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Fragment impact modeling and experimental results for Insensitive Munitions compliance of a 120mm warhead

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Abstract

The US Army ARDEC at Picatinny Arsenal, NJ is currently developing a 120mm munition to achieve greater Insensitive Munitions (IM) compliance. Several international standardization agreements (STANAGs) outline various IM threats that are designed to simulate the hazards munitions are commonly exposed to on the modern battlefield. These threats include sympathetic reaction (SR), shaped charge jet impact (SCJ), cook-off (CO), and bullet and fragment impact (BI/FI). FI is the focus of this effort. As per NATO STANAG 4496 Ed. 1, FI testing is conducted at 2530±90 m/s with a 14.3mm diameter, L/D~1, 160˚ conical nosed mild steel fragment. Reaction violence resulting from FI can be mitigated by the use of an internal or external liner, commonly referred to as a particle impact mitigation sleeve (PIMS), applied to the warhead body. High rate continuum models were used to interrogate the shock and penetration responses of several PIMS-enhanced 120mm warheads loaded with PAX-3 explosive. The concepts were subsequently tested at the GD-OTS test facility. Test outcomes are reported and are compared with modeling predictions. The models indicate a significant reduction in the induced shock pressures due to application of the PIMS, and provide a good distinction between the initiating and non-initiating impacts which were experimentally observed. However, more work is needed to reduce the violence of the resulting subdetonative responses.

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Keywords: Fragment Impact; Insensitive Munitions; Explosives; Shock Initiation; James Criterion; Detonation; Deflagration

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1. Introduction

All U.S. munitions are required by international agreement to be made IM compliant to the extent practical. This entails that the munition in both its operational and logistical configurations must react nonviolently when subjected to a wide array of simulated threats encountered on the modern battlefield. These include fragment and bullet impact (FI/BI), fast and slow cookoff (FCO/SCO), sympathetic reaction (SR), shaped charge jet impact (SCJI). Response severity is categorized into detonation (Type I), partial detonation (Type II), explosion (Type III), deflagration (Type IV), and burn (Type V). The determination of reaction severity is made based on photographic evidence, witness plate damage, fragment size and throw distance, and blast gauge pressure readings. Currently, work funded by the Program Executive Office for Ammunition (PEO Ammo) is establishing and improving the Insensitive Munitions (IM) response of a 120mm warhead. This work documents several modeling and experimental results for the warhead subjected to the NATO standard FI test.

2. Fragment Impact Testing

The NATO standard FI test utilizes an 18.6g, 14.3mm diameter, L/D ~ 1, 160° conical-nosed mild steel cylindrical fragment, with a Brinell hardness of less than 270. STANAG 4496 Ed. 1 [1] specifies a standard impact velocity of 8300±300 ft/s. Two aim points are specified in STANAG 4496: the center of the largest presented area of explosive, and the most shock-sensitive location. In the U.S., a smooth bore 40mm powder gun is typically used to propel the fragment, which is mounted in a plastic sabot. Such guns are available commercially and are used by various test facilities, with many being obtained from Physics Applications, Inc. (PAI). A replaceable barrel section, called the wear section, is used since testing at such high velocities produces significant barrel erosion. The powder charge is adjusted until the correct velocity is achieved, and the diameter of the sabot is adjusted to ensure a good fit [2]. Velocity is measured using time-of-arrival gauges and/or by high speed camera, the latter typically being closest to the item along the shot line. Fig. 1 shows the fragment, sabot, and a typical gun.

Fig. 1. NATO standard fragment (left), typical sabot (center), and 40mm smoothbore gun (right)

Consistently achieving a velocity of 2530 m/s using single stage powder guns has proven to be challenging, and some variability in the impact conditions is often observed, which can affect test outcomes. Modeling studies using the NATO fragment [2] have identified significant differences in input shock and penetration pressures when excessive yaw or aim point error is introduced. The aim point accuracy requirements can be very stringent for smaller diameter items. Potential causes of projectile velocity, yaw and aim point variations are reviewed in [2].

3. Methodology and Configurations of Interest

The design of munitions to mitigate violent response to FI involves several considerations. Of primary concern is the extremely strong initial impact shock that is driven into the munition. The severity of the input shock pulse transmitted into the explosive can be substantially reduced by designing appropriate barriers or warhead liners to take advantage of impedance mismatch, edge rarefactions, and fragment breakup. Such barriers are often referred to as Particle Impact Mitigation Sleeves (PIMS) [3, 4]. A secondary concern is shear initiation, which is a pressure-dependent mechanism and is thought to be caused by adiabatic shear banding in the explosive leading to thermal initiation [5-7]. To our knowledge, it is not possible to quantitatively design against, but efforts are made to avoid it by keeping the penetration pressure as low as possible. Finally, violent sub-detonative responses, which occur over a much longer time frame, are often observed which result in the ejection of large fragments over very large distances. These responses, which are often unacceptably severe by IM standards, are highly complicated and depend on a number of variables including confinement and damage to the explosive [8, 9]. In order for the response to be judged