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Gun Launch Dynamics of Pyrotechnics

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Outline

- Objective of Study
- Mechanical Behavior of Pyrotechnics
- Dynamic FEA of 105 mm Illumination Round
- Behavior of Illumination Candle During Gun Launch
- Summary
- Future Work

Objective

The purpose of this study is to:

- Determine mechanical properties (with thermal and strain dependence) of standard pyrotechnic
  - Perform mechanical testing on standard pyrotechnic (binder, oxidizer, fuel) to determine structural behavior of material
  - Evaluate similarities (if any) between PBX and pyrotechnics
- Determine impact of gun launch on illumination candles in 105mm projectile through modeling and simulation.
  - Explore various design parameters: length, diameter, etc.

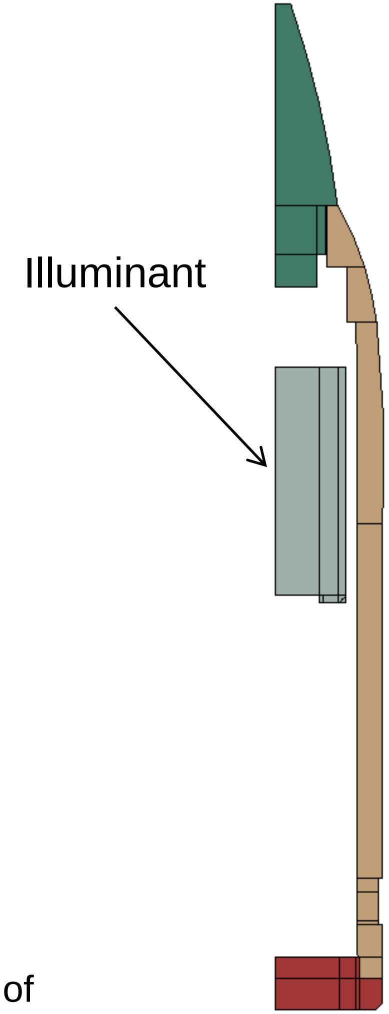

Figure 1. Fuze, projectile body, base and illuminant (gray) of 105mm projectile in half symmetry, axisymmetric model. The voids are locations for other ancillary components(not depicted).

Mechanical Behavior of Pyrotechnic

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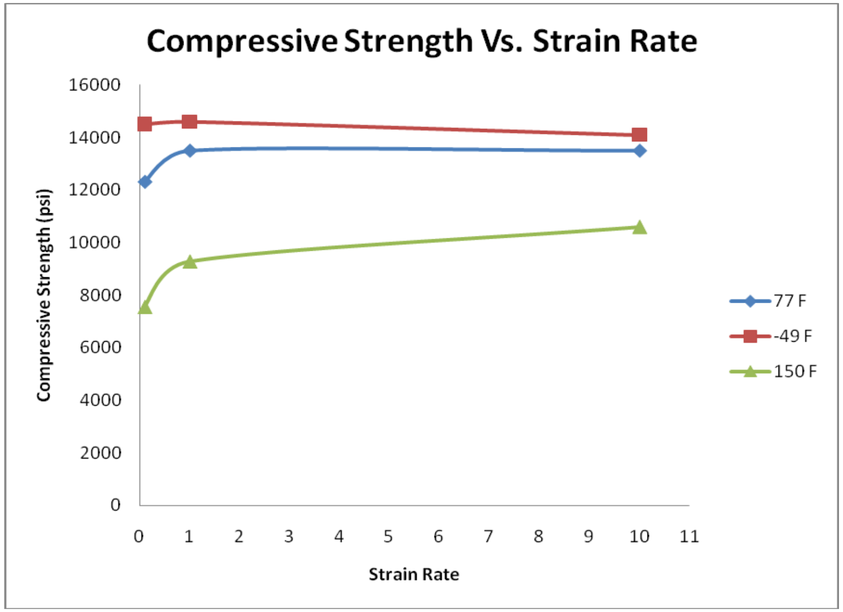
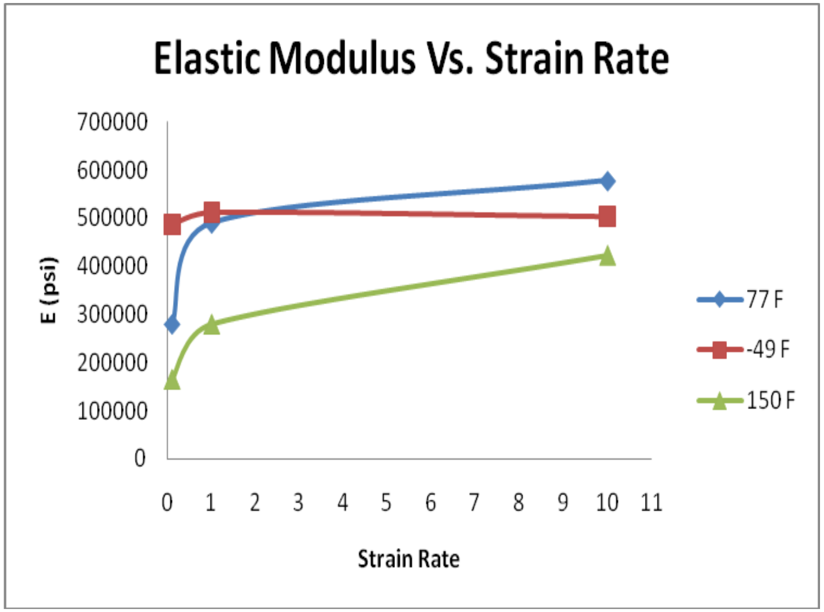




