Shooting holes in small arms – A terminal effects case study

Introduction

1. Small arms ammunition is the cornerstone for the generation of land combat power and is the primary tool for the dismounted combatant. When Land Forces gets small arms ammunition capability right; a range of effects and natures fall logically into place. However, small arms design and effects is a complex domain which requires detailed study.

Background

2. As a Defence Organisation and as a part of a wider international community, we understand the safety aspect of weapon systems. We freely share data to ensure any signposts are identified in order to mitigate risk. This is again a persistent characteristic of our munitions system. Because of this, there is a range of tests that are standardised (as far as reasonably practicable) to ensure data is compatible across the diverse range of Nations which constitutes NATO and the UN. These tests, (extract contained in table 1) seek to replicate the operational pressures associated with munitions employment.

Test	Description
Function and casualty	The function and casualty test is a weapons integration test that replicates the stresses of firing.
Accuracy and dispersion	The accuracy and dispersion test is a test designed to assess the accuracy and dispersion of the round throughout its entire trajectory.
EPVAT	Electronic Pressure, Velocity, Action Time (EPVAT) is a series of three measurements which ascertains whether the cartridge is safe to operate in designated weapon systems.
Terminal effects	The terminal effects test is a test that is focussed on terminal performance and is conducted against a mild steel plate.

Table 1: Small arms interchangeability tests (MOPI-MC (extract))

3. The same does not apply when it comes to understanding munitions suitability. Although a munition may be safe to utilise, if it is not imparting its energy into a target efficiently and effectively, one would argue that it is not suitable for employment. However, here lies the current problem; there is no standard series of tests to ascertain whether a munition is imparting its energy into a target with regards to its specific defeat mechanism. Furthermore, not much is known about these elements for a range of reasons; too scientifically complex to understand or model, classified armour and therefore classified defeat mechanism or the lack of understanding on how these munitions achieve their principle function.

Common misconceptions

4. Unfortunately, small arms theory is dominated by misconception and pseudo-science including "energy dump", "overpenetration" and "hydrostatic shock". Each of these concepts share a central theme; that there is a magic figure which ranks small arms ammunition lethality, based on the sudden deposition of energy from the projectile. These related concepts are fixated on the rapid transfer of energy to the target, rather than the mechanics of wounding including cavitation and penetration. This attempts to emphasise the temporary cavity with little regard for the other aspects of wounding.

5. In the case of kinetic energy calculations, momentum alone is also inadequate to describe the complexity of terminal ballistics. Kinetic energy relates to the energy that an object possesses due to its motion or the work needed to accelerate a body of a specific mass

from rest to its stated velocity. Kinetic energy may give a bold indication of effectiveness however it does not take into consideration energy lost during the event to heat, flash or bullet deformation.

Redefining small arms test and evaluation

6. From an informed point of view, terminal ballistics needs to have a thorough clean out to ensure we understand how small arms systems operate and therefore perform. To defeat a target, there are a range of considerations; penetration, cavitation, accuracy and projectile design. Each of these elements attempt to explain how small arms munitions defeat a target. Each of these elements attempt to defeat, in the case of a human, one of three critical systems; the cerebral, the vascular or the skeletal.

7. These considerations vary from target to target. For example, against a modern soldier utilising complex body armour, projectile design and penetration would need to be optimised to ensure defeat. For light targets including vehicle or material, projectile design and accuracy would need to be optimised. These two simple scenarios demonstrate the complexity of modern small arms systems and point to how Land Forces may need to reconfigure depending on mission and threat.

8. To support this effort, Proof and Experimental Establishment – Graytown has conducted a range of dedicated trials to help inform and understand the current discussion regarding small arms. In conjunction with Army Headquarters, Graytown have developed a mechanism to characterise small arms effects outside what is stipulated in the NATO MOPI-MC using three separate tests. These tests are outlined below:

9. **Phase 1 - Hard target.** The hard target test was conducted in accordance with the MOPI-MC which provided a foundation for further tests as well as providing an opportunity to export the results to the NATO community to support NATO interchangeability. Test measurements are made on projectile penetration (Penetrate/Bulge). An example of the test is outlined in figure 1.

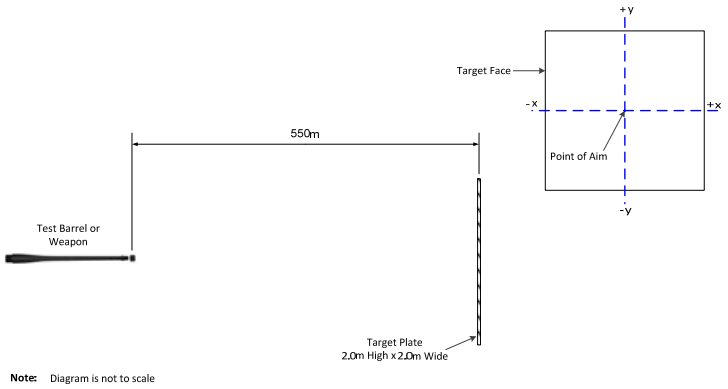

Figure 1: Hard target test

10. **Phase 2 - Hard target array.** The hard target array test builds upon phase 1 tests by characterising effective penetration of multiple targets. Using multiple steel targets separated by polystyrene. Test measurements are made on projectile penetration per layer, projectile fragments and the pathway of the projectile. These elements are outlined in figure 2.

