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PENETRATOR / SHAPED CHARGE SYSTEM PART II: INFLUENCE OF DESIGN PARAMETERS

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Aspects important by the adoption and integration of a shaped charge (SC) into a multipurpose round designed as penetrator / shaped charge system have been investigated. The design approach was performed in a step-by-step manner based on a standard SC. The first step was the enclosure of the SC into a thick steel casing. Then the length of the warhead was increased almost twice the original taking into account the adaptation of the initiation system. Finally the integration procedure was finished by closing the penetrator hull at the front end. The influence of these significant parameters on the penetration performance in RHA targets will be discussed. Additional numerical simulations were carried out in the first part of this paper.

INTRODUCTION

The typical application of shaped charges (SC) has been the defeat of main battle tanks (MBT). However, the MBT ceased to be the target of primary interest and structural targets come into the focus. A penetrator / shaped charge system, which stimulated the presented study, was proposed as a multipurpose round [1]. It is intended to act against a variety of targets. Blast-fragment effects defeat structural targets after penetration into the structure, but the performance of the shaped charge should be still sufficient against the MBT.

The Penetrator / Shaped Charge System is obtained by the adaptation and integration of a conventional SC into a penetrator casing (Figure 1). The calibre of the standard SC was 105 mm with a 50° Cu-Liner of 1.9 mm wall thickness. For the high explosive, cast TNT/HMX 15/85 with a density of 1.85 g/cc was used. The initiation system consisted of an explosive train with a standard detonation wave shaper (DWS).

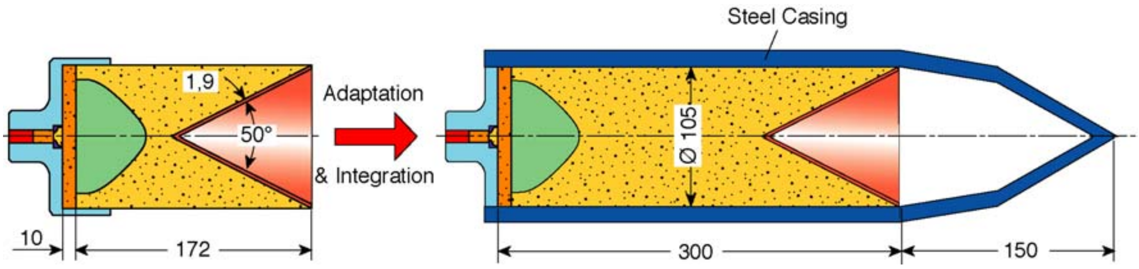

Figure 1. Adaptation and integration process of a standard SC into a penetrator casing

It is well known that the performance of a SC depends very strongly on the symmetry and production accuracy of the warhead. During the integration process several optimized parameters of the SC had to be adapted to achieve the new warhead:

- Thick metal casing with different materials (ductile / brittle)
- Large L/D ratio influencing the detonation wave relative to the liner
- Shifted initiation system to reduce the distance between wave shaper and liner and thus improving the liner collapse process
- Thickness of penetrator nose reducing the jet performance

The influence of these significant parameters on the SC performance was the main interest of this study. In a stepwise approach to the penetrator warhead, starting with the cased standard SC up to the integrated SC, numerous tests were carried out. Due to the relatively large test matrix, only two shots per parameter set could be carried out, nevertheless allowing statements on possible trends and feasibility aspects.

Numerical simulation support concerning the influence of asymmetrical effects is given in part I of this paper [2].

TEST SET-UP AND EXPERIMENTAL TESTS

Performance tests reported in this paper were all done at a standoff of eight calibres (840 mm) to a target consisting of rolled homogeneous armor (RHA) plates. In several tests, also the crater bottom velocity was determined and X-ray pictures of the jet were taken.

In the following, the mentioned stepwise approach of the integration process will be discussed. All SC test samples were handmade prototypes. We suspect that their occasionally observed variable performance was due to a lack of alignment accuracy.