- Uniaxial Compression tests performed at strain rates 0.1/s, 1/s, and 10/s and temperatures -49°F, 77°F, and 150°F.
- Strength and modulus exhibit decreasing sensitivity to strain rate with increasing strain rate and at temperatures below 150°F
  - Sensitivity to strain rate highest at low strain rates. For PBX, the binder dominates mechanical behavior at low strain rates and fuel and oxidize dominate the mechanical behavior of the material at high strain rates*
- Slight increase in elastic modulus with strain rate for hot and ambient samples

*D.A. Wiegand and B. Reddingius, 2005, "Strengthening and Stiffening of Plastic Bonded Explosives Under Pressure and Metal-Like Mechanical Properties", U.S. Army ARDEC Technical Report, AD-E403 069

FEA of Illuminant: 105mm Illumination Round

Analysis Overview

- Analysis simulates a 105mm projectile gun launch to capture stresses experienced in pyrotechnic during setback and setforward
- Structural analysis performed using ABAQUS/Explicit v. 6.9.1
- 2D-axisymmetric model of standard 105mm projectile
  - Model includes all inner components with specific material properties
  - Focus on illuminant behavior (mesh refined)
- Full model: 7172 nodes, 6292 elements

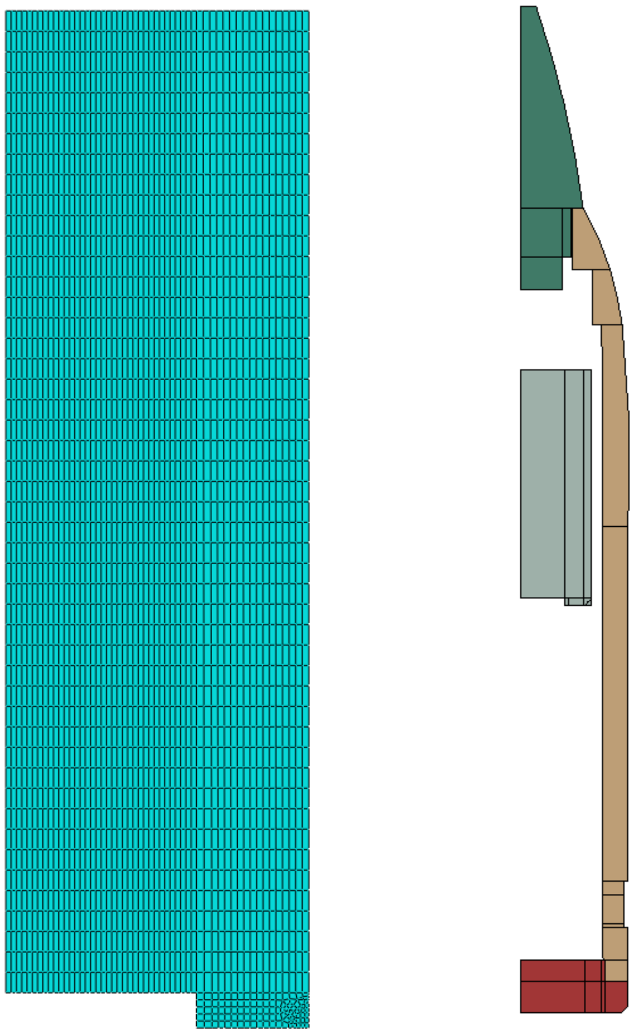


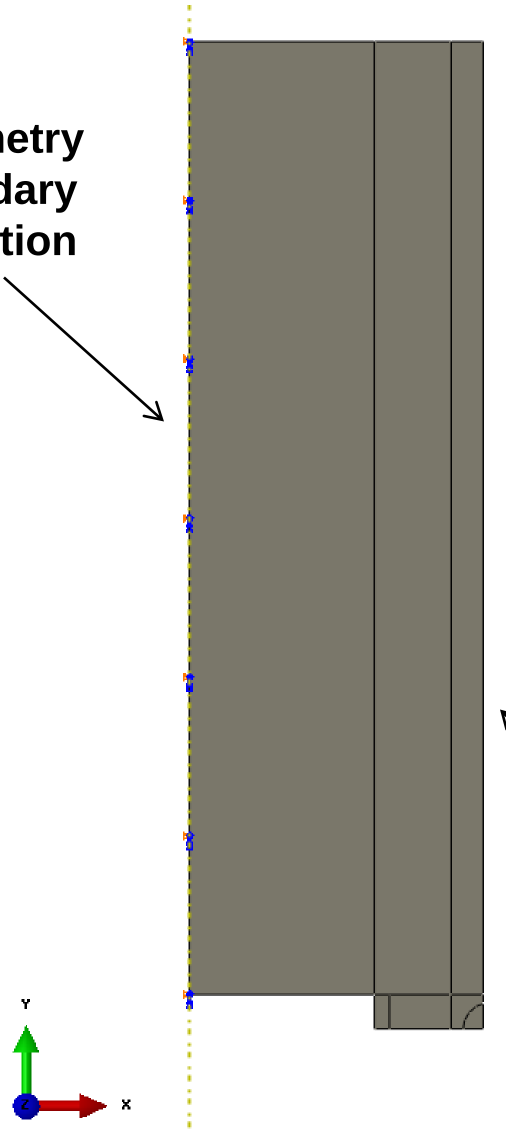
Figure 2. a) A depiction of the 2D-axisymmetric pyrotechnic model. The meshed model of the pyrotechnic compound consists of 2761 nodes and 2652 elements. **b)** 105mm projectile and general location of illuminant.

Assumptions

- 2D axisymmetric model:
  - decrease model complexity and analysis run time
  - Unfortunately, projectile spin behavior cannot be performed using this method
- Voids in original model were removed:
  - Projectile components are pressed into body
- Effects of simplifying complex parts negligible:
  - Full 3D baffle gaskets have through holes that are filled to create one continuous 2D part profile
- Pyrotechnic material shape simplified to fill the cylindrical case

