Development of a Small Shaped Charge Insensitive Munitions Threat Test

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Abstract

Rocket propelled grenade (RPG) shaped charge attack threats are of particular concern for Insensitive Munitions (IM) development. In response to these threats, the U.S. Project Engineering Office for Ammunition (PEO Ammo) worked with ARDEC to develop a highly reproducible and well characterized standardized 81mm shaped charge jet initiation test configuration. This test was adopted by the U.S. DoD for RPG threat testing as specified in MIL-STD-2105D and is completed as per STANAG 4526. Recent U.S. Insensitive Munitions shaped charge initiation attention has been focused on realistic smaller shaped charge threats. STANAG 4526 discusses standardized threats related to “Top Attack Bomblets” and SCJ with “Characteristics of 50mm Rockeye”. As a representative shaped charge for smaller size threats than the RPG, the 50mm Rockeye munition has been commonly recommended for testing. However, recent testing of the 50mm Rockeye munitions has shown a large undesirable variability of jet tip characteristics. This large variability in jet tip characteristics would be consistent with a large variability in munitions response to the 50mm Rockeye jet attack. Additionally, it has become clear that this shaped charge does not represent a commonly observed threat. For this reason, an effort is currently underway to identify a dominant smaller shaped charge threat and to develop a surrogate small shaped charge threat test configuration that provides very reproducible jet characteristics. The result to date is that 40mm grenades have been identified as a dominant smaller shaped charge threat and a surrogate consistent in approach with previous efforts has been designed.

Keywords: Shaped Charge; Insensitive Munitions; Explosives; Detonation

Nomenclature

V shaped charge jet velocity (mm/μs)  
D shaped charge jet diameter (mm)  
V^2D Held’s criteria (mm^3/μs^2)

1. Introduction

A commonly used metric for explosive detonation initiation thresholds for shaped charge jet attack that was developed by Held [1] is V^2D, where V is the jet velocity and D is the diameter. In the STANAG 4526 Edition 2 [2], four V^2D levels (table 1) are defined to represent the attack severity for munitions initiation from different sizes of shaped charges. Many technical experts have expressed concerns about the representativeness of these V^2D as they are considered far too high for...
the different classes of aggressions [3]. These levels would require the selection of shaped charges significantly larger than the class of aggression they are intended represent. For this reason, the testing is often performed to evaluate the reaction against a shaped charge belonging to a class of aggression rather than a V²D and standardized test configurations are being developed.

Table 1. Standardized V²D values from STANAG 4526 Edition 2.

<table>
<thead>
<tr>
<th>Threat</th>
<th>Representative V²D (mm³/µs²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Attack Bomblet</td>
<td>200</td>
</tr>
<tr>
<td>SCJ with characteristics of 50mm Rockeye</td>
<td>360</td>
</tr>
<tr>
<td>Rocket Propelled Grenade</td>
<td>430</td>
</tr>
<tr>
<td>Anti-Tank Guided Missile</td>
<td>800</td>
</tr>
</tbody>
</table>

2. Rocket Propelled Grenade Shaped Charge Threat

It is well known that Rocket Propelled Grenades (RPG) are widely available, used throughout the world and that a large variety of grenades are made in many different countries [4]. As RPG grenades have become one of the most dominate threats, the insensitive munitions (IM) community has recently been largely focused on RPGs for shaped charge jet initiation IM testing [5, 6]. A variety of grenades are available with basic RPG shaped charge grenades being dominantly used. In response to these threats, the U.S. Project Engineering Office for Ammunition (PEO Ammo) worked with ARDEC to develop a highly reproducible and well characterized standardized 81mm shaped charge jet initiation test configuration [6]. This test was adopted by the U.S. DoD for RPG threat testing as specified in MIL-STD-2105D and is completed as per STANAG 4526. Recent U.S. IM shaped charge initiation attention has been focused on realistic smaller shaped charge threats.