Short Shape Charge with Steel Casing

The standard SC usually equipped with a thin aluminium casing was tested in three different variants: bare, 5 mm and 10 mm steel casings (Figure 2). For this purpose the alloy steel with the lower strength in this study (42CrMo4) was used.

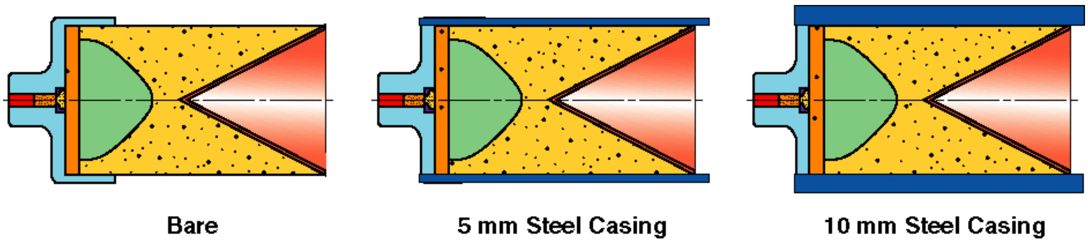

Figure 2. Short standard SC: bare, 5 mm and 10 mm steel casing

The penetration performance in the RHA target in form of a bar chart is shown in Figure 3. A dashed line marks a standard SC performance of eight calibres (840 mm). No negative influence of the casing on the crater depth can be ascertained. On the contrary, a tendency to higher performance can be observed with the 10 mm casing.

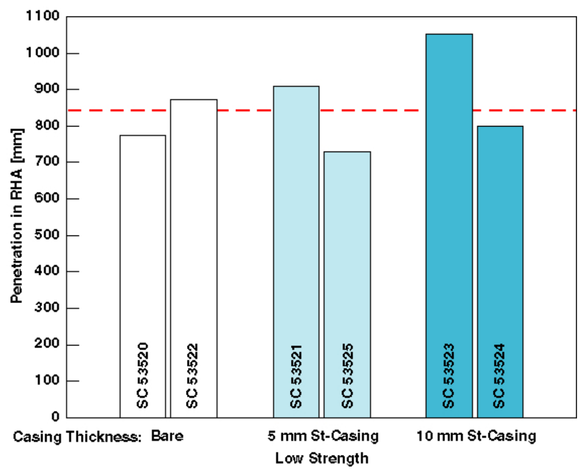

Figure 3. Penetration performance of short standard SC with increasing casing thickness

Long Shaped Charge with Steel Casing

The next step towards the final warhead system was the increase of the SC length from 182 mm to 300 mm (from L/D = 1.7 to 2.8). This new design is shown in

Figure 4. Due to this charge lengthening, the distance between the DWS and the liner apex increased from 18 mm to 136 mm, a very unusual value for a shaped charge. Again, steel casings with a thickness of 5 mm and 10 mm each were applied. Because of the high relevance to a penetrator hull, this time also the material quality was varied: ductile low strength material (42CrMo4) and a brittle high strength material (30CrNiMo8).

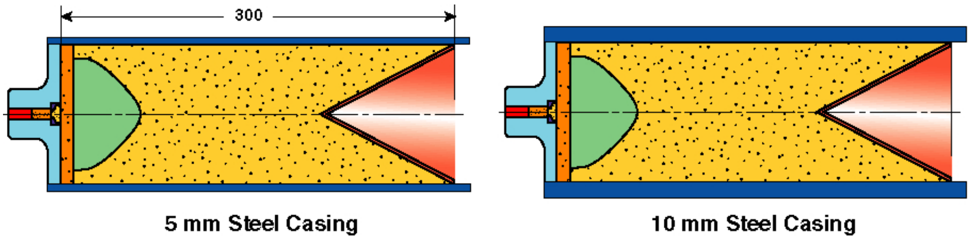

Figure 4. Long SC with ductile and brittle steel casings of 5 mm and 10 mm thicknesses

The results of this test series are presented in Figure 5. In spite of the large distance of the initiation system to the liner and the expected unfavourable impinging angle of the detonation wave at the liner, the SC performance is quite good. This time, a relatively large scatter in the data can be ascertained. The reason for that is definitely the low precision due to the mentioned relatively simple production process of these prototypes. Concerning the “high performance shots”, a thick casing again seems not to negatively influence the jet penetration.