Boundary Conditions, Constraints

Symmetry Boundary Condition

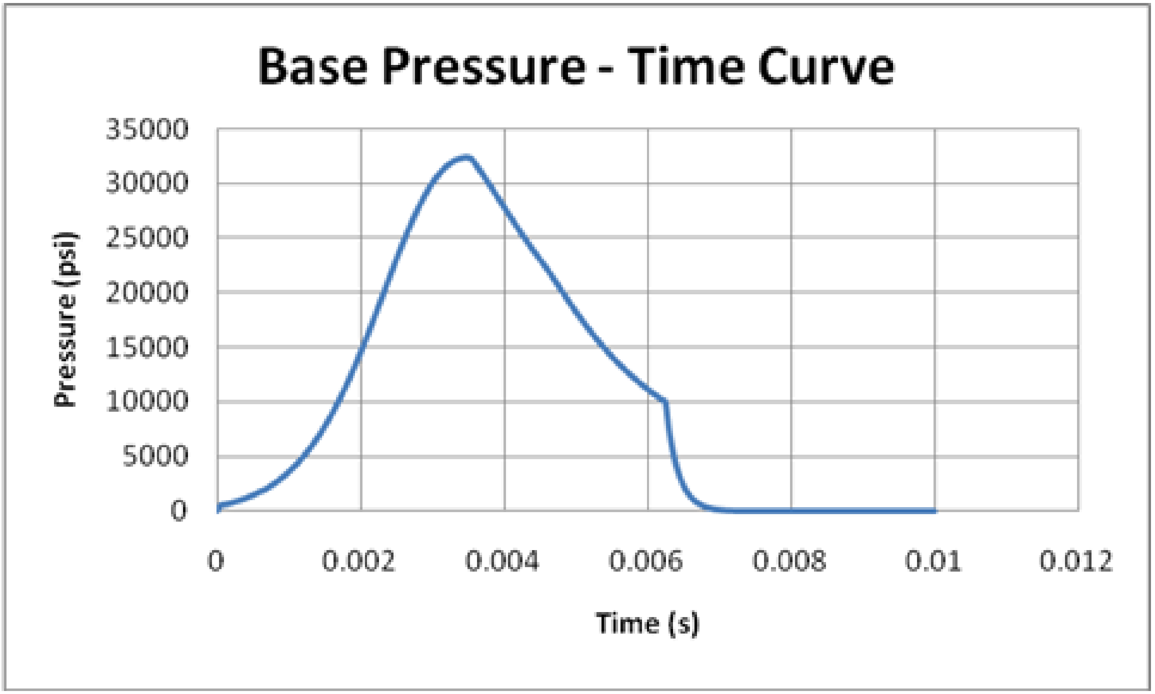


Adhesive interaction

- The pyrotechnic is confined by a fiberboard liner inside a steel cylinder capped at both ends (not depicted).
- A tie constraint simulates the adhesive bond between illuminant surface and fiberboard liner.
  - Nodes aligned along edge of illuminant and cylinder
- Model is oriented in the y axis

Figure 3. Model of the pyrotechnic compound. The axis of symmetry is shown.

Load



