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Protection of Light Armours Against Shaped Charge Projectiles*

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Abstract. The hereby work describes the examples of protection of light fighting vehicles armoured with additional reactive armours. The way of protecting of light fighting vehicles with the use of composite-reactive armours against penetration with HEAT projectiles (with a penetration ability of 300 mm RHA) and against small calibre (up to 14,5 mm) armour-piercing bullets are shown on the example of the BWP-1. Technical parameters of the CERAWA-1 armour and its assembly on BWP-1 are presented. The work also presents the results of static tests of several variants of reactive-passive panels of light fighting vehicles against PG-7 projectiles' perforation at the angle of 60° and 72° from normal to the cassette surface. Depending on the surface mass of the light reactive-passive armour panels, different levels of damage to the armour witness plate were achieved.
Keywords: materials technology, explosion, explosive reactive armour, shaped charge projectile, armour protection

1. INTRODUCTION

Armours of fighting vehicles after the II World War and other wars, especially in the Middle East, usually reached a high degree of resistance to perforation of shaped charge projectiles.

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It concerns first of all: HEAT (*high explosive anti-tank)* hand grenades, tank rounds and guided missiles with the penetration ability of up to h = 1300 mm of the RHA (*rolled homogeneous armour*) [1-3].

Armours of such vehicles must effectively disturb the penetration of shaped charge projectiles and be resistant to the detonation of large quantity of high-energy explosive, contained in the shaped charge projectiles. Such quantity of explosive in guided missiles and in shaped charge projectiles as well as thick casing of such projectiles, effectively destroy ERA reactive armours usually situated as additional protection [3]. Only a few constructions of reactive armours, eg. ERAWA-1 and 2, are minimally sensitive to such destructive effect [3].

The armours of light and medium fighting vehicles (BWP), are not resistant to perforation even by typical HEAT hand grenades, eg. RPG-7. Nowadays such vehicles are protected with the use of other, lighter than RHA armours from the perforation of RPG-7 hand grenades with the PG-7 projectiles (the most often used in the world) with the penetration ability of h = 300 mm of the RHA and against AP bullets of the calibres d = 7,62÷14,5 mm. The BWP protection from the perforation of PG-7 projectiles is provided by different reactive armours (Fig. 1).

a b

Fig. 1. Light fighting vehicles with ERA cassettes (1) protecting from PG-7 type shaped charge projectiles; a – Bradley with different non modular cassettes, b – FV432 Mk3 BULLDOG with modular cassettes

For a large quantity of light western LFVs and Russian BWP-1 type LFVs made around the world, as well as the proposals for their modernization by the Polish [4] industry, the necessity arose for increasing the protection level of this type of armours. It is for this purpose that the modular CERAWA-1 composite--reactive armour [5, 6] which protects against the perforation of shaped charge projectiles with the penetration ability of h = 300 mm RHA and against 14,5 mm AP bullets has been developed.

This armour, with the mass of 920 kg and the area of 3,5 m^2 protects front upper, bottom and side parts of the hull and the front and side part of the turret. During horizontal firing, the CERAWA-1 cassettes, inclined at some angle, effectively shield the whole front plate, despite the fact that their area is much smaller than the area of this plate. This armour, fastened on the BWP-1, was displayed at the III International Exhibition of Defence Industry – Kielce ’95 in Poland. Thanks to its full modularity, small thickness and easy assembly method, the CERAWA-1 [7] armour can be applied to other fighting vehicles.

2. TESTS OF THE REACTIVE-PASSIVE ARMOUR

The static tests which were carried out, tested the protective ability for the reactive-passive armour panels with ERAWA-1 reactive cassettes composed from an aluminium alloy, during penetration with a shaped charge jet generated by a PG-7 projectile [8]. Three different constructions of armour panels (Fig. 2) have been used and on every panel, the tests with the use of shaped charge projectiles placed at angles of α = 60° and α = 72° from normal to the surface of the external cassette were carried out.

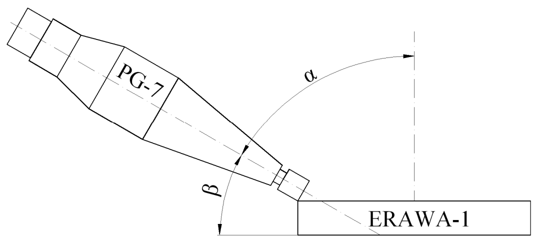


Fig. 2. The arrangement of the PG-7 shaped charge projectile in relation to the ERAWA-1 reactive cassette

The panel of the reactive-passive armour (Fig. 3) consisted of the ERAWA-1 cassette (1) made of an aluminium alloy which was screwed on to the steel channel section (4) with the length of 500 mm by means of nuts (7).

