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EVALUATION OF HIGH EXPLOSIVE PARAMETERS FOR REACTIVE ARMOUR

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Explosive reactive armour elements are sandwiches consisting of steel facings covering an explosive core. The layer thicknesses are 2 to 10 mm each. Frequently C-4 explosive has been used so far. However this type is fully detonating even in very thin layers after initiation by a shaped charge jet. This has been confirmed by a test series.

In order to confine collateral damage further tests with the PBXN-110 explosive should show a reduced reactivity when applied in subcritical thickness. A reduction in jet stopping performance has to be accepted. In additional tests PBXN-110 explosive with increased binder content (40% instead of 12%) was blasted with the same 40 mm shaped charge type. The results are presented and discussed.

INTRODUCTION

Explosive sandwiches are the principal element of the well-known and universally applied explosive reactive armour (ERA) for protection against shaped charges. Their efficiency strongly varies with impact angle. The best performance is displayed at angles up to 40°, beyond this value the performance drops continually to zero at 90°. Other important parameters are type and thickness of the explosive core layer.

As a drawback the detonation of ERA elements induces considerable collateral damage.

A way to reduce this damage would be to tailor the reactivity of the explosive: A limited reaction for small charge jets and full performance against full calibre jets. Theoretically this tailoring can be reached by a subcritical explosive layer thickness. The verification of this approach is described below.

TEST SET-UP

Fig. 1 shows the test arrangement. The test charge is a 40 mm shaped charge developed for research purposes, placed at a distance of 2.5 calibres in front of a steel skirt of 5 mm thickness. This skirt prevents interactions between the detonation fumes of the

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charge and the ERA element. Skirt and ERA element are screwed together at a distance of 30 mm, the inclination angle is 40°. The ERA element configuration varies with explosive type and processing technology; this will be described in detail below. Explosive layer thickness is between 0.5 and 5 mm.

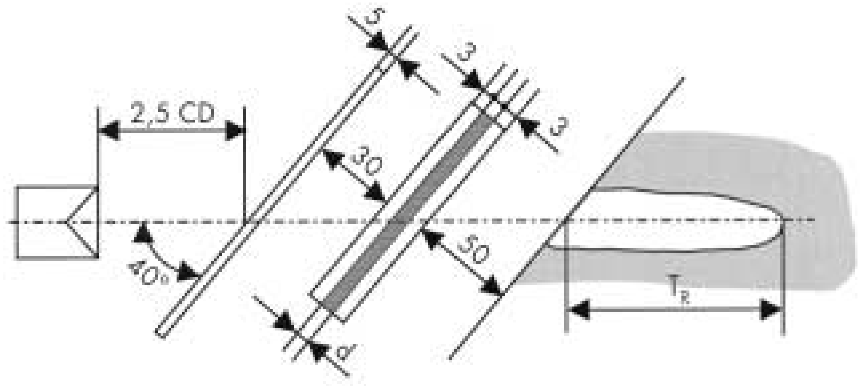

Figure 1. Test set-up.

The residual penetration of the charge after passing through the ERA element is measured with witness plates of 270 HB RHA and 25 mm thickness, spaced at 50 mm distance. The total distance from the charge base and the witness plates is 240 mm plus 1.58 times explosive layer thickness.

TEST CHARGE

The test charge consists of an extrusion moulded 60° copper cone (OFHC) and of 88 g of Oktastit VIII high explosive. Oktastit VIII is an octogen-based high performance explosive comparable to the internationally well-known LX-14. The charges were pressed and machined to dimension on a lathe.

The HI type ignition contains a centerline PIC and a booster A typical feature of this charge is the leading bulb. This is stopped by the skirt sheet to eliminate undesired interactions. Tip speed of the jet (behind the bulb) is 7230 m/s, the rear end speed 2050 m/s and the slug speed 584 m/s.

The penetration performance of the test charge is 220 mm RHA (260 BHN) at 100 mm stand-off and 250 mm RHA at 250 mm stand-off; these values are very well reproducible.

ERA ELEMENTS

Three explosive types were investigated: Composition C-4, PBXN-110 and PBXN-110 with reduced octogen content, called PBXT-60.

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Composition C-4 has been developed by the US Army in the forties; it is frequently used in ERA elements. C-4 contains 91% of a bimodal hexogen, a polyisobutylene binder, a considerable amount of dioctyladipate (DOA) plasticizer as well as engine oil. The maximum theoretical density (TMD) is 1.67 g/cm^3. Its putty-like consistence allows filling it into recesses in ERA elements and relatively thin layers with densities between 1.53 and 1.59 g/cm^3 may be generated.

