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COMBINED BULLETPROOF AND ANTICUMULATIVE LIGHTWEIGHT ARMOR

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In order to protect armored vehicles from kinetic and small-caliber shaped-charge ammunition (SCA) it is necessary to use bullet-resistant armor [1] as well as shaped-charge-resistant explosive reactive armor (ERA) [2] with significantly reduced level of shock impact loading on protected object. It is common to use ceramic-metallic or ceramic-composite double-layer target with ceramic outer layer to achieve enhanced bullet-resistance [3, 4]. The usage of the traditional ERA is constrained by significant impact of the driven steel plates on the protected object. In present paper, a structure of conjoined combined armor is described. The armor protects vehicles from kinetic energy projectiles as well as from small-caliber SCA and preserves the affordable level of shock impact on protected object (fig. 1).

The usage of shaped-charge-resistant ERA with ceramic outer layers was substantiated in papers [5, 6]. It is experimentally established that due to dispergation explosive driven ceramic liner, used in ERA, reduce impact loading on protected object in comparison with metallic liners but the level of protection from cumulative jet is preserved and even increased in case of identical mass of the metallic and ceramic plates. The prolonged impulse of the explosive driven ceramic plates leads to a reduction in its amplitude, and this is a physical explanation to a lower impact loading on the protected object.

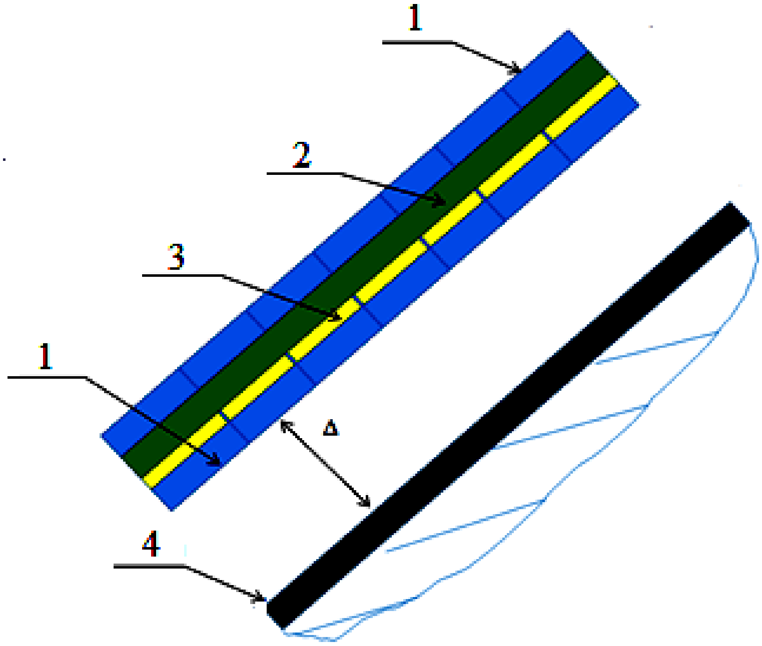


Figure 1. Structure of combined bullet-resistant and shaped-charge-resistant armor: 1 – discrete ceramic layer; 2 – sub layer; 3 – HE layer with detonation diodes; 4 – damper

One or two rows of the ERA elements are located behind the bullet-resistant structure in the combined armor. They consist of a flat HE charge with detonation diodes [4] and discrete ceramic plates (fig. 1). The detonation diodes are expected to drive the detonation in the only direction, upward in the ERA element, which allows to decrease the mass of the HE charge and thus to reduce the shock impact of the ERA outer layer on the protected object. A discrete ceramic layer is used as an outer liner. When explosive projection occurs, ceramic plates fragmentize and the dense stream of the fragments effectively disrupts the jet and provides a low impact on the more distant protected object with collision.

An X-ray radiography of the process of explosive ceramic plate projection on a static copper wire was used in order to verify the effectiveness of the jet disruption by the dense stream of the fragments. The scheme of the experiment and the results are shown on fig. 2a and 2b.

SiC ceramic plate (50x50x10 mm) was driven by the detonation products of the sliding detonation in plastic-bonded explosive PVV-5A (23 g) and was projected on copper wire with the diameter of 1.8 mm, stretched between two supports at an angle of 30° with the plate. It is possible to make a conclusion from the results (fig. 2b) that the stream of the fragments distorts and collapses the wire, cutting it locally. Maximal speed of the fragments was 558 m/s. Yield of the wire at t = 65 μs was 2.44 mm, at t = 83 μs – 5.11 mm. Lateral velocity of the wire was 148 m/s, but considering the velocity of the jet element which is 8000 m/s, lateral velocity will go down to 50 m/s.

Bullet resistance of the combined armor was estimated using the analytical model of ceramic-metallic target perforation [3], structure of the armor was optimized using the criteria of maximal penetration speed with constant areal density. Some results are shown in table 1. B_4C armor structures have the least mass per meter, but considering the expensiveness it is proposed to use double-layered SiC structures. In order to protect the object from 12.7 AP bullet B-32 the armor must be 7 mm thick. VT23 titanium alloy 3.6 mm thick was used as the sub-layer. Such structure has the least mass per meter.

