Characteristics of Propellant Bed Response When Subjected to High-Velocity Fragment Impact

Brian Krzewinski
U.S. Army Research Laboratory
brian.e.krzewinski.civ@mail.mil
410-278-6206
• Purpose
• Assumptions
• Set up
• Results
• Conclusion
• Future plans
• Historical Insensitive Munitions (IM) testing of large-caliber gun propulsion systems has typically resulted in violent reaction (type III or IV) for Fragment Impact (FI)
• Fragments from these reactions are hazardous to any personnel or equipment nearby
• This problem has been identified as a technological gap within the IM Plan of Actions and Milestones (POA&M) of several large-caliber gun propulsion systems
• Solving this technology gap by 2018 was identified as a primary goal by the Joint IM Technology Program (JIMTP) lead for the Large caliber gun propulsion Munition Area Technology Group
Assumptions

- The reaction always commences somewhere along the line of the fragment’s trajectory and subsequently propagates away from this point.
- There will be mechanically damaged energetic materials in the region of impact of varying size, which can cause non-uniform gas generation.
- A strong compressive wave travels through the propellant bed away from the point of impact, which compacts the propellant bed and ultimately results in a substantial mechanical loading event that leads to the failure of the container.

Approved for public release; distribution unlimited.
Experimental Setup

- High Speed camera
- Fragment Launcher
- Container/Force Gauge Assembly
- Break Screens
- Pencil gages

Approved for public release; distribution unlimited.
• 6 in diameter tube
• Internal length 17 in
• One end has a pin locking lid
• Other end incorporates a piston assembly
• 1 or 2 rows of embedded instrumentation

Approved for public release; distribution unlimited.
• Piston assembly and piezoelectric force transducer to measure the compressive force at one end of the container
• Piezoelectric pins to measure reaction front in the propellant bed
• Fiber optic assemblies to measure ignition time of arrival
• Time of arrival screens to measure fragment velocity
• High-speed video of the event to look for anomalies
<table>
<thead>
<tr>
<th>Test Number</th>
<th>Propellant</th>
<th>Igniter</th>
<th>Fiber Optics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Live</td>
<td>Live</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>Live</td>
<td>Inert</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>Inert</td>
<td>Live</td>
<td>Yes</td>
</tr>
<tr>
<td>4</td>
<td>Live</td>
<td>Live</td>
<td>No</td>
</tr>
<tr>
<td>5</td>
<td>Live</td>
<td>Inert</td>
<td>No</td>
</tr>
<tr>
<td>6</td>
<td>Inert</td>
<td>Live</td>
<td>No</td>
</tr>
</tbody>
</table>
Inert Propellant /Live Igniter Results

- Test 3 Inert/Live velocity of 8211 ft/s
  - Type V (Burning reaction)
- Test 6 Inert/Live velocity of 8340 ft/s
  - Type V (Burning reaction)
- Both containers had a small entrance hole slightly larger than the fragment diameter and a petaled exit hole
- No other damage was observed
Inert Propellant/Live Igniter Force Measurements

- Peaks not identical but are of the same approximate magnitude
- Likely due to propellant bed variability
Live Propellant/Live Igniter
Results

• Test 1 Live/Live velocity of 8244ft/s
  – Type III (Explosion reaction)
• Test 4 Live/Live velocity of 8309ft/s
  – Type III (Explosion reaction)
• Both containers split into many pieces, bent their end cap around the locking pin, and left propellant marks on the plunger end
• Shielding prevented end caps from leaving the immediate area

Approved for public release; distribution unlimited.
• Peak force over 24 times that of the inert/live experiments
• Peak duration similar for both live/live experiments
Live Propellant/Inert Igniter
Results

• Test 2 Live/Inert velocity of 8287ft/s
  – Type III (Explosion reaction)
• Test 5 Live/Inert velocity of 8215ft/s
  – Type III (Explosion reaction)
• Both containers split into many pieces, bent their end cap around the locking pin, and left propellant marks on the plunger end
• The welds holding the piston together also broke on test 2
• Shielding prevented end caps from leaving the immediate area
- Peak force over 26 times the force witnessed in the inert/live experiment
- Peak duration similar for both live/inert experiments

Clipped due to overextending the force transducer
• Inclusion of live igniter material appears to have no effect on overall reaction mechanisms
• Experiments with the live propellant react fairly symmetrical from the point of impact

### Live Propellant

**Piezopin TOA**

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 0
- 0.0001
- 0.0002
- 0.0003
- 0.0004

- Pin Number (1=endcap side, 7=plunger)
- Live/Live
- Live/Inert (1)
- Live/Inert (2)

### Inert Propellant

**Piezopin TOA**

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 0
- 0.0001
- 0.0002
- 0.0003

- Pin Number (1=endcap side, 7=plunger)
- Inert/Live (1)
- Inert/Live (2)

Approved for public release; distribution unlimited.
Conclusion

- A strong compressive wave appears to be traveling through the live propellant bed
- The response is fairly symmetrical when live bed propellant is used
- Container break up is due, in part, to the strong compressive wave
- There is little time available to mitigate the reaction using traditional venting schemes
  - Maximum force is reached roughly 1 ms after fragment impact
Future Plans

- Altering the deposited energy
  - Adding ballistic barriers
  - Lowering fragment velocity (majority of credible impacts are less than 8300 ft/s)
- Experimenting with other propellants to determine effects of propellant energies
- A completely inert experiment (to isolate the non reactive force)