3. Rockeye Shaped Charge Characterization

STANAG 4526 Edition 2 discusses standardized threats related to “Top Attack Bomblets” and SCJ with “Characteristics of 50mm Rockeye”. As a representative shaped charge for smaller size threats than the RPG, the 50mm Rockeye munition has been commonly recommended for testing. As the Rockeye shaped charge is commonly used as a representative submunition for IM shaped charge testing, it was experimentally characterized for short standoff jet tip properties and compared to the RPG shaped charge IM threat testing surrogate. Three tests were performed to compare the V²D values. Two were done with the Rockeye, and one with the 81mm RPG surrogate warhead configuration. RP-80 detonators were used to detonate all of the warheads. Figure 1 shows an inspection x-ray of a Rockeye shaped charge. The Rockeye warhead tests were set up so that the early jet formation was captured and is shown in figure 2. The setup for the 81mm surrogate is shown in figure 3. Figure 4 presents early time flash x-rays for the RPG shaped charge IM threat testing surrogate. In all three tests the flash x ray times were pulsed at early times to capture the jets before breakup. As shown in table 2, the Rockeye V²D values are calculated to be 119.8 mm³/µs² and 165.5 mm³/µs², and the 81mm surrogate is calculated to be 141.3 mm³/µs². There is a considerable jet tip velocity difference between the two Rockeye warheads. As seen from the x rays, the Rockeye jets were not straight due to possible liner and warhead fabrication techniques, as well as possible jet perturbation due to interaction with the probe configuration. The 81mm RPG surrogate configuration produced relatively straight jets in all tests. The 50mm Rockeye munition show a large undesirable variability of jet tip characteristics. This large variability in jet tip characteristics would be consistent with a large variability in munitions response to the 50mm Rockeye jet attack. Additionally, it has become clear that this shaped charge does not represent a commonly observed threat.
Figure 1. Rockeye static x-ray.

Figure 2. Rockeye jet tip flash x-ray characterization at short standoff (43.6μs and 53.1μs flash times).

Figure 3. IM RPG threat test configuration (left) and warhead (right).
Figure 4. RPG surrogate jet tip flash x-ray characterization at short standoff (68.7μs and 80.8μs flash times).

Table 2. Reduced jet tip data for Rockeye (8-028, 8-035) and 81mm (8-036) tests.

<table>
<thead>
<tr>
<th>Test</th>
<th>$t_1$ (μs)</th>
<th>$t_2$ (μs)</th>
<th>Vel (mm/μs)</th>
<th>dia1* (mm)</th>
<th>dia2** (mm)</th>
<th>dia3*** (mm)</th>
<th>Average $V^2D$ (mm²/μs²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-028</td>
<td>43.6</td>
<td>53.1</td>
<td>6.28</td>
<td>3.07</td>
<td>3.01</td>
<td>3.03</td>
<td>119.81</td>
</tr>
<tr>
<td>8-035</td>
<td>39.7</td>
<td>50.1</td>
<td>7.56</td>
<td>2.55</td>
<td>3.06</td>
<td>3.08</td>
<td>165.54</td>
</tr>
<tr>
<td>8-036</td>
<td>68.7</td>
<td>80.8</td>
<td>6.37</td>
<td>3.29</td>
<td>3.64</td>
<td>3.52</td>
<td>141.32</td>
</tr>
</tbody>
</table>

* Early single time image  
** Early time from double image  
*** Late time from double image

4. Smaller Shaped Charge Threats

An effort was undertaken to identify a realistic dominant smaller shaped charge threat and to develop a surrogate small shaped charge threat test configuration that provides very reproducible jet characteristics. The result to date is that 40mm grenades have been identified as a dominant smaller shaped charge threat. A large number of 40mm and smaller shaped charge grenades and ammunition are readily available and used throughout the world. Low velocity grenade launchers are available in multiple grenade and single grenade configurations. Figure 5 shows photographs of a variety of low velocity grenade launchers that are available. A very large number of grenade variations are available, with many of them containing shaped charges. Figure 6 shows photographs of a variety of 40mm grenades.
Figure 5. Low velocity grenade launchers.