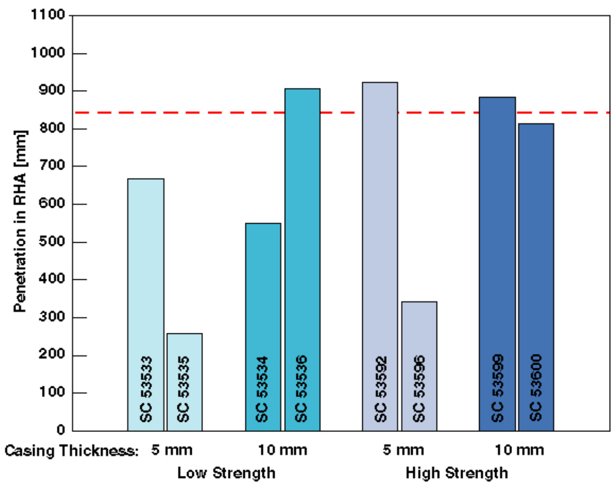

Figure 5. Penetration performance of the long SC with various steel casings

Long Shaped Charge with Steel Casing and Shifted Initiation System

For these tests, the initiation system of the long SC was shifted towards the liner to get the same DWS distances as in the standard SC (Figure 6). A borehole was drilled into the rear high explosive part for the electrical wires. Besides, the plastic mounting was varied in its diameter (d = 20 mm and 50 mm) avoiding premature initiation of the rear high explosive part by shock waves. All prototypes were produced with a 5 mm thick high strength steel casing.

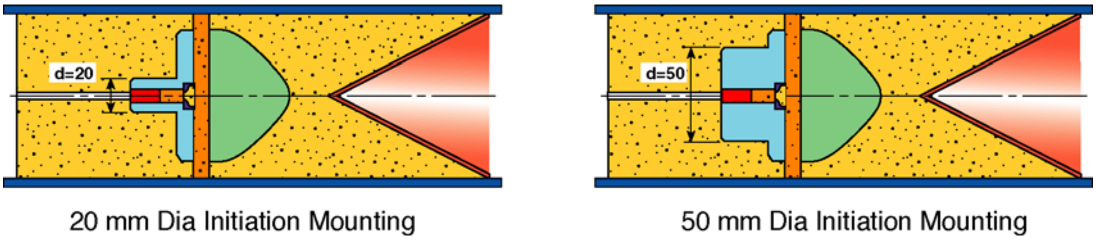

Figure 6. Long SC with steel casing and shifted initiation system

The results of these SC performance tests are demonstrated in Figure 7. It could be expected that the improved initiation configuration should also improve the jet performance. This was not the case. Nevertheless, the crater depths of the best shots were in the same order of magnitude as expected for a standard SC design. Part of the scattering to lower values was again caused by the simple production technique of these prototypes. No influences from the explosive train mounting can be ascertained, i.e. the rear part of the high explosive was not prematurely initiated.

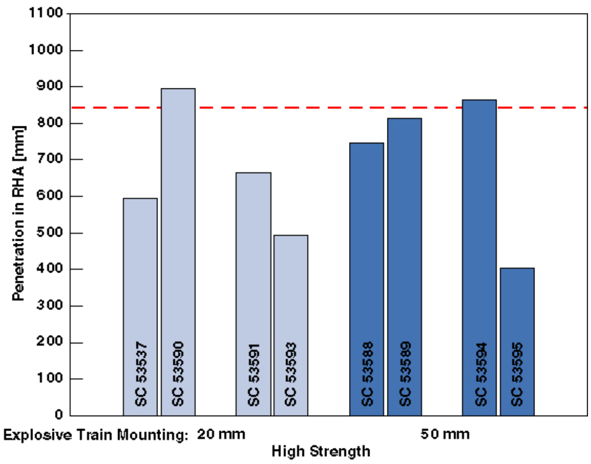

Figure 7. Penetration performance of the long SC with shifted initiation system

Long Shaped Charge integrated in Closed Penetrator Casing

The last step in the approach to the warhead was the integration of the long SC into a generic penetrator casing, i.e. the closing of the penetrator hull at the front end. The design is shown in Figure 8. The casings consisted of low strength steel with thicknesses of 5 mm and 10 mm. The nose of the penetrator had for all samples a constant casing thickness of 7 mm with a line of sight of 14 mm for the jet to penetrate. As no improvements were achieved with the shift of the initiation system, the explosive train was left at the rear part of the penetrator.

