Application of Synthetic Mineral Alloys as Materials for Bulletproof Vests and Products for Different Objects Protection

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***Abstract* – Authors study ballistic properties of the material which has never been used for impact protection and the presented results prove that synthetic mineral alloys belong to the field of bulletproof ballistic protection and particularly to the means of objects' protection from kinetic threats. Although the material has been described in connection with such specific embodiments as SVD and a cumulative jet, it is evident that many alternatives and modifications of their application for various protective articles are possible.**

***Keywords* – bullet resistant material, cumulative jet resistant material, non-metal materials, synthetic mineral alloys.**

1. Introduction

Earlier the protection against high velocity projectiles and explosives was used only by military forces, but at present, for the reason of the number of terrorist attacks growing, the protection from this kind of threats contributes to the demand for bullet - and shockwave resistant elements of uniform in many kinds of professions (airport staff, emergency doctors and others) and for many kinds of constructions, for example, materials for waste receptacles in public places or for the protection of passenger trains. The common materials for bullet-proof uniforms and constructions are non-metal materials based on ceramics, because they have high ballistic resistance properties and low densities [1]. But ceramics is an expensive material and the technology of ceramic elements production is limited by the nomenclature of shape and size. Therefore the development of alternative materials for bulletproof vests, products for protection and different objects is actual.

One of the alternative materials for bullet and shockwave threat is synthetic mineral alloys. Synthetic mineral alloys, produced by silicate raw melting, after thermal processing give the final material consisting of different crystal phases (spinel, pyroxene) and the glass-phase; the crystal phase includes separate mineral-groups of high hardness (approximately 10-12 GPa (Vickers)) and pyroxene phase. The method of making products from these materials is casting. It represents the main difference from ceramic, because articles of any shape and size can be produced from alloys' casting; it means that the elements of half sphere or pyramidal forms can be produced. Some researchers describe studies which prove that this type of form can improve bullet and impact resistance characteristics. Those materials have high compressive strength (200-300 MPa), low thermal expansion ((5-25)•10-6 K-1 at temperature 100-1000˚C), are impermeable to gases, liquids, biohazards and are resistant to thermal shock [2], [3], [4]. Synthetic mineral alloys have never been used as protection from any impact before, because they are fragile materials. Some our studies show that synthetic mineral alloys can dissipate kinetic energy under high velocity impact through non-dislocation mechanism of deformation; this effect is possible for synthetic mineral alloys only under high stress in short time period [5], [6], [7].

2. The aim

The goal of the study is the disclosure of synthetic mineral alloys' characteristics as of the materials for bulletproof vests elements and other protection products.

3. Objects of study and methods

To disclose the possibility of synthetic mineral alloys' in bullet resistant and related applications usage we did experimental studies. For ballistic properties evaluation we used the rules from the Russian standards of Body Armor Ballistic Resistance (State Standards : P 51136-98, P 51112-97, P 50941-96) likewise the NIJ 0101.04. We used a cumulative jet test to evaluate the possibility of our material's usage for different objects' protection.

The ballistic test included two stages: shooting and results evaluation (penetrated or not penetrated) and the study of destroyed elements and elements parts' of plates made of synthetic mineral alloys.

To make the samples, we used two types of synthetic mineral alloys, which differ from each other in the concentration of Cr_2O_3, the way of thermal processing and, as a result, in structures. Fig. 1 shows the structure of synthetic mineral alloys samples.

4. Results of shooting experiments

Synthetic mineral alloy samples for shooting were made of four parts, each had size 150x120 mm, the final size of samples was 300x240 mm, the thickness was 13 mm. The parts were joint to each other with a special polymer substance. The samples were wrapped in twaron with the help of glue, two layers on the front surface and four layers on the back surface. The layers of twaronwere stacked crosswise. After being wrapped, the samples were dried in furnace in vacuum at 130°C.

Table 1. The Results of samples' made of synthetic mineral alloys shooting

The characteristics of weapons' types and tests results	The type of weapon		
	The PM (Pistolet Makarova - Makarov's Pistol)	AK-74	SVD Dragunov
The type of cartridge	9-mm 57-H-181C	5,45-mm 7H6	7,62-mm 57-H-323C
The type core of cartridge	steel	steel	steel
Mass, gram	5,9	3,4	9,6
Velocity, m/s	305-325	890-910	820-840
Distance, m	5	7	7
The Result for two type of samples	No penetration	No penetration	1 type - no penetration 2 type - Penetration