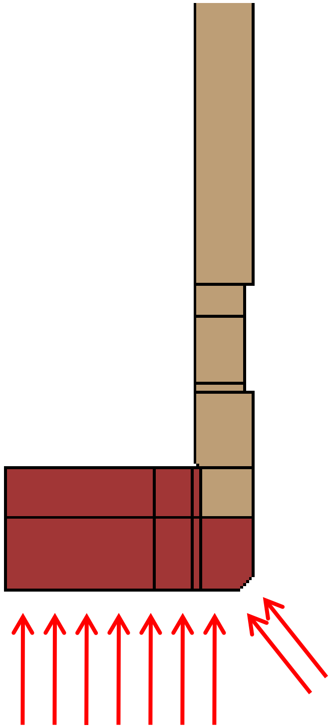


Figure 4. a) A surface force, simulating the Zone 7 propellant charge, is applied to the outer surface of the base of the projectile. The 105mm projectile experiences a maximum pressure of approximately 32000 psi for 6 ms. **b)** Zoom in of projectile base. Arrows depict force placement.

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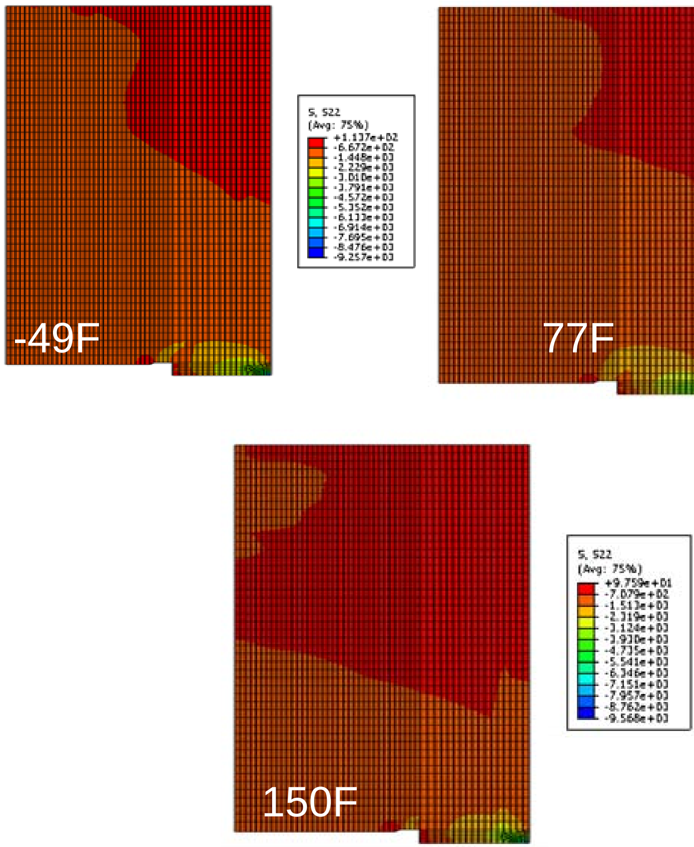
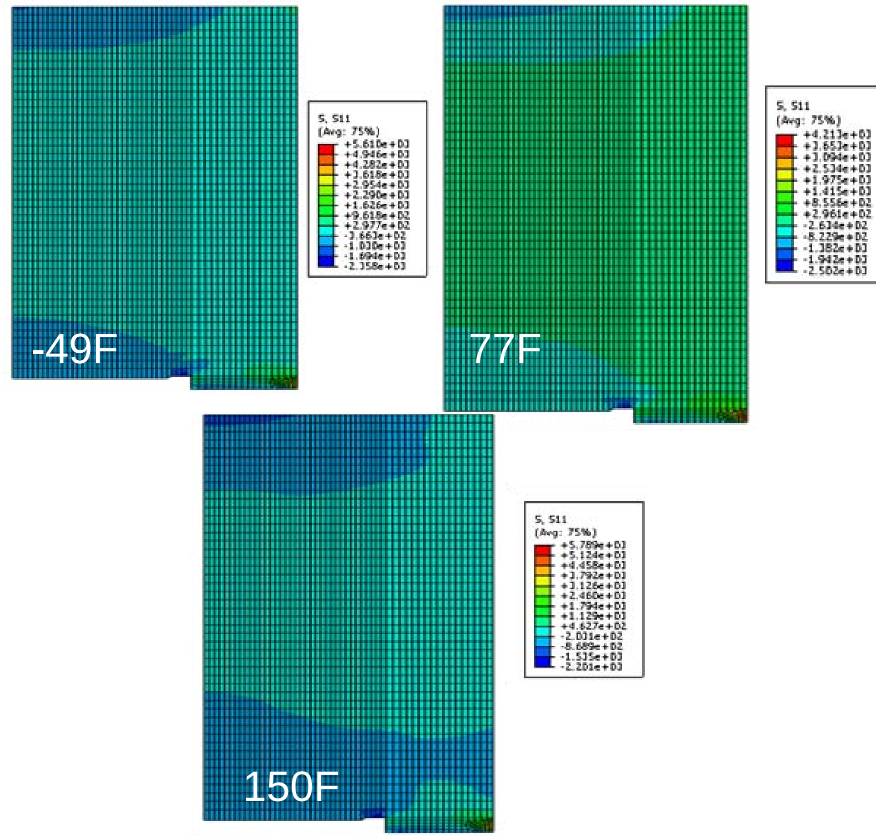
Behavior of Illumination Candle During Gun Launch

