THE COMPUTATIONAL STUDY OF THE AERODYNAMIC DESIGN OF A SEGMENTED ROD PROJECTILE

Joanna Szmelter and Shohaimi Abdullah

Abstract. A purpose of this study was to provide an enhanced understanding of typical impact and aerodynamic behaviour of segmented rod projectiles. A range of designs was examined by computational modelling. In all cases the segments have been treated as a dynamically changing configuration of free-flying bodies separated at launch. The paper highlights difficulties of this approach showing that, prior to impact, the segments rapidly lose alignment, which reduces effectiveness of penetration. Investigation of alternative design concepts is recommended.

INTRODUCTION

The long-rod penetrator that utilises the advantage of the high launch velocity is, at present, the dominating type of kinetic energy (KE) penetrator. It has a penetration capability in homogeneous targets that approaches a limit value at velocities close to 2,000 m/s. As the velocity increases, the KE produces a wider, rather than a deeper, penetration channel [1]. To overcome this limitation unconventional projectiles such as the segmented rod projectile—the emphasis of this paper—and the telescopic projectile have attained the greatest attention.

At velocities above 2,000 m/s, both segmented and telescopic penetrators give deeper penetration in steel armours than a homogeneous conventional projectile with the same initial geometry [2-3]. An in-depth study of the penetration of segmented projectiles also has been conducted by the authors [4].

Designing segmented rod projectiles to impact the target at the same point, one after another, in a straight line, is a problem for ammunition designers. Detailed consideration must be given to ensure that:

- the velocity of the projectile is maintained throughout the flight;
- the projectile can withstand the intense aerodynamic heating from travelling through the atmosphere at hypervelocity, without being destroyed or deformed; and
- the dispersion of the projectile trajectories around the nominal flight path is small enough to assure target hits.

The retention of the trajectory of the flight requires the segments to be in line, with minimum yaw, and with the separation maintained until impact. Any misalignment in the segments will reduce the effectiveness of the penetrator. In this paper, the feasibility of designing a segmented rod projectile that can fulfil the above requirements is examined. The results presented are based on calculations carried out assuming that the segments are separated immediately after leaving the muzzle.

Studies that examine the aerodynamic characteristics of segmented projectiles have not been extensively conducted before. Preliminary investigations were reported in [5-8]. Our analysis exploits Computational Fluid Dynamics (CFD) code, [9] that provides a cost-effective and fast turn-around approach for analysing the aerodynamic behaviour of segmented projectiles in flight.

In the choice of computational method, the simplifying assumptions of two-dimensional and inviscid flow have been made. The validity of such assumptions for the extremely complex aerodynamics of segmented projectiles, and their limitations, were discussed in [10]. In effect, this method can not provide accurate predictions, but is suitable for estimations and should be viewed as an engineering tool.

A numerical analysis has been compared to the determination of the alignment of the segments resulting from a physical impact experiment (conducted previously to compare the segmented projectile penetration performance against a continuous projectile). The experiment involved the impact of a five-segment projectile of EN31 steel fired into a BS968 steel cylindrical target. The target was cut to measure the penetration (see Figure 1 drawn from the original photograph).

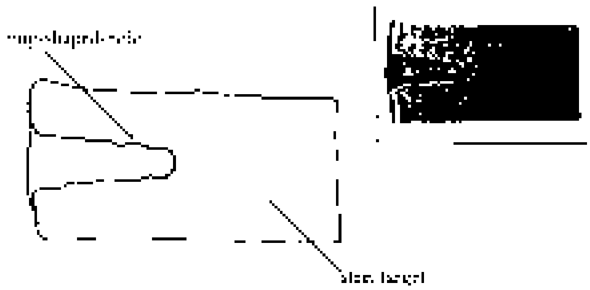

Figure 1. Illustration of penetration of five segments, segmented projectile into a cylindrical target.

The cutout of the target shows, as expected, a five-ring-shaped-crater, which characterised the penetration of the five-segment projectile. It also reveals that the rings are different in size, that they are distorted and that their centres do not form a straight line. The possible interpretation needs to take into account the trajectory of the segments immediately prior to impact. The difference in the ring size and their distortion can be explained by the different yaw angles of the impacting segments. Additionally, the non-alignment of the centres of the rings is likely to reflect the vertical lateral separation of the segments. In the numerical analysis depicting the experiment, a three-segment projectile was used. The distance covered by the leading segment was 0.18 m from the muzzle. The sample contour plot of the projectile at 9.42e-5 s is shown in Figure 2. In all computations, at the moment of impact, a small vertical displacement between the segments was calculated. However, the segments still stayed approximately aligned. The value of the angular displacement due to yaw of the segments were significantly different. This agreed with the interpretation of the shape of penetration crater obtained in the experiment.