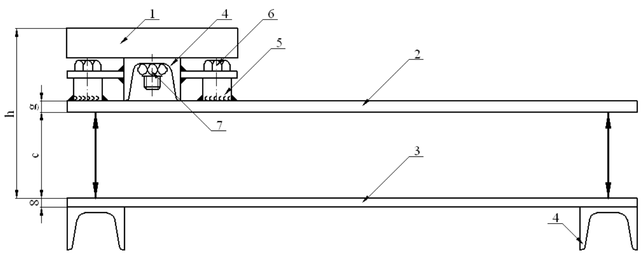


Fig. 3. Reactive-passive panel – version 1:
1 – ERAWA – 1 cassette, 2 – steel plate 1, 3 – RHA plate 2 (witness),
4 – steel channel section, 5 – sleeve, 6 – screw, 7 – nut

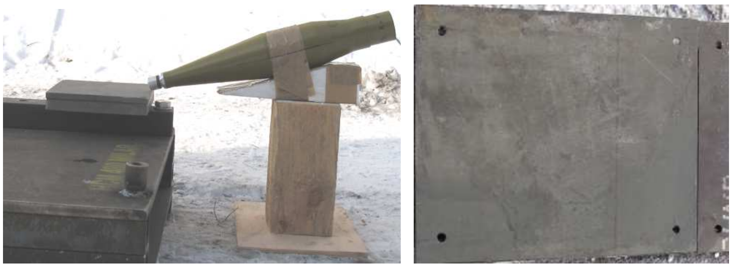
This channel section was screwed with screws (6) to the steel plate 1 (2) to which the sleeves (5) with screwed holes were welded on. The channel section with the ERAWA-1 cassette was placed on the steel armour plate 2 – the “witness”, with the thickness of 8 mm (3) without additional fixing. The steel plate 1 (RHA or St3) with the area of 500 × 500 mm was supported in two places on the RHA plate 2 (witness). The RHA plate 2 (witness) with the size of 600 × 500 × 8 mm was arranged on two channel sections without any fixing.

Setting of PG-7 shaped charge projectiles in relation to ERAWA-1 reactive cassettes [8] and parameters of all panels with the height of $c < 160$ mm were shown in Table 1.

TABLE 1. Parameters of panels of passive-reactive armours

No. of panel /No. of variant	Setting angle of PG-7 projectile in relation the surface of ERAWA-1 cassette, deg	Material of plate 1	Surface mass of panel, m [kg/m^2]
1/1	72	RHA	227
2/1	60	RHA	227
3/2	72	St3	211
4/2	60	St3	211
5/3	72	RHA	221
6/3	60	RHA	221

The view of panels of version 1 with ERAWA-1 cassettes before and after the initiation of the PG-7 projectile is shown in Figures 4-5.



a **b**

Fig. 4. Panel 1 with the ERAWA-1 cassette before the initiation of the PG-7 projectile at an angle of α = 72° (a) and the RHA 2 plate (witness) after the initiation of the projectile (b)

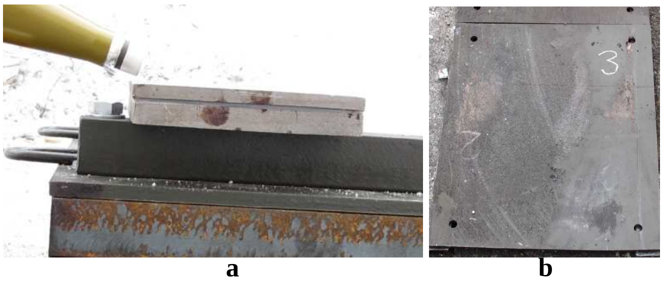
On the armour plate 2 (witness) no traces of shaped charge jet were ascertained. The PG-7 shaped charge jet was stopped by the detonation of explosive in the ERAWA-1 cassette as well as the RHA plate 1 which was damaged in the place where the cassette was fixed.

a **b**

Fig. 5. Panel 2 with the ERAWA-1 cassette before the initiation of the PG-7 projectile at an angle of α = 60° (a) and the RHA plate 2 (witness) after the initiation of the projectile (b)

The shaped charge jet pierced the RHA plate 1 and on the witness armour plate a trace appeared in the form of a copper layer from the shaped charge jet, but the penetration of the armour witness plate did not take place.