A numerical simulation of 12.7 AP B32 interacting with the target at 60° was conducted using a three-dimensional dynamic finite element program of LS-DYNA with the SPH algorithm in order to validate the characteristics of the armor. The results are shown in figure 3.

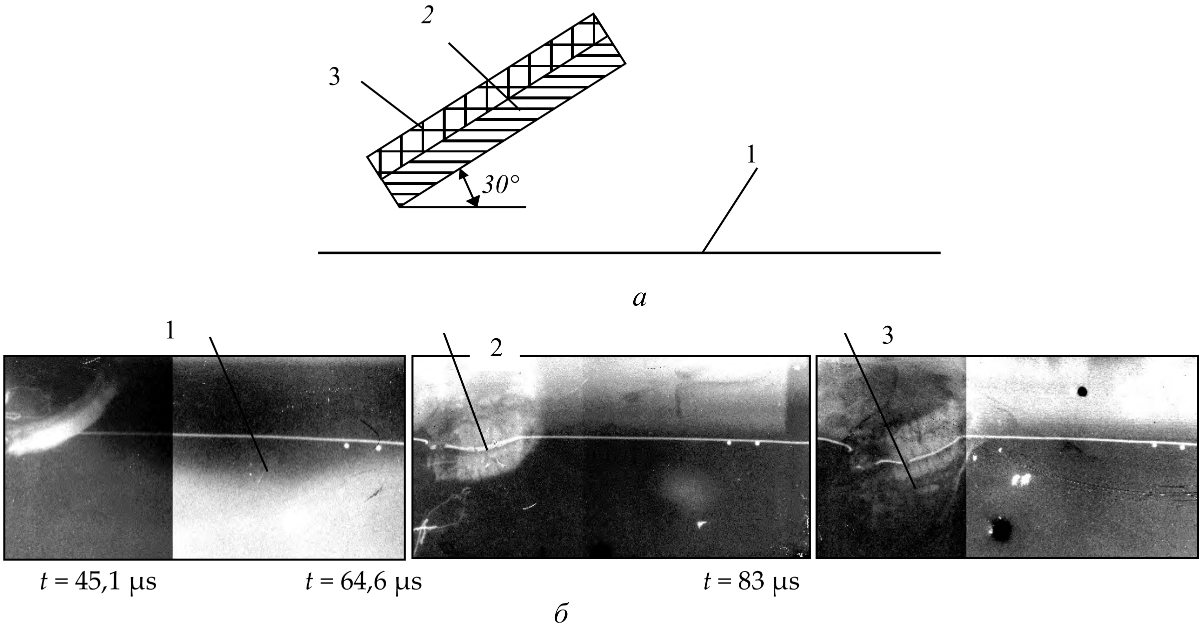
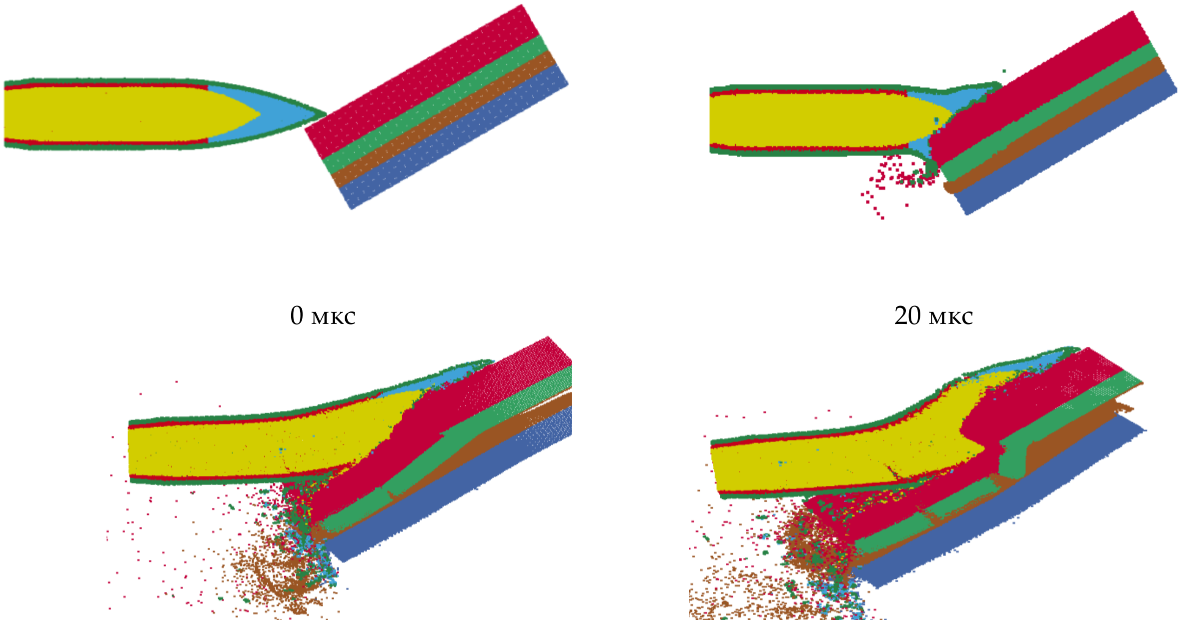