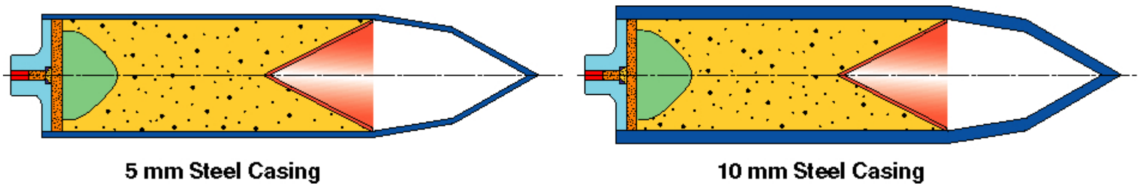

Figure 8. Long SC in closed low strength penetrator casings with 5 mm and 10 mm thicknesses

For this test series, several flash X-ray (FXR) pictures were taken to study the influence of the penetrator nose on the jet. Figure 9 shows a typical double FXR exposure of the jet perforating the penetrator nose. The first exposure (top) shows only a reduction of the jet tip velocity. In the second exposure (bottom) also lateral disturbances can be seen at a jet part well behind the tip region also decreasing the performance.

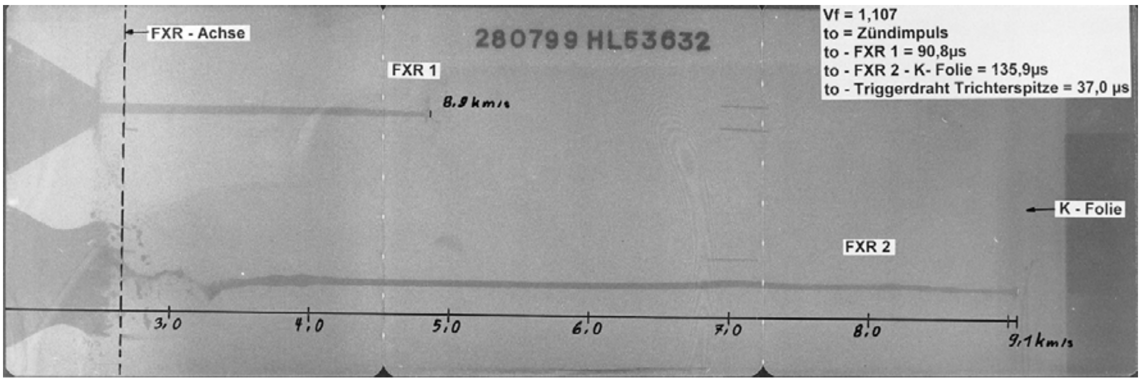

Figure 9. Typical double exposure FXR record of the jet after penetrator nose perforation

The results of this FXR-study can be summarized as:

- loss of jet tip velocity from v_{j0} = 9.9 mm/µs to about 9.1 mm/µs
- local jet disturbances causing lateral jet velocities and thus further decrease in performance

These influences reduced the jet performance shown in Figure 10. But, with roughly one calibre on the average, the decrease is not too big. The scattering of the data is relatively small underlining the statement that scattering in the two preceding variants was mainly caused by imperfections during the production process.