In the following version 3 (Fig. 6-7) instead of the RHA plate 1 the steel St3 plate 1 with the area of 500 × 500 mm was used and the remaining elements of the armour were exactly the same as in tests 1 and 2.



a **b**

Fig. 6. Panel 3 with the ERAWA-1 cassette before the initiation of the PG-7 projectile at an angle of α = 72° (a) and the RHA plate 2 (witness) after the initiation of the projectile (b)

a **b**

Fig. 7. Panel 4 with the ERAWA-1 cassette before the initiation of the PG-7 projectile at an angle of α = 60° (a) and the RHA plate 2 (witness) after the initiation of the projectile (b)

The shaped charge jet pierced the St3 steel plate and penetrated the armour witness plate in the depth of *DP* = 4,5 mm. As a result of the detonation of explosive in the shaped charge projectile and in the reactive cassette the deflection of the armour witness plate about 8 mm also occurred.

The shaped charge jet pierced the St3 steel plate and also pierced through the armour witness plate – *DP* = 8 mm. The deflection of the upper metal sheet as a result of the initiation of the explosive in the shaped charge projectile and in the reactive cassette amounted to 22 mm.

In the subsequent version 3 of the reactive-passive armour (Fig. 8) its construction with relation to variants 1 and 2 was changed so that the steel plate 1 with the area of 500 × 500 mm was supported in three places on the armour plate 2 (witness), i.e. every 150 mm – in the places of centres of following aluminium ERAWA-1 cassettes. This three-point support caused that the construction in variant 3 to became stiffer than in variants 1 and 2. The distances between plates 1 and 2 in variant 3 of the panel were smaller than the distances in variants 1 and 2.

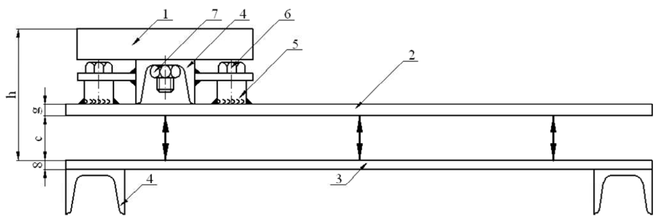


Fig. 8. Panel of the reactive-passive armour – version 3:
1 – ERAWA –1 cassette, 2 – steel plate 1, 3 – RHA plate 2 (witness),
4 – steel channel section, 5 – sleeve, 6 – screw, 7 – nut

The view of panels with ERAWA-1 cassettes in version 3 before and after the initiation of the PG-7 projectile is presented in Figures 9-10.

a **b**

Fig. 9. Panel 5 with the ERAWA-1 cassette before the initiation of the PG-7 projectile at the angle of α = 72° (a) and the RHA plate 2 (witness) after the initiation of the projectile (b)

The shaped charge jet was stopped by the detonation of explosive in the ERAWA-1 cassette and by the RHA plate 1, and the deflection of the RHA plate 2 (witness) was 11 mm.

a **b**

Fig. 10. Panel 6 with the ERAWA-1 cassette before the initiation of the PG-7 projectile at an angle of α = 60° (a) and the RHA plate 2 (witness) after the initiation of the projectile (b)

The shaped charge jet pierced the RHA plate 1, on the armour witness plate where a trace appeared in the form of a copper layer from the shaped charge jet, but the penetration of the armour plate 2 (witness) did not take place. The deflection of the armour plate 2 (witness) amounted to 13 mm. The list of the results of static tests with the use of shaped charge PG-7 projectiles and panels of reactive-passive armours is shown in Table 2 and in Figure 11.

TABLE 2. Results of the firing at panels of passive-reactive armours with the use of PG-7 projectiles

No. of panel / No. of variant / setting angle of PG-7, α [°]	Material of steel plate 1 / penetration depth of RHA plate 2 (witness), *DP* [mm]	Sizes of holes in RHA plate 2 (witness), *a* x *b* [mm]		Deflection of RHA plate 2 (witness), *d* [mm]
		inlet	outlet	
1 / 1 / 72	RHA / -	-	-	-
2 / 1 / 60	RHA / 1	~3 × 3	-	-
3 / 2 / 72	St3 / 4,5	51 × 13	-	8
4 / 2 / 60	St3 / 8	34 × 17	10 × 6	27
5 / 3 / 72	RHA / -	-	-	11
6 / 3 / 60	RHA / 2	~3 × 3	-	13

