

THE SYNTHETIC MINERAL ALLOYS AS MATERIAL FOR BOMB RESISTANT WASTE RECEPTACLES

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Abstract: *These results characterize synthetic mineral alloys as material with a good capacity for energy dissipation. In the process of a high velocity impact on synthetic mineral alloys, the kinetic energy is transformed into the wave energy, which is proof that structure of synthetic mineral alloys kinetic energy dissipated experiencing multiple conversions with transformation of structure. The present results prove that synthetic mineral alloys relates to the field of bomb resistant and specifically to methods and articles for protecting an object from kinetic threats. Although the material has been described in conjunction with specific embodiments, it is evident that many alternatives, modifications and variations thereof will be apparent to those skilled in the art.*

Keywords: BOMB RESISTANT, KINETIC ENERGY ABSORPTION, BULLET PROOF, SAFETY

Blast mitigation devices, such as bomb resistant waste receptacles, are being deployed to replace one of the softest terrorist targets- trash receptacles. Trash receptacles, which are a necessity for waste management pose a serious threat to public safety and infrastructure security, considering how easily they can conceal an explosive device planted by a terrorist. The trash receptacle becomes part of the attack and maximizes the intensity of the explosion by spraying shrapnel and fragmentation at great distances. It must also be understood that a terrorist attack using ordinary trash receptacles and remote activated or time delayed explosive devices can be easily coordinated to strike multiple places simultaneously or in stages without exposing the terrorist.

One of effective way to eliminate issues of potential dangers of waste receptacles is using especial materials for producing these products. We offer use as bomb resistant material the synthetic mineral alloys. Synthetic mineral alloys relates to the field of materials and including high hardness mineral-group crystal phase (approximately 10-12 GPa (Vickers)) and pyroxene phase, methods of making this materials and products are casting. This materials have high compressive strength (200-300 MPa), low thermal expansion ($(5-25) \cdot 10^{-6} \text{ K}^{-1}$ at temperature 100-1000°C), are impermeable to gases, liquids, biohazards and are resistant to thermal shock [1-2].

The goal of study is disclose possibility of use of the synthetic mineral alloys in bomb resistant and related applications, primarily as material for waste receptacles and products for protection an different objects.

The structure and composition of synthetic mineral alloys are similar to those of mafic and ultramafic igneous rocks. The structure contains a synthetic mineral alloys amorphous phase (2 to 30%) and two or more mineral phases. Siminals are not glass-crystalline materials because they are not crystallised using catalysts. Siminals contain an average of 50% SiO₂; therefore, synthetic mineral alloys melts often split into two liquid phases. The structure of siminals represents a special case of a condensed medium. Some studies noticed that the main part of material fore protection devices have untypical deformation mechanism in hypervelocity impact action - undislocation. Amorphous and composite materials with a heterogeneous structure, which include synthetic mineral alloys are most susceptible to deformation undislocation mechanism than others [3].

Some studies noticed that the synthetic mineral alloys can be similarly of a glass-ceramics having spinel-group crystal phases used for bomb and bullet protection, but the synthetic mineral alloys have a relatively low cost of production than prevalent materials, because these materials can be produce from a man-made raw materials. Products made from synthetic mineral alloys can be any size and any shape, because a raw materials is cheaper than traditional ceramic or glass raw materials and technology of casting permit make product any configuration. For disclose possibility use of the synthetic mineral alloys in bomb resistant and related applications we made experimental studies.

Experimental studies were held on pneumatic installation high-speed penetration (fig. 1), apparatus for dynamic compressive strength tests (fig. 2) (velocity of impact 60-650 m/s) [4-5], tests on landfill by shooting from different type of firearms and Electromagnetic Induction Launcher EML (railgun, velocity of impact 2800-3000 m/s). In experiments with pneumatic installation high-speed penetration and apparatus for dynamic compressive strength results were fixed heat the sample back surface by using an infrared camera CEDIP Silver 450M (tab. 1 and 2).

