An Initial Evaluation of Several Promising High Blast Explosives

Authored by:
Paul Braithwaite
ATK Aerospace Group
Paul.Braithwaite@ATK.com

Prepared for:
2013 NDIA IM/EM Symposium
San Diego, California
7 - 10 October 2013
Outline

• Overview and introduction

• Theoretical studies

• Safety and handling properties

• Test methodology

• Test results

• Summary and conclusions
Overview and Introduction

- Blast explosives are used in many commercial and military applications
  - Building demolition, runway cratering, quarrying, etc.
- Blast explosives often utilize aluminum to increase temperature, blast, and impulse
- A challenge associated with aluminized blast explosives is to formulate them in such a manner that the aluminum reacts during the early stages of the explosive event
  - This is a particularly challenging problem for small and medium sized articles
- This paper presents results of an interesting study that examines the role of specific formulation changes on blast explosive performance
Formulation Approach

• A single formulation family was evaluated during this study
  • Binder system, explosive content, and total solids were held constant
  • A single grade of aluminum was used in all formulations
  • All research compositions utilized a solid oxidizer
  • Oxygen balance was varied by changing the ratio of aluminum to oxidizer
  • Several different solid explosives were evaluated in the formulation family
• Theoretical results were compared with two baseline aluminized explosives to ensure the new formulations had predicted properties in a reasonable range
• Six representative research explosives were selected from a larger group for discussion in this paper
Predicted Density and Mechanical Energy

- Density of candidate research explosives was universally higher than the baseline compositions

- Mechanical energy varied with formulation detail
  - Research explosives were predicted to have equal to or better mechanical energy than baseline compositions

- Formulation notes
  - B1 contains Al
  - B2 contains Al and an oxidizer
  - R1 through R4 used explosive 1
  - R5 and R6 used explosive 2
Detonation Velocity and Pressure

- Explosives were formulated so the research and baseline compositions had similar calculated detonation velocities
  - Range was 0.48 km/sec
- Calculated detonation pressures for research explosives were generally higher than baseline compositions and decreased as aluminum was added
  - Calculated pressures are in the expected ranges
Oxygen Balance and Detonation Temperature

• Oxygen balance for the research explosives was more favorable than baseline compositions
  • Reference oxygen balance for well known materials:
    • TNT:  -74.0%
    • NG:  3.5%
    • AN:  20.0%
  • Predicted detonation temperatures for research formulations were higher than for baseline compositions
  • Expected to aid in aluminum combustion

Calculated Detonation Temp. of Candidate and Baseline Compositions Relative to B1

Calculated Oxygen Balance of Candidate and Baseline Compositions Relative to B1
Safety and Handling

- Small-scale safety testing was performed on several of the research explosives and the two baseline compositions

- Results indicate all compositions are safe to process

- Research explosives have lower thermal stability than baseline compositions but all exotherms are in the expected range

<table>
<thead>
<tr>
<th>Formulation</th>
<th>ABL Impact (cm)</th>
<th>ABL Friction (lb @ ft/s)</th>
<th>ESD (J)</th>
<th>SBAT (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>80</td>
<td>800 @ 8</td>
<td>8</td>
<td>322</td>
</tr>
<tr>
<td>B2</td>
<td>13</td>
<td>25 @ 8</td>
<td>8</td>
<td>332</td>
</tr>
<tr>
<td>R1</td>
<td>17</td>
<td>25 @ 8</td>
<td>8</td>
<td>263</td>
</tr>
<tr>
<td>R2</td>
<td>11</td>
<td>50 @ 4</td>
<td>8</td>
<td>272</td>
</tr>
<tr>
<td>R3</td>
<td>21</td>
<td>50 @ 6</td>
<td>8</td>
<td>263</td>
</tr>
<tr>
<td>R5</td>
<td>11</td>
<td>100 @ 4</td>
<td>8</td>
<td>272</td>
</tr>
<tr>
<td>R6</td>
<td>17</td>
<td>25 @ 8</td>
<td>8</td>
<td>268</td>
</tr>
</tbody>
</table>
Test Methodology

- Two different tests were selected to generate initial performance data on selected candidate compositions

  - Detonation velocity in standard LSGT tubing and hemispherical detonation

  - Samples of B1 were also tested at the same time to improve our ability to compare test results

Diagram:

- Blasting cap
- Booster
- Acetate cards
- Witness plate
- Velocity pins

Pressure Transducers:
- T3
- T2
- T1

Hemispherical Charge
- Booster
Detonation velocity was checked on three research compositions (R2, R4, and R6) and baseline composition B1.

Results for all research explosives were very close to the predicted values.

Calculations under predicted Vd for the baseline explosive but were in good agreement (+0.08 mm/μ sec) with literature values for this explosive composition.

<table>
<thead>
<tr>
<th>Explosive</th>
<th>Calculated Detonation Velocity Relative to B1 (mm/μ sec)</th>
<th>Measured Detonation Velocity Relative to B1 (%)</th>
<th>Calculated - Experimental Velocity (mm/μ sec).</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>0.00</td>
<td>100.0</td>
<td>0.66</td>
</tr>
<tr>
<td>R2</td>
<td>0.24</td>
<td>94.9</td>
<td>0.03</td>
</tr>
<tr>
<td>R4</td>
<td>-0.03</td>
<td>90.1</td>
<td>-0.07</td>
</tr>
<tr>
<td>R6</td>
<td>-0.09</td>
<td>89.2</td>
<td>-0.08</td>
</tr>
</tbody>
</table>
Hemisphere Blast Testing

• Hemispherical charges of one baseline explosive, B1, and five research compositions, R1 through R5, were prepared

• All charges had similar masses & were initiated with a standard charge

• All explosives processed well and the resulting charges had densities above 99% of their theoretical maximum density

• Testing was performed at ATK’s Northern Utah explosive test facility
Peak Pressure

- Peak pressures at both T2 and T3 transducer locations for the research explosives were nearly all higher than for the baseline composition
- R5 had a peak pressure more than 1.5 times that of B1
- Trend of decreasing $P_{CJ}$ with higher aluminum content was not observed
- Results at T1 are not reported due to test difficulties
Positive Impulse

- With the exception of impulse data for R1 at T3, all measured impulse values for the research explosives were substantially greater than for B1

- R5 was again the top performer with a relative positive impulse more than three times greater than B1

- Appears to be a trend of increasing impulse with increasing aluminum level for explosives R1 through R4 close to charge 0.0
Application

- Data generated in subscale tests were used to select a composition for a small prototype warhead
- Results were most impressive!
Summary

• Formulation approach was found to be a very useful tool when developing new high blast compositions

• Subscale test results gave promising results that translated well into the selection of an explosive for a small prototype warhead
  – Results support further development of this formulation line

• Additional testing is needed to verify that the large improvement in performance is realized in large-scale articles