Figure 2. Experiment scheme (*а*) and X-ray radiography of the disruption process (*б*); *а:* 1 – copper wire; 2 – explosive driven ceramic plate; 3 – HE charge; *б*: 1 – copper wire; 2 –ceramic fragment stream; 3 – transverse wave in a wire

Table 1. Calculated characteristics of ceramic-metallic structures on impact of the 12.7 APB B32

Ceramics	Sub-layer Material	Ceramics/sub-layer thickness, mm	Maximal penetration speed, m/s	Mass per meter, kg/m^2
SiC	Steel 44	7,7 / 2,1	838	40,6
	AMg6	8,4 / 6,5	837	43,5
	V95	8,2 / 6	837	42,5
	VT23	7 / 3,6	837	37,8
Al_2O_3	Steel 44	6,8 / 2,5	838	46
	AMg6	7,5 / 7,7	837	49,4
	V95	7,3 / 7,1	837	48,2
	VT23	6,2 / 4,2	837	42,8
B_4C	Steel 44	8,6 / 1,9	836	36,2
	AMg6	9,5 / 5,5	839	38
	V95	9,3 / 5,1	838	37,1
	VT23	8 / 3	839	33,2



0 мкс

20 мкс

50 мкс

70 мкс

Figure 3. Stages of the bullet impacting the combined armor

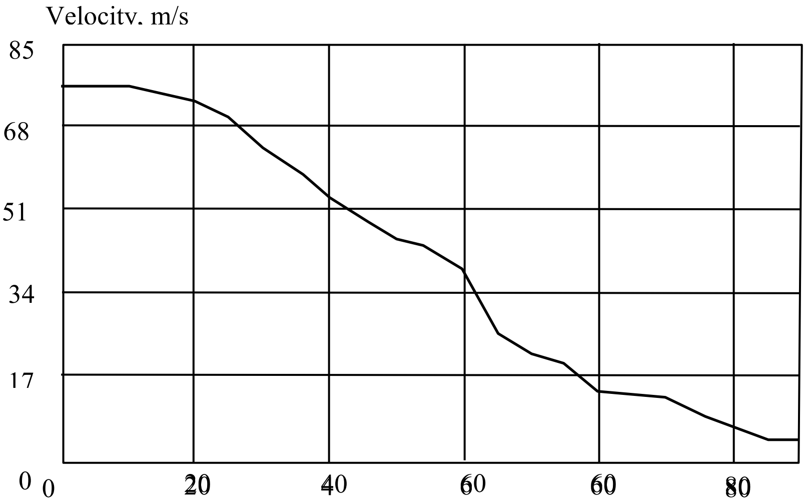


Figure 4. Time-velocity dependence of the slug

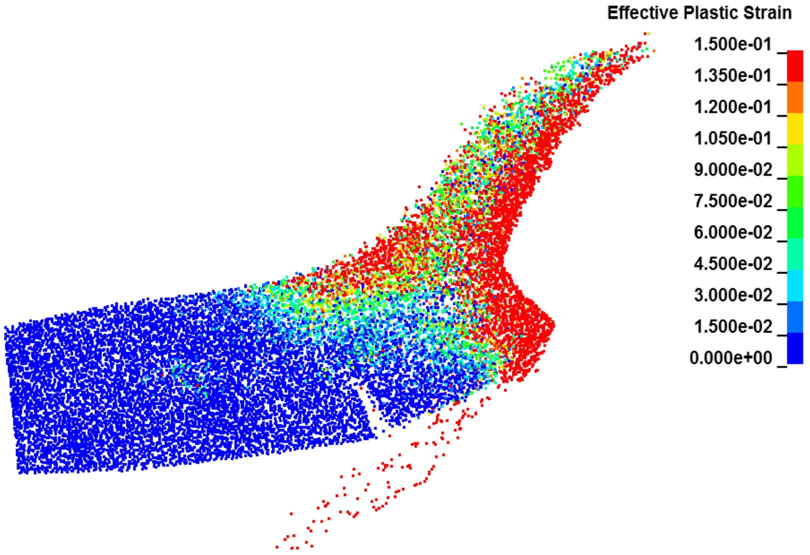


Figure 5. Effective plastic strain contour on the slug at 70 μs
(maximal plastic strain for the slug material was 0.08)

The slug decelerates intensively (fig. 4) and damaged (fig. 5) in the penetration process. On the last stages of the penetration at *t* > 60 μs the remnants of the core rotate on an angle from 5° to 14°. This effect adds up to the deceleration of the core of the bullet, therefore increases the bullet resistance of the armor.

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