2012 Insensitive Munitions & Energetic Materials Technology Symposium

SOLID ROCKET MOTOR VENTING SOLUTIONS

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Outline

• Background
  – Description of the problem
  – Historical review

• Aerojet Propellant Testing

• A Shape Memory Alloy Venting Solution

• Description of a Standard Test Motor

• Test Results

• Summary and Conclusions

• Acknowledgements
System Background

- Man-portable (small, light-weight)
- Low-cost, lightweight case which provides reliable pressure capability.
- The propellant is a cross-linked, double-base formulation containing nitramine and a mixed energetic plasticizer.
- State-of-the-art, lower-sensitivity propellants fall short of performance goals.

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<th>Modes</th>
<th>IM Reactions</th>
<th>Component</th>
<th>FCO</th>
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<tr>
<td>Field Handling</td>
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<td>Propulsion Unit</td>
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<td>N/A</td>
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<td>Transportation and Storage</td>
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<td>Propulsion Unit</td>
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Type I: Detonation
Type II: Partial Detonation
Type III: Explosion
Type IV: Deflagration/Propulsive
Type V: Burning
The Cookoff Problem

• Energetic materials are not meant to survive long durations in high heat environments without undergoing thermal decomposition.
  – Faster heating (fuel fire) usually causes a surface ignition of the energetic material.
    • Most of the material remains in an undamaged state prior to burning.
    • Confinement at the ignition location can lead to drastically different results.
  – Slow heating often results in extensive damage prior to ignition.
    • Ignition occurs in the bulk, due to self-heating.
    • Hardness of the material in this damaged state can influence reaction by adding to confinement.
Why Venting?

• The burn time of a rocket motor is controlled by:
  – Propellant quantity
  – Burning surface area
    • dependent on grain design and surface regression of the propellant
  – Ballistic properties of the propellant
    • dependent on operating pressure & temperature

• Product gases increase the pressure in a feedback loop unless they can be removed from the system at an adequate rate.
  – Critical vent area where gases produced by decomposition can be effectively released to the surroundings without increasing pressure;
Aerojet Propellant Testing
• Phase changes and decomposition result in void formation and swelling in the propellant.
  – Non-CTE growth began 118°C-121°C (245°F-250°F) in three Slow Cookoff Visualization (SCV) Tests, 3.6-6.5 cm (1.4-2.5-inch) diameter.
  – Unconfined propellant growth exceeds 100% in SCO heating.
  – Propellant softens, non-violent burning when vented.
Determining Critical Vent Area

- Aerojet performed burning rate measurements as a function of pressure at various temperatures from 21°C and 115.6°C (70°F to 240°F).

- Burning rate dependence used with rocket motor design tools to determine the critical vent area.
  - This method of analysis and the justification for use in fast cookoff mitigation has been reported previously.
  - Necessarily assumptions:
    - Burn rate temperature sensitivity would remain linear up to autoignition
    - Burning rate equation was valid to low pressures.

- Calculations based on the ambient grain configuration, with the assumption that all grain surfaces were ignited simultaneously.
A Shape Memory Alloy Venting Solution

- Compact ring
  - Less than 9g for a 5.08cm (2-inch) diameter test motor
  - Providing 11.4cm² (1.76-inch²) vent area

- Ring can be implemented in the tactical motor with only minor modifications to parts that would already exist.

Venting Plug is held in place by snap ring. SMA phase change releases plug at ~100°C
Vent Design Inert Demonstration Testing

- Inert motor in oven hooked to supply pressure:
  - Rapidly pressurized @ 21°C & 71°C (70°F-160°F).

  - **Vent held 13.8 MPa (2000 psi) pressure.**

![Graph showing pressure vs. time for different temperatures.](attachment:graph.png)

- Pressure taken well upstream from motor. Drop is not a failure of closure.

- Motor held pressure.
Vent Design Inert Demonstration Testing

- Conditioned at 250°F and gradually pressurized.
  - **Vent opened @17 psi.**
Vent Design SCO Testing
Vent Design SCO Testing
• Closure vented on propellant ignition @260°F.
  – Propellant extinguished (dP/dt)

• Continue heating resulted in mild burn.
Summary & Conclusions

• Insensitive Munitions design requires system solutions.
  – Often times replacing the propellant is not viable.

• Aerojet characterized the high-temperature behavior of a high-performance minimum-signature propellant.

• Aerojet successfully demonstrated this venting device in inert gas testing and in slow heating testing with a loaded test motor.
  – This testing marks a leap forward for passive venting in small systems due to the low weight and simplicity of the mechanism.
  – The entire feature replaces material already in use in the motor case construction, with the exception of the critical components.
Acknowledgements

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