Impact of Gun Launch





Axial Load Profile (Maximum)

Temperature (°F)	Axial (psi)	Radial (psi)	% Compressive Strength (Axial Stress)
-49	8902	2358	63
77	9257	2502	69
150	9568	2201	90

Radial Load Profile (Maximum)

Design Considerations

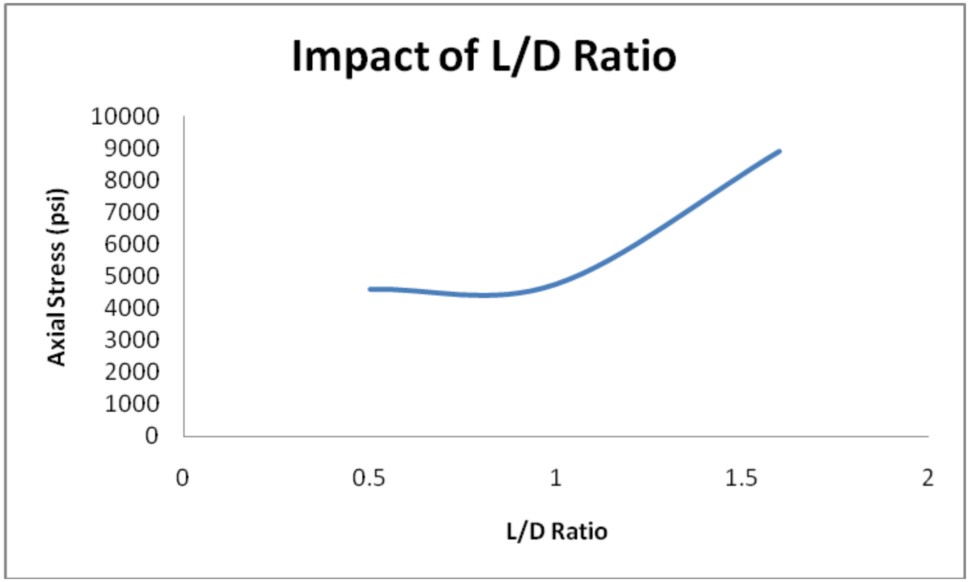


Figure 5. Impact of L/D Ratio of Axial Stress Profile of Pyrotechnic

- The aspect ratio of the pyrotechnic impacts the material