PBXN-110 was developed in the eighties for insensitive munition and has since found its way into numerous IM applications. PBXN-110 consists of 88% octogen and 12% binder. The binder is an inert polyurethane (HTPB R 45 M) crosslinked by isophoron diisocyanat (IPDI). An IDP plasticizer increases elasticity. The maximum theoretical density of PBXN-110 is 1.686 g/cm^3, which can be approached by an advanced casting technology.

Two ERA element variants were manufactured:

A) A rubber frame with 3 x 4 compartments was placed on a steel plate (180 x 244 x 2,5 mm), then the compartments were filled with one layer of explosive sheets of 4.5 mm total thickness. The arrangement was covered with a second steel plate of the same dimensions.

B) Instead of a compartmented frame rubber edges only were usod and filled with 3 x 4 sheets of explosive in one or two layers.

The third explosive type included in the investigation is PBXT-60, containing 60% of a bimodal octogen and 40% of the same binder system used in PBXN-110. To reduce shock susceptibility fine grain octogen (10 µ mean grain size) was used. The TMD is 1.307 g/cm^3 which can approximately be reached with standard processing procedures (98–99% TMD).

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RESULTS (see also Fig. 4)

Target	Residual Penetration TR (mm)	Comment (see fotos)
Inert (3 mm rubber layer)	145 150	Sandwich plates not deformed, only around the slitlike perforation (foto 1)
Composition C4 5 mm	22 24	Detonation *
Composition C4 1.5 mm	37 37	Detonation *
Composition C4 1 mm	44 36	Detonation *
Composition C4 0.5 mm	50 44	Detonation* (see foto 2)
2.25 mm PBXN-110 in rubber-grid	132 170	Decaying deflagration *. Sandwich plates wave-like deformed; explosive residues found. T_R same as inert sandwiches (foto 3)
2.25 mm PBXN-110 in rubber frame	55 98	Decaying explosion/deflagration *. Sandwich plates wave-like deformed; great spread. Bigger perforation holes (foto 4, 5)
2.5 mm PBXN-110 in rubber frame	98 108 106	Decaying deflagration *. Sandwich plates wave-like deformed; explosive residues found. Small, slit-like perforation holes. Low spread (foto 6)
3 mm PBXN-110 in rubber frame	55 44 50	Detonation *, but relatively high T_R compared with C4 (foto 7)
	70	Decaying deflagration * (foto 8)
2 x 2.25 = 4.5 mm PBXN-110 in rubber frame	25 20	Detonation * (foto 9)
2.5 mm PBXT-60 in steel ring	80 70 80	Detonation *; T_R relatively high, compared with C4. Heavy collateral damages
4 mm PBXT-60 in steel ring	50 50 42	Detonation * T_R relatively high, compared with C4.

* according to STANAG 4439

Table 1. Reaction behaviour of ERA elements depending on the explosive layer thickness and type of explosive used (see also Fig. 2 and 3)