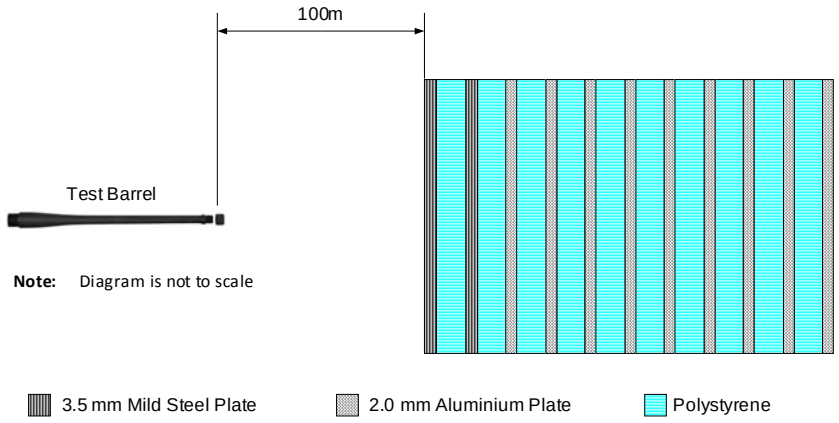

Figure 2: Hard target array test

11. **Phase 3 - Ballistics gelatine.** Ballistics gelatine is designed to simulate living soft tissue and is the standard for evaluating the effectiveness of small arms against humans. Ballistics gelatine was implemented in conjunction with the NIJ Standard however synthetic gelatine was utilised due to its ease of use and long shelf life. The ballistics gelatine allows for the capture of temporary and permanent cavitation as well the ability to understand frangibility and the travel path of the projectile and fragments. These elements are outlined in figure 3.

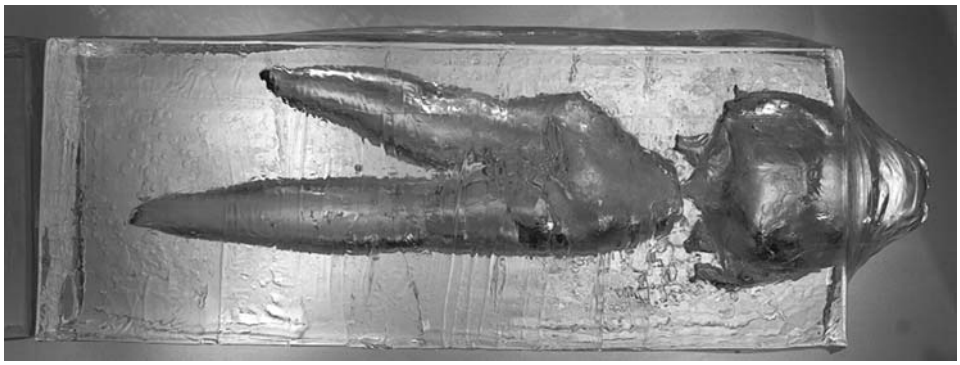

Figure 3: Ballistics gelatine test

Mechanisms of defeat

12. Small arms design and effects are an enigma. Small arms are expected to be effective across a range of missions and operational theatres, while efficiently applying effects on targets at applicable ranges. When understanding small arms mechanism of defeat, there are four principal factors:

a. **Penetration.** Penetration relates to the ability of small arms projectiles to overcome material tension and strength in order to disrupt targets. Penetration is the critical factor in small arms effectiveness. Penetration is dependent on a range of factors including projectile construction and observed velocity.

b. **Permanent cavitation.** Permanent cavitation is the total volume created by the disruption of the small arms penetration in the target set. This factor is mostly associated with tissue damage (wounding theory). Permanent cavitation is a function of projectile penetration and is dependent on a range of factors including projectile construction, observed velocity and projectile cross-section.

c. **Temporary cavitation.** Temporary cavitation is the total volume created by the expansion of the tissue during penetration. Temporary cavitation is caused through the transfer of energy generating a pressure wave during the projectile's passage

through the medium and is mostly associated with tissue damage (wounding theory). Temporary cavitation is a function of projectile penetration and is dependent on a range of factors including projectile construction and observed velocity.

d. **Frangibility and fragmentation.** Frangibility relates to the intentional design of the projectile to fragment upon entry into soft targets causing extreme and intentional damage to the target. Fragmentation relates to unintentional fragmentation that occurs during an event and can be a combination of primary (stripped jacket) and secondary (armour or bone) which causes additional trauma.

Conclusion

13. Through the use of new technologies and test methods, Proof and Experimental Establishment - Graytown can facilitate small arms characterisation and assessment into the future. Considering the range of predominantly Land projects that are being delivered, a suite of new small arms tests is critical in delivering an enhanced capability.

Biography

MAJ Mathew Brooks is the Officer Commanding, P&EE GT where he thinks of novel ways to test and evaluate weapon systems, munitions, explosive ordnance and Defence Platforms. He holds multiple graduate and post-graduate qualifications. The author would like to the acknowledge WO2 Michael Martin, LTCOL Ben McLennan and CAPT Bryan Brown.