the thickness of anodic layer can reach 300 µm. The aluminum oxide films obtained by this method represent porous ceramic structure with high mechanical impact strength: its hardness reaches from 5000 MPa to 6500 MPa.

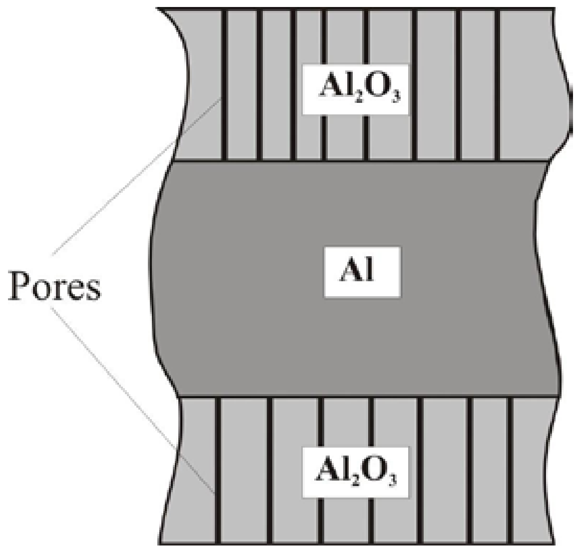
In this work, oxide films were obtained using aluminum foil up to 100 µm thick. A plate obtained as a result of anodization process is a sandwich with plastic aluminum as inner layer and two outer ceramic layers of aluminum oxide (Figure 1).

At the first stage of work, the plates in the number from 18 to 28 pcs were connected using film polymeric adhesive 220 µm thick.

To evaluate ballistic efficiency of plates obtained, tests for determining the dependence of ballistic efficiency parameter upon initial rate of an indenter were conducted. A steel ball 6.3 mm in diameter and 1.06 g in weight was used as the indenter. About 20 shots were fired at each sample. Maximums of obtained curves determine values of speeds for which protection of this type of armor is the most effective (Figure 2), i.e. this armor should show the most efficiency at speeds of ~430 m/s.



a



b

Figure 1. Multilayered anodized plate:
a - photograph of plate surface;
b - schematic of one layer of anodized plate.

A failure pattern of armor under study is of a particular interest. Around the opening there are concentric circles, their diameter near the opening (fragment entrance place) grows with increasing the fragment speed, and the opening diameter (fragment exit place), on the contrary, decreases with increasing the fragment speed (Figure 2). The tested sample remains plane practically until speed of 700 m/s that testifies to its vitality. At speeds of 650 to 700 m/s, the ballistic efficiency curve increases that gives preconditions for using the developed plate in making hybrid armor with aramid fabrics, ceramics and others. Value V_{50} for the sample with a backing of aramid fabric was 694 m/s.

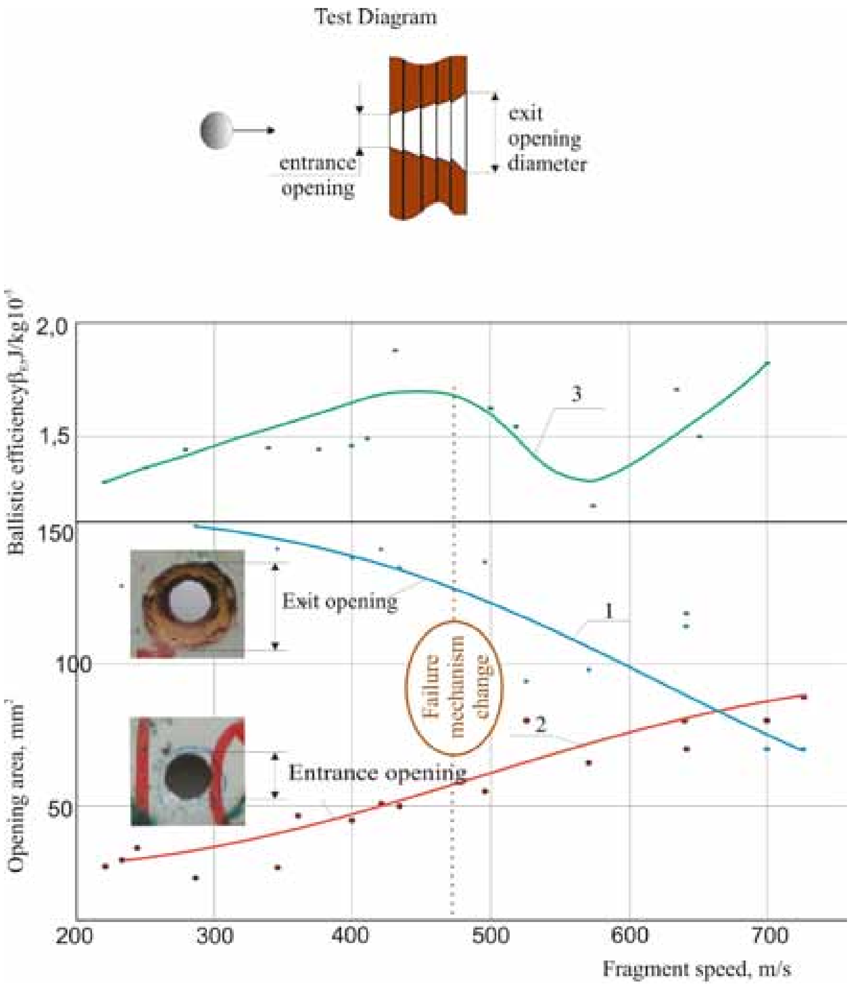


Figure 2. Failure area (1, 2) and ballistic efficiency BE (3) of the sample made of 18 layers of oxidized aluminum foil (surface density of ~6.9 kg/m2) cemented with polymer film as a function of fragment speed.

The test results show that the presence of ceramic layer on aluminum substantially increases the armor plate vitality: a sample measuring 10 cm x 15 cm remains practically plane after 18 shots, although in the indenter entrance and exit place there are concentric "funnels". The developed armor plate was found effective over the range of speeds corresponding to the second (II) protection level according to GOST R 50744-95 that creates the preconditions for developing more lightweight II-level armor. Also, the aluminum-ceramic armor with surface density of 7 kg/m^2 showed a result similar to steel armor with surface density of 17 kg/m^2. Furthermore, there is a possibility of further decrease of the armor plate weight and thickness at the expense of selection of more thin film-forming adhesives.

Literature

1. *1. A.Yu. Letnikov, I.F. Kobylkin and I.V. Kulakov State and development outlooks of protective armor-clothes structures // Double Technologies, 1998, № 2. C. 81-82.*