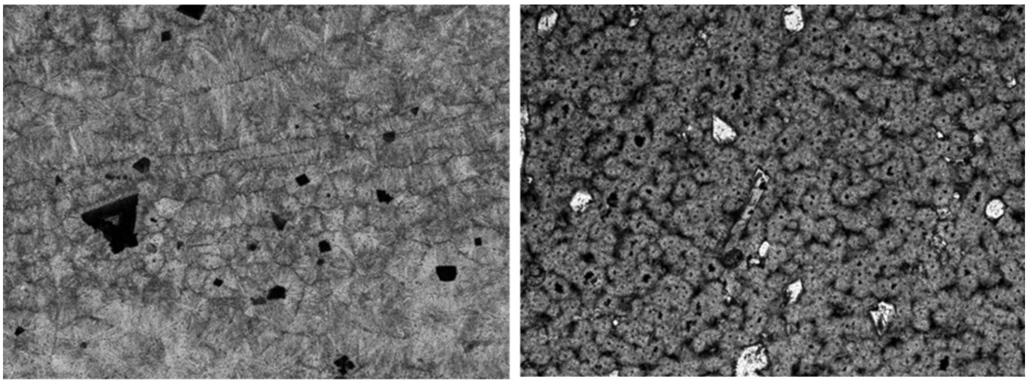

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Figure. 1. The structures of synthetic mineral alloys: (a) first type, (b) second type

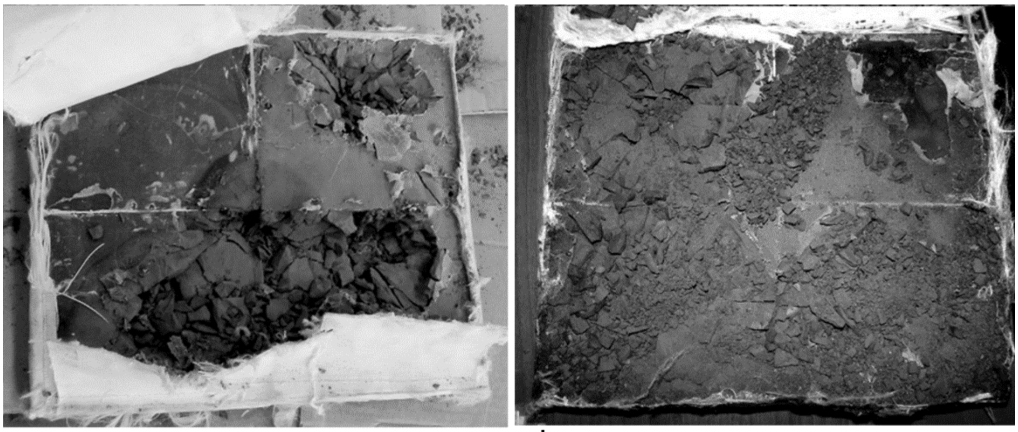

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Figure. 2. Opened samples after shooting (a) first type synthetic mineral alloy (b) second type synthetic mineral alloy

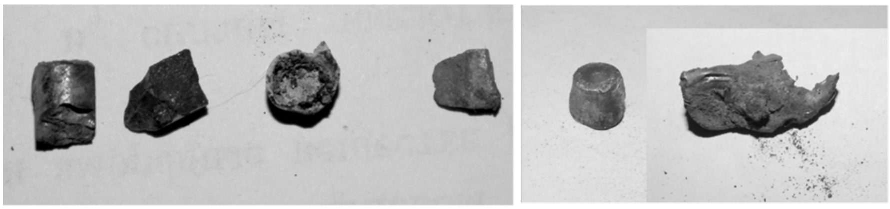

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Figure. 3. Fragments of core and copper jacket of bullet (a) first type synthetic mineral alloy (b) second type synthetic mineral alloy

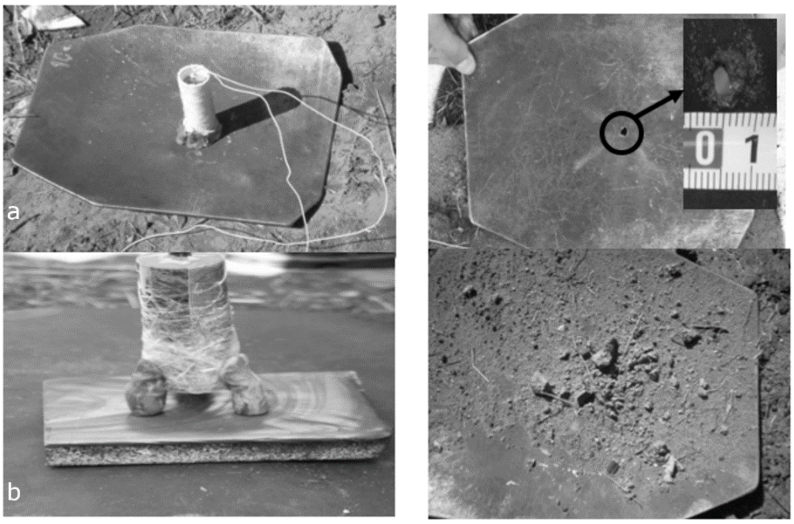

Fig.4. The results of cumulative tests: a) control test б) synthetic mineral alloy test