Table 1: Results of experiments on the high-speed destruction of synthetic mineral sample alloys by using pneumatic equipment

No test	Parameters of the punch	Impact velocity, V m/c	Temp T _{max} , °C	The point of impact
1	cylindrical shape (L=50mm, Ø5mm, M=7,4g)	650	114	upper
2	cylindrical shape (L=45mm, Ø5mm, M=6,8g)	125	43	middle
3	cylindrical shape (L=45mm, Ø5mm, M=6,8g)	80,6	110	bottom
4	cylindrical shape (L=45mm, Ø5mm, M=6,8g)	49,5	70	middle
5	spherical shape (Ø6mm, M=1g)	65	121	bottom

Table 2: Results of experiments on the high-speed destruction of synthetic mineral sample alloys by using dynamic compressive strength tests equipment

No test	Speed impact of the punch on the rod, V m/c	Temp T _{max} , °C	The point of impact	The maximum value of stress, Pa	The maximum strain rate, 1/s
1	22,7	185	upper	$3 \cdot 10^8$	$3,0 \cdot 10^3$
2	25	175	middle	$4 \cdot 10^8$	$2,5 \cdot 10^3$
3	23,1	101	bottom	$5,8 \cdot 10^8$	$2,8 \cdot 10^3$
4	24	195	middle	$4,3 \cdot 10^8$	$2,6 \cdot 10^3$

Result of study show that the parameters of fracture of sample depend of reference point. Found that at a strain rate $\sim 2,5 \cdot 10^3$ 1/s, samples are destroyed into fragments smaller than 0.5-1 mm (it is approximately size of crystalline aggregates in the structure, aggregates contains from three type of mineral phase). Dependence of the strain rate on the value of stress has not linear character is predominantly parabolic curves. Temperature surface sample at the moment of fracture is 40 – 195°C. Heating of the back surface of sample was uneven, on the back surface of the sample was found

areas with the highest temperature, the higher the impact rate, the greater these areas [6].

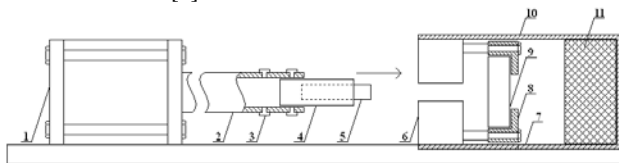


Fig. 1. The scheme of pneumatic installation of high-speed penetration: 1 – chamber of high pressure, 2 – gun, 3 – photosensor; 4 – holder for puncher, 5 – puncher, 6 – device for separating puncher from holder, 7 – stabilizing casing, 8 – holder for target, 9 – target (sample), 10 – receiving chamber, 11 – trap for particles of fracture

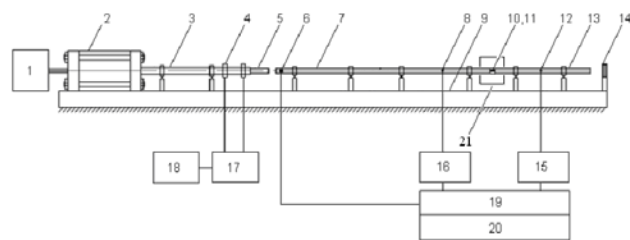


Fig. 2. The scheme apparatus for dynamic compressive strength tests (plate impact): 1 – compressor; 2 – accelerator; 3 – gun; 4 – photodiode speedometer; 5 – puncher; 6 – piezocrystal; 7 – load bar; 8, 12 – tensor resistors; 9 – stabilizing casing; 10, 11 – sample, mirror; 13 – support bar; 14 – buffer; 15, 16 – device for signal amplification with tensor sensors sensor; 17 – device for sensor of measurement velocity; 18 – device for frequency measurement; 19 – main sensor; 20 – PC, 21 – holder for mirror

The phenomena of heating on surface in the moment of impact can be due to exemption some of the energy of chemical bonds.