RESULTS

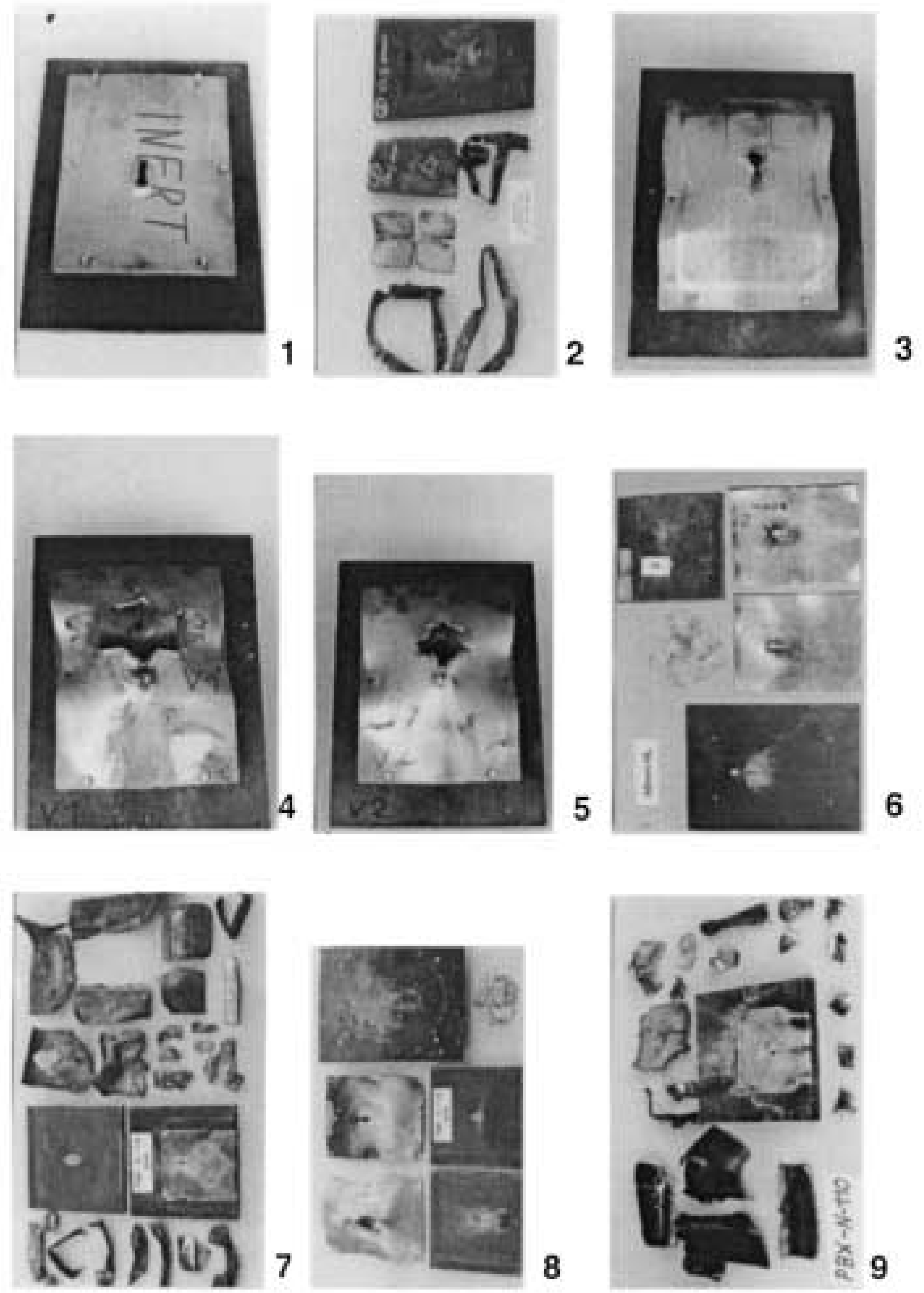

Figure 2. Fotos showing the state of ERA after 40 mm shaped charge attack (see also Tab. 1 and Fig. 3).

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DISCUSSION

The test results (summed-up in Fig. 3) confirm the fact that a 40 mm shaped charge initiates C-4 explosive in layers as thin as 0.5 mm, the residual penetration TR in the witness plates being accordingly small. A ten-fold layer thickness (5 mm) merely halves TR to 20 mm. In contrast to this a 2.5 mm layer of PBXN-110 displays a wave-like sandwich sheet deformation, a sign of a locally restricted weak reaction. The residual penetration of 100 mm confirms this, however it is distinctly smaller than the ca. 150 mm of an inert sandwich.

On the contrary all three PBXT-60 specimens of 2.5 mm thickness detonated, even though the residual penetration was rather high, ranging from 70 to 80 mm. These high TR values may be caused by a delayed initation, as explained in Fig. 4 and 5. E.g. a 10 µs delay would let an additional jet length of 70 mm pass undisturbed through the sandwich.

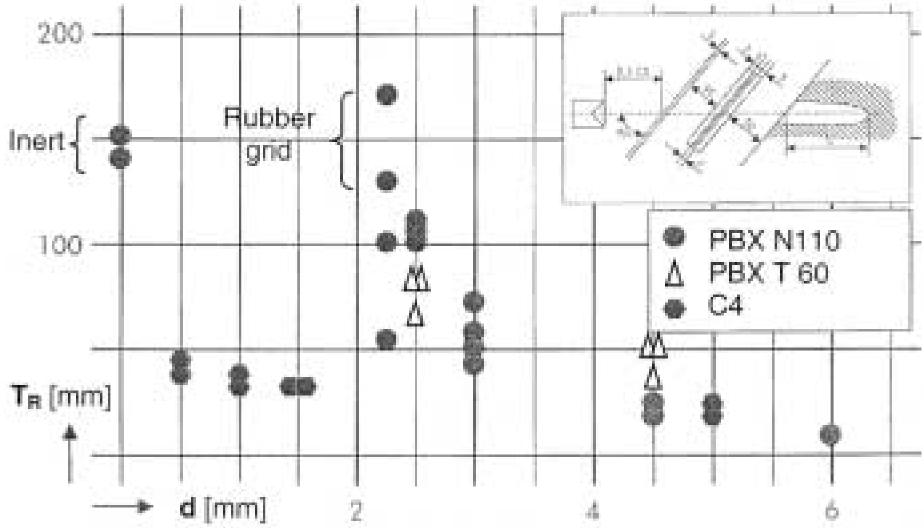

Figure 3. Residual penetration T_R of the 40 mm test charge versus thickness d of explosive layers.