The highest level of body armor according to Russian standards is VIa (by SVD with armor piercing incendiary cartridge). The results of the first type of synthetic mineral alloys samples'shooting with different substrates:

1. Back plate is 13 layers of twaron. The shot was directed into the place of parts joint. Result – the sample was penetrated.
2. Back plate is 13 layers of twaron. The shot was directed into the middle of sample's upper left part at the distance of 95 mm from the first shot. Result – penetrator-core was stuck in the plate.
3. Back plate is steel with carbon content of 0,25%, the thickness is 2,2 mm. The distance from parts'joint was 110 mm. Result – no penetration.

The results of the second type of synthetic mineral alloys samples' shooting with different substrates:

1. Back plate is 13 layers of twaron. The shot was directed into the place of parts' joint. Result – the sample was penetrated.
2. Back plate is 13 layers of twaron. The shot was directed into the middle of sample's upper left part at the distance of 95 mm from the first shot. Result – no penetration.
3. Back plate is 13 layers of twaron. The shot was directed into the middle of sample's upper right part at the distance of 95 mm from the first shot. Result – the sample was penetrated.

The results of tests with the other types of weapon are represented in table 1.

After shooting the samples were opened from the back surface (fig. 2) and the way of destruction and plate fragments were studied. In the first type sample, which shows us a more stable result, the craters have smaller size than in the sample made of the second type of synthetic mineral alloys; the surface of fracture is non-shining and uneven(not like with ceramics); radial cracks expand in the impact zone. In synthetic mineral alloys of the second type radial tensile cracks spread all over the plate. Various cracks formed in the sample lead to the formation of coarse chunks as well as of fine powder. The conoid cracks in the first type sample are closer to each other, and the fragments' fraction in the contact zone with the bullet is less than in the second type sample. The differences between the deformation and destruction of bullets themselves are even more interesting. The fragments of core and copper jacket were found among the sample's fragments of the first type (fig. 3); the bullet core was destroyed. In the second type sample's fragments only the copper jacket without severe strain was found.

5. Result of cumulative jet test

Cumulative jet test was carried out on firing field. For the creation of a cumulative jet we used TNT (50 g), detonator, cumulative jacket – conical funnel made of steel with the thicknessof 0,8 mm (h=45mm, Ø=30 mm.)

The scheme of experiment is shown in fig. 4.: a cumulative charge was placed on top surface of sample made synthetic mineral alloy (plate - 180x120x15 mm), the synthetic mineral alloy sample was placed on the top surface of an armor steel plate (thickness – 7 mm).

To carry out a comparative evaluation the parallel control test was done. At this test the cumulative charge was placed on the armor steel plate's top. In both tests the distance of 30 mm was left between the charge and the surface of the top layer to form the cumulative jet correctly. As the result of control test the cumulative jet penetrated the steel plate (diameter of crater is 2-3mm), the plate was deformed and the crater was formed in the ground under the plate. As the result of the test with synthetic mineral alloy, the steel plate under the sample wasn't fractured. The synthetic mineral alloy sample was destroyed.

To describe the ground of synthetic mineral alloys resistance to cumulative jet, the reviews of the principle of reaction between armor and cumulative jet should be made. At the moment when the cumulative jet hits the protection, the point of contact has maximum stress. In the perpendicular direction from the contact point, stress is reduced to zero in the border of the crater. The material of armor moves into the zone of minimal stress, as at a plastic deformation. The lower the ability to deformation is, the smaller the damage of armor becomes. Synthetic mineral alloys have poor ability to plastic deformation, because they are fragile materials and their deformation process includes sequential series of stress and relaxation accumulation, representing an intermittent process. This way of deformation liquidates the jet, because the multiple ricochets of the latter aredeveloped.

6. Conclusion

Practical tests on a landfill by shooting from different types of firearms were used for the evaluation of the possibility to use synthetic mineral alloys for bulletproof products. Synthetic mineral alloys (prepared as above stated) were tested in accordance with the Russian standards of Ballistic Resistance of Body Armor (State Standards:P 51136-98, P 51112-97, P 50941-96) likewise the NIJ 0101.04 and shown to effectively neutralize kinetic threats at the I-IV level. The cumulative jet test shows that synthetic mineral alloys can neutralize kinetic energy of that threat. The present results prove that synthetic mineral alloys belong to the field of bulletproof ballistic protection and particularly to the means of objects' protection from different threats.

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