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Inconsistency in 9 mm bullets: Correlation of jacket thickness to post-impact geometry measured with non-destructive X-ray computed tomography

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ABSTRACT

Fundamental to any ballistic armour standard is the reference projectile to be defeated. Typically, for certification purposes, a consistent and symmetrical bullet geometry is assumed, however variations in bullet jacket dimensions can have far reaching consequences. Traditionally, characteristics and internal dimensions have been analysed by physically sectioning bullets – an approach which is of restricted scope and which precludes subsequent ballistic assessment. The use of a non-destructive X-ray computed tomography (CT) method has been demonstrated and validated (Kumar et al., 2011 [15]); the authors now apply this technique to correlate bullet impact response with jacket thickness variations. A set of 20 bullets (9 mm DM11) were selected for comparison and an image-based analysis method was employed to map jacket thickness and determine the centre of gravity of each specimen. Both intra- and inter-bullet variations were investigated, with thickness variations of the order of 200 μm commonly found along the length of all bullets and angular variations of up to 50 μm in some. The bullets were subsequently impacted against a rigid flat plate under controlled conditions (observed on a high-speed video camera) and the resulting deformed projectiles were re-analysed. The results of the experiments demonstrate a marked difference in ballistic performance between bullets from different manufacturers and an asymmetric thinning of the jacket is observed in regions of pre-impact weakness. The conclusions are relevant for future soft armour standards and provide important quantitative data for numerical model correlation and development. The implications of the findings of the work on the reliability and repeatability of the industry standard V_{50} ballistic test are also discussed.

1. Introduction

Jacketed bullets typically contain a certain mass of heavy metal, such as lead, encased within a metal sleeve – the jacket. The jacket is intended to reduce friction within the rifle/gun barrel and ensures that the payload is uncompromised during delivery to the target. Depending on its velocity and the nature of the target a bullet's jacket might deform or rupture upon impact [1]. It has long been asserted that jacket thickness is a major contributor to bullet fragmentation and penetrative power [2]; however no major numerical modelling work to date has attempted to account for its impact on ballistic performance. Such models would be difficult to validate in the absence of a reliable method to measure jacket thickness variations non-destructively, both before and after impact. Present analytical models [3–8] consider only the gross geometry of bullets and make unjustified assumptions about the consistency and symmetry of the projectile and its casing. As such, a robust way to test correlation between ballistic performance and jacket thickness variation is desirable for the development of accurate numerical simulations.

Many methods of measuring the physical parameters of bullets have been documented. Destructive testing reveals detailed information regarding jacket thickness [9], however such methods are restrictive, may introduce inaccuracies due to deformation in the machining process and preclude studying geometric features of a bullet both pre- and post-impact. Although non-destructive radiographic techniques have been employed [10–13], they have not been exploited to their fullest potential. X-ray radiography lends itself to estimation of jacket thickness in a 2D plane; however, it cannot capture 3D geometry. X-ray computed

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