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PROCESSING SOLID PROPELLANTS FOR RECYCLING

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(POSTER ABSTRACT)

Rapid evolution in the structure of military forces worldwide is resulting in the retirement of numerous weapon systems. Many of these systems include rocket motors containing highly energetic propellants based on hazardous nitrocellulose/nitroglycerin (NC/NG) mixtures. Even as the surplus quantities of such material increases, however, current disposal methods--principally open burning and open detonation (OB/OD)--are coming under close scrutiny from environmental regulators. Environmentally conscious alternatives to disposal of propellant and explosives are thus receiving renewed interest.

Recycle and reuse alternatives to OB/OD appear particularly attractive because some of the energetic materials in the inventories of surplus weapon systems represent potentially valuable resources to the commercial explosives and chemical industries. The ability to reclaim such resources is therefore likely to be a key requirement of any successful technology of the future in rocket motor demilitarization.

The demilitarization process depicted on this poster meets this requirement. In particular, the essential elements of an innovative thermal cycling process termed "cryocycling" are presented as part of a systems approach to the demilitarization of tactical rocket motors. In this process, we subject rocket motors/propellants to repeated thermal cycles between ambient and liquid nitrogen temperatures. The thermal gradients generated during cryocycling produce material- and geometry-dependent stresses in the propellant. We observe that stress relieving cracks form quickly during both the freezing and thawing portions of a cryocycle when internal stresses exceed the strength of the propellant. Representative analyses of this process, using both analytical and finite element methods, are shown on the poster. It is clear that cracking occurs on each cycle; and that these cracks effectively reduce the size of the original propellant grain to a characteristic size distribution in the range of 1-5 mm after 3-5 cycles. It is important to note that, by using liquid nitrogen in the process, we insure that the energetic content of the propellant is unchanged and that no secondary waste streams are generated. The resulting cryocycled material is thus ideally suited for a variety of applications in the commercial explosives industry, including booster charges for mining and specialty explosives for metal formig.

In this era of scaled back military efforts, we feel that cryocycling of rocket motor propellant for reapplications in the explosives industry is literally turning swords into plowshares. We also note that our results to date suggest that cryocycling is particularly effective for tactical rocket motor propellants based on NC/NG mixtures that are typically found in demilitarization inventories worldwide. In summary, we conclude from our efforts that cryocycling is safe, widely applicable, environmentally benign, and economically competitive with other alternatives to OB/OD.

*Presenter
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Cryocycling

- Definition: Cycling a propellant's temperature between ambient and 77K (-196° C)—liquid nitrogen temperature.

- Temperature cycling increases cracking and decreases average particle size.

- A propellant's ultimate particle size depends on its material properties.
Cryocycling Facility
Cryocycling Results for Mighty Mouse Rocket Motor

(8 inch section with ethylcellulose wrap)

<table>
<thead>
<tr>
<th>Cycle#</th>
<th>Number of Pieces</th>
<th>Cool/Warm Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>430</td>
<td>25/60 min</td>
</tr>
<tr>
<td>2</td>
<td>≈3000</td>
<td>15/30 min</td>
</tr>
<tr>
<td>3</td>
<td>≈10,000</td>
<td>15/30 min</td>
</tr>
</tbody>
</table>
Section of Mighty Mouse Double-Base Rocket Motor

Before Cryocycling

After First Cryocycle
Sample of Size-Reduced Propellant from Mighty Mouse Motor After Three Cryocycles
Cryocycling Modeling Activities

Goal

- Determine optimum initial and boundary conditions for cycling a given propellant to its characteristic size

Approach

- Acquire temperature-dependent properties (ambient to LN) - Inert & live propellant
- Thermal & mechanical properties
- Simulate evolution of thermally driven stresses & strain
- Simulate evolution of internal fractures
Effect of Temperature on Mechanical Properties of LW CYH

Rate = 3.4 \times 10^{-3} \text{ sec}^{-1}

Stress (KP)

Engineering Strain
Complementary Aspects of Cryocycling Modeling Efforts

- Thermal/Stress Histories
  - Idealized Geometry and Boundary Conditions
  - Finite Difference Methods

- First Fracture
  - Real Geometry and Boundary Conditions
  - Finite Element Process Simulation

- Subsequent Fracture
  - Ultimate Particle Size
  - Fracture Mechanics and Non-Deterministic Network Model
Sample Calculations of Thermo-Elastic Stress

Hoop Stress

Constant Modulus

Temperature-Dependent Modulus

\( \Delta t = 1000 \text{ sec} \)
Conclusions

- Surplus rocket propellant should be viewed as a resource rather than a waste.
- Size reduction enhances reuse/recycle options for propellant.
- Cryocycling can process propellants rapidly without generating additional waste.
Cryocycling

**Advantages**

- Liquid nitrogen is environmentally friendly.
- Process increases surface area.
- Small motors can be batch processed.

**Disadvantage**

- More effective on some compositions than others.
Issues Driving Demilitarization of Explosives and Propellants

- DoD and DOE demilitarization inventories of explosives and propellants are growing rapidly.

- Open Burning/Open Detonation of energetic materials becoming less environmentally acceptable.

- Most recycle and reuse options require processing to reduce particle size of bulk material.
END

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DATE