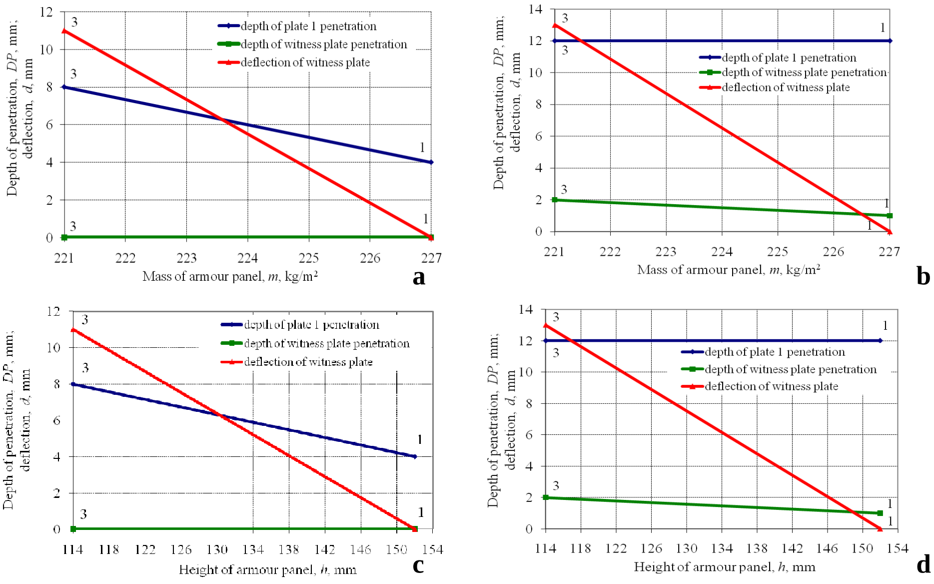


Fig. 11. The depth of penetration of the plate 1, the RHA plate 2 (witness) and the deflection of the RHA plate 2 (witness): in the function of mass of the armour panel for the angles of α = 72° (a) and α = 60° (b), in function of the height of the armour panel for the angles α = 72° (c) and α = 60° (d)

3. CONCLUSIONS

On the basis of tests carried out, the following conclusions can be drawn:

1. The panel of the reactive-passive armour with ERAWA-1 cassettes from aluminium alloy can protect light armoured fighting vehicles against the perforation by PG-7 projectiles hitting this armour at an angle of $60^o \leq \alpha \leq 72^o$ ($18^o \leq \beta \leq 30^o$ from the surface of the armour).
2. After the perforation of the reactive-passive armour on the surface of the hull of protected vehicle, small craters with a depth of several millimetres and traces of dispersed copper from the shaped charge jet of PG-7 can occur.
3. The best protection was provided by the reactive-passive armour in version 1. The shaped charge jet did not pierce plate 1 with the size of 500 ×500 mm both for the angle of α = 72° as well as for α = 60°. There was also no deflection of the steel armour witness plate with the size of 600 × 500 × 8 mm as a result of the initiation of the explosive of the shaped charge jet projectile and the ERAWA-1 cassette.

4. The protection against the perforation of the shaped charge jet was also provided by the reactive-passive armour in version 3. Deflections of the steel armour witness plates (11 mm – panel 5 and 13 mm – panel 6) occurred for $\alpha = 60°$ and $\alpha = 72°$ setting angles of the shaped charge jet PG-7 projectile in relation to the normal external surface of the cassette; the deflections were caused by the smaller distances between plates 1 and 2 and also because of the greater stiffness of plate 1 as a result of its being supported in three places on the plate 2 (witness) and as a result of smaller distances between plates 1 and 2 in variant 3 of the panel than the distances in variants 1 and 2.

REFERENCES

[1] Witkowski I., *Light and medium armoured fighting vehicles* (in Polish), Publishing House WiS, Warsaw, 1993.
[2] Wiśniewski A., Włodarczyk E., Zubik T., Habaj W., Podgórzak P., Protection of fighting vehicles (in Polish), *Problems of Armament Technology*, Military Institute of Armament Technology, vol. 89, 2003.
[3] Wiśniewski A., *Armours – construction, designing and research* (in Polish), Scientific and Technical Publishing House, Warsaw, 2001.
[4] Bramowicz J., Pawlak S., Wojdan J., Modernization of infantry fighting vehicle BWP-1 (in Polish), *Problems of Armament Technology and Radiolocation*, Military Institute of Armament Technology, vol. 58, 1996.
[5] Wiśniewski A., Bramowicz W., Wojdan J., Jaskot S., *Segment armour protection*, Polish Patent No. 178940, 1995.
[6] Wiśniewski A., Passive-reactive armours, *Proceedings of IVth International Armament Conference „Scientific Aspects of Armament Technology"*. WAT, Waplewo, 9-11 October 2002, pp. 820-829, 2002.
[7] Foss C.F., CERAWA-1 Explosive reactive armour system. *Jane's Armour and Artillery*, Jane's Information Group Limited. 1996.
[8] Wiśniewski A., Tomaszewski Ł., Pacek D., Tesing of protective ability of reactive panels, *Report of the Military Institute of Armament Technology*, (unpublished), Zielonka, 2010.