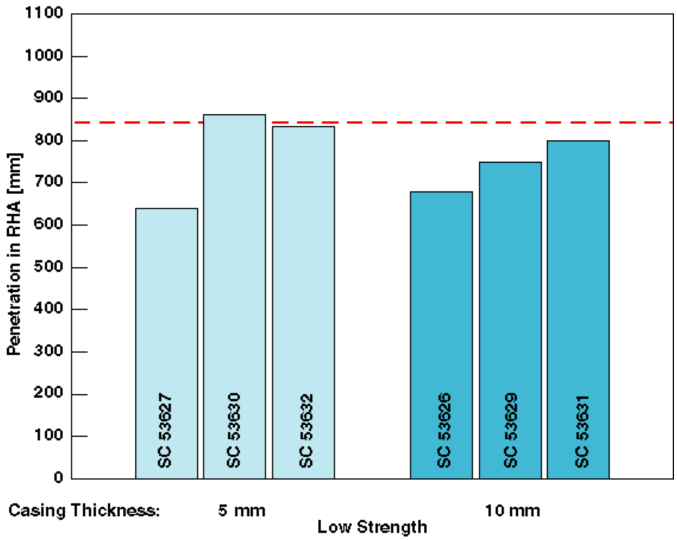

Figure 10. Penetration performance of the long SC integrated in closed penetrator casing

CONCLUSIONS

Four different design variants based on a standard SC design were tested. The main objective was to demonstrate the feasibility of such a penetrator system. The influence of a thick – brittle or ductile – penetrator casing was another crucial point. Figure 11 summarizes the results graphically as mean penetration values for the four variants.

The steel casings on the standard SC showed no negative influence on the crater depth, comparable to a common eight calibres (840 mm) performance. The long SC variant shows a reduced mean value of the depth due to asymmetries caused by the simple production technique. The evaluation of exclusive thin/thick and ductile/brittle casing values (four shots each, Figure 11) revealed trends of improved performance while using a thick and/or brittle casing material. The numerical simulations [2] also suggested an increased performance with thicker casings, but no answer could be given concerning the question of ductile / brittle material. The shift of the initiation system towards the SC liner resulted in no improved performance. Finally, the closing of the penetrator hull showed satisfactory results. There was just a decrease of about one calibre performance.

The main conclusion is, that such a penetrator / shaped charge system is feasible with only a small decrease in performance and is a veritable alternative to a tandem warhead system as a multipurpose round against armoured vehicles and structural targets.

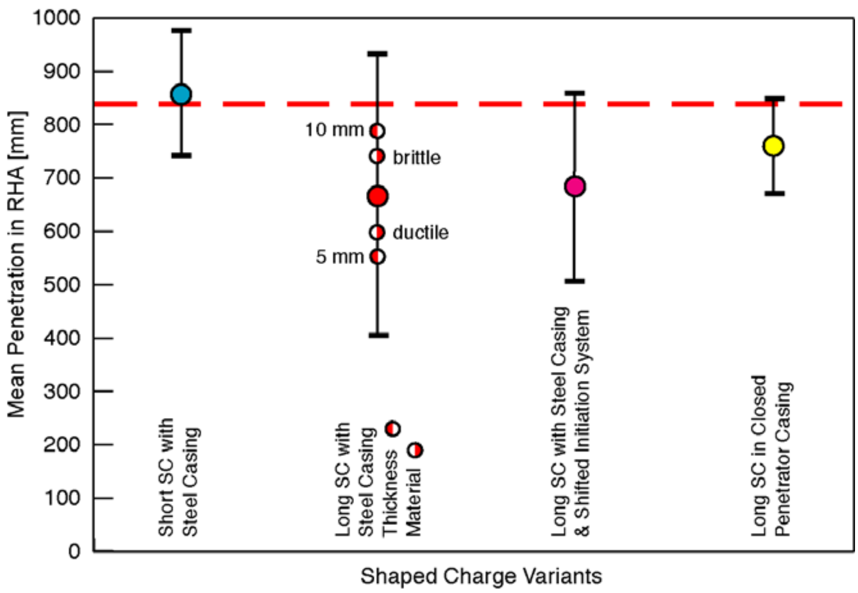

Figure 11. Summary of mean penetration for all four investigated designs

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[2] W. Arnold, E. Rottenkolber, Penetrator / Shaped Charge System, Part I: Simulation of Asymmetrical Effects, *this Proceedings*