Figure 6. A variety of 40mm grenades.
5. Representative 40mm Shaped Charge Grenade

A representative 40mm shaped charge grenade configuration was developed as a baseline for jet characterization. The representative 40mm shaped charge grenade configuration is split back initiated in the apex region of the liner. Although this initiation is typical of 40mm shaped charge grenades, it can negatively affect shaped charge jet properties and produce somewhat inconsistent performance behavior. Modeling and simulation is being used to develop the surrogate small shaped charge and test configuration. The CALE [7] arbitrary Lagrange-Eulerian high rate continuum model was used extensively. The high rate continuum modeling was conducted to accurately identify the jet mass characteristics. As many 40mm grenades have been observed to perform somewhat erratically, this characterization provides a sound basis for achieving consistent testing configurations that clearly represent 40mm shaped charge grenades characteristics. Figure 7 shows representative modeling of the representative 40mm shaped charge grenade configuration. It is noted from the modeling the nose fuze produces considerable jet interaction and is known to consume high velocity jet as a result. Testing of the representative 40mm shaped charge grenade configuration was conducted and resulting jet x-rays are presented in figure 8. The jet tip velocity results agreed quite well with the modeling results.

![CALE modeling of the representative 40mm shaped charge grenade configuration.](image)

Figure 7. CALE modeling of the representative 40mm shaped charge grenade configuration.

![Flash radiograph results of the representative 40mm shaped charge grenade configuration.](image)

Figure 8. Flash radiograph results of the representative 40mm shaped charge grenade configuration.
6. Small Shaped Charge Surrogate Development

As consistent controlled performance is required for IM testing, the development of a small shaped charge surrogate has been undertaken based on producing jet characteristics similar to the representative 40mm shaped charge grenade. A resulting surrogate shaped charge initiation test configuration was developed with the objective of overcoming the issue of testing variability observed from production 40mm grenades. Figure 9 shows representative CALE modeling of the resulting 40mm surrogate shaped charge configuration. It was designed to be somewhat geometrically similar to the representative 40mm grenade, although it is built with high precision and quality materials and methods and is rear initiated in order to provide consistent performance. The geometry consists of a COMP-A3 loaded 40mm conical shaped charge. A relatively thick aluminum stripper plate, known as the “buffer plate”, is placed in front of the liner at a fairly short standoff. The aluminum buffer plate is required to strip away some of the high velocity jet, similar to the nose fuze on the representative 40mm grenade. The thickness and positioning of the aluminum plate is situated in order to produce accumulated jet mass profiles similar to the representative 40mm grenade with and without a nose fuze. Figure 10 presents the calculated jet accumulated mass profiles comparisons. The resulting jet characteristics are similar to those produced by the representative 40mm shaped charge grenade. High precision shaped charge hardware has been fabricated. Testing of the surrogate small shaped charge configuration is planned. Figure 11 presents a photograph of the surrogate shaped charge configuration hardware.

Figure 9. CALE modeling of the resulting 40mm surrogate shaped charge configuration.

Figure 10. Comparison of representative and surrogate small shaped charge calculated jet mass profiles.
7. Summary

Recent U.S. Insensitive Munitions shaped charge initiation attention has been focused on realistic smaller shaped charge threats. STANAG 4526 discusses standardized threats related to “Top Attack Bomblets” and SCJ with “Characteristics of 50mm Rockeye”. As a representative shaped charge for smaller size threats than the RPG, the 50mm Rockeye munition has been commonly recommended for testing. However, recent testing of the 50mm Rockeye munitions has shown a large undesirable variability of jet tip characteristics. This large variability in jet tip characteristics would be consistent with a large variability in munitions response to the 50mm Rockeye jet attack. Additionally, it has become clear that this shaped charge does not represent a commonly observed threat. For this reason, an effort is currently underway to identify a dominant smaller shaped charge threat and to develop a representative surrogate shaped charge threat test configuration that provides very reproducible jet characteristics. The result to date is that 40mm grenades have been identified as a dominant smaller shaped charge threat and a surrogate consistent in approach with previous efforts has been designed.

References