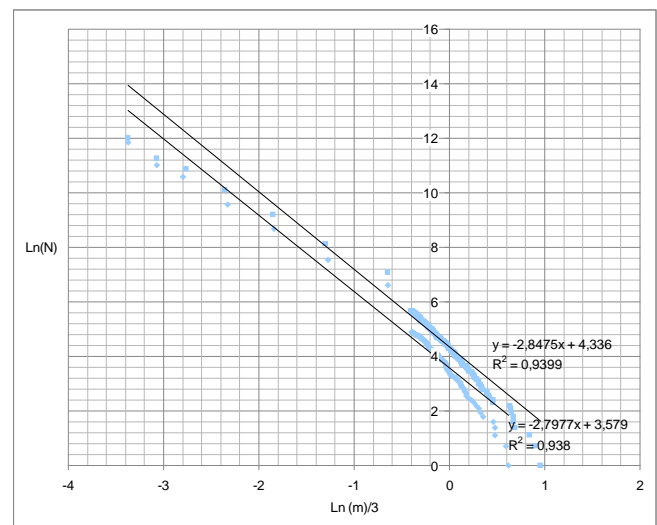
Practical tests on landfill by shooting from different type of firearms [7-8] was used for evaluation ability of using synthetic mineral alloys for bulletproof products. All the synthetic mineral alloys plates prepared as above were tested in accordance with Russian standards of Ballistic Resistance of Body Armor (GOSTs 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. No penetration through the glass- ceramic plates was observed in most part of tests. The results of tests represented in table 3.

Table 3: The Results of shooting of samples from synthetic mineral alloys

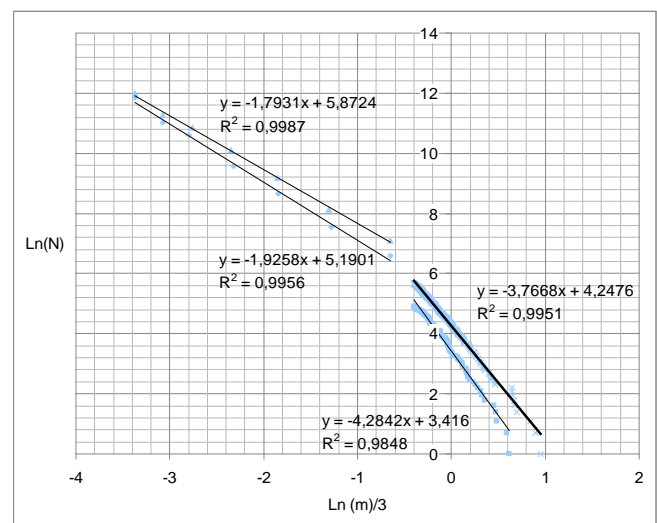
The characteristic of type weapons and condition of tests	The type of firearms			
	The PM (Pistolet Makarova - Makarov's Pistol)	AK-74	SVD Dragunov	SVD Dragunov
The type of cartridge	9-mm 57-H-181C	5,45-mm 7H6	7,62-mm 57-H-323C	7,62-mm 7-B3-3
The type core of cartridge	steel	steel	steel	hardened steel
Mass, gram	5,9	3,4	9,6	10,4
Velocity, m/s	305-325	890-910	820-840	800-835
Distance, m	5	7	7	7
The Result	stop or partial penetration	stop or partial penetration	stop or partial penetration	partial penetration or penetration

Hypervelocity impact made using a punch from Lexan with rate 2800-3000 m/s, rate of punch was accelerated by Electromagnetic Induction Launcher EML (railgun) [9].