The tested explosive types have different initiation characteristics:

- C-4 is immediately initiated by the shock wave: shock to detonation transition (SDT)
- PBXN-110 and PBXT-60 seem to be initiated by deflagration to detonation transition (DDT), causing some delay.

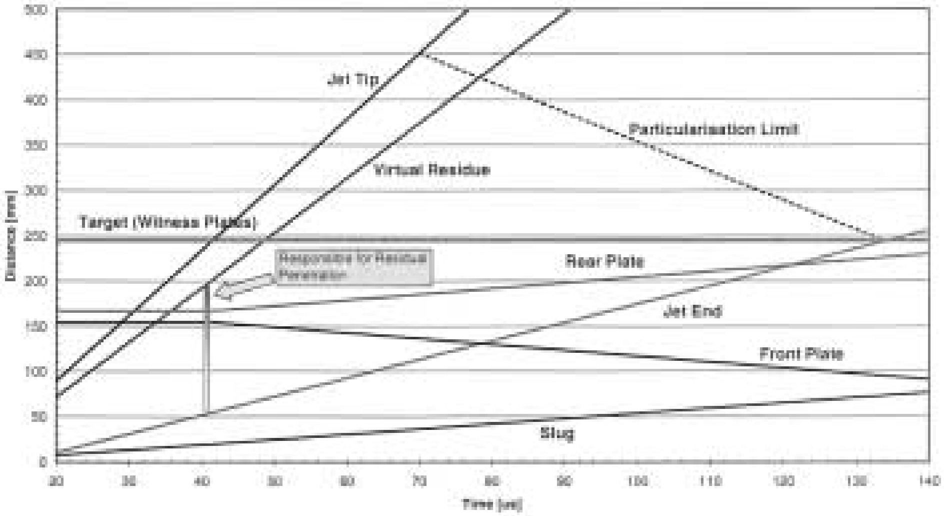

Figure 4. Dynamic of jet plate interaction.

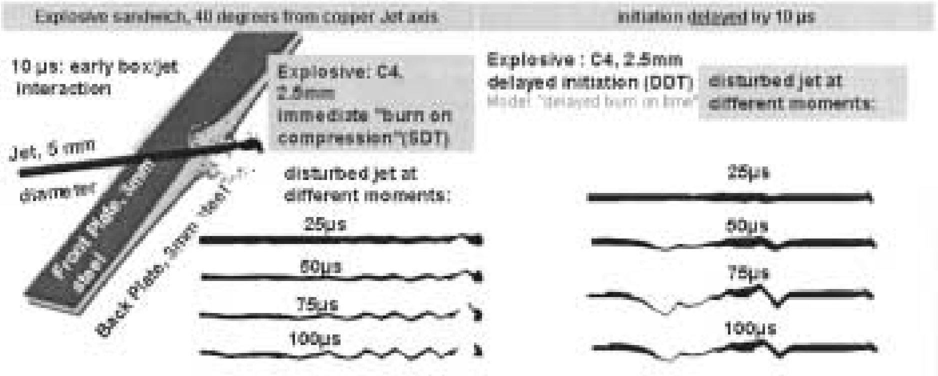

Figure 5. Simulation of 40 mm jet impacting a 2.5 mm C4 sandwich, reaching SDT and with 10 µs delay.

Even 4 mm of PBXT-60 still yield a relatively high T_R of ca. 50 mm, comparable to that of .5 mm of C-4. It takes 4,5 mm of PBXN-110 to reach the desired small T_R of around 25 mm. To some degree the results may have been influenced by the boundary conditions of the tests, such as the different shapes (square / round) or the different confinements (steel / rubber).

CONCLUSIONS

The test results clearly show that any initiation delay deteriorates the efficiency of ERA sandwiches. Insensitive explosives such as PBXN-110 and PBXT-60 usually have relatively large critical diameters. ERA sandwiches having a subcritical explosive layer thickness lead to a distinct residual penetration scatter. The intended tailoring of a weak reaction to both reduce collateral damage and reach a reproducible small residual penetration could not be fully reachod by the described test series. Further tests with medium and big caliber shaped charges are planned.

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