Two types of samples of material were used, both types of samples had a disk shape with a diameter of 80 mm. The height of the first kind of samples was 33 mm, and the second - 100 mm. The target sample was placed at a distance of 0.45 m from the muzzle of the railgun.



a



b

Fig. 3. Cumulative distribution function of the target fracture fragments: a - sample D = 80 mm, h = 33 mm at a rate punch V = 2800 m/s, b - sample D = 80 mm, h = 100 mm at a rate punch V = 3000 m/s

For evaluation of the results was used by fractional analysis, scanning electron microscopy and X-ray microprobe analysis. Cumulative distribution functions of fracture fragments by size are shown in Fig.3 The study by scanning electron microscopy was revealed spherical particles (Fig. 4 [10]) among fragments of destruction. These spherical particles are composed of iron oxide according to microprobe spectrum analysis, the structure they are similar to the aerosol particles. Among the fragments of destruction have been found yet amorphous particles and fragments with signs of plastic deformation, while the plastic deformation isn't peculiar for synthetic mineral alloys[11-12]. Research by rate 2800-3000 m/s indicated that for these materials is typical ultrafine grinding and changing the crystal structure defects, aerosol formation, amorphization, and beginning mechanism of the plastic deformation.

A kinetic threat impacting ceramic armor is deformed and the kinetic energy dissipated by inelastic deformation of the armor through a combination of a pulverization energy mechanism and a fracture energy mechanism. In the fracture energy mechanism, kinetic energy is absorbed by the plate from synthetic mineral

alloys, distributed throughout the plate and subsequently expended by the shattering of the plate itself along many radial and circumferential cracks. In the moment of impact in structure of materials as synthetic mineral alloys can be local heating as one of stage of absorbed kinetic energy.

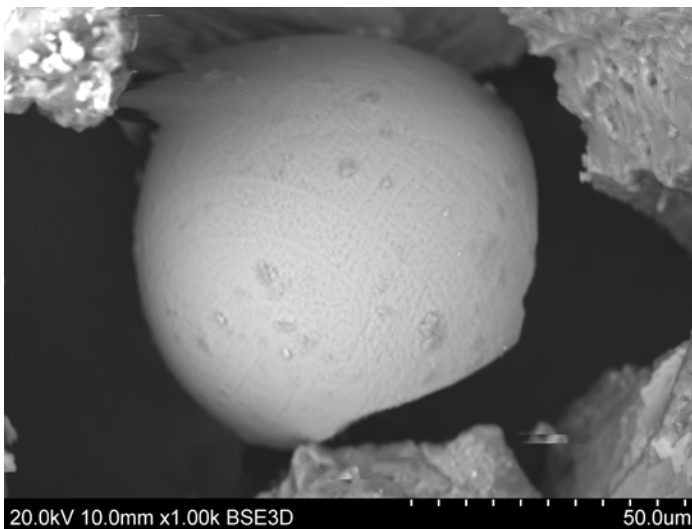
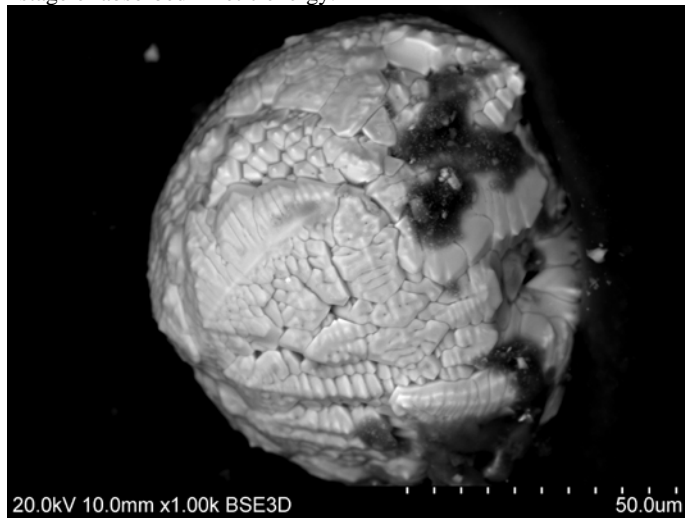


Fig. 4. Spherical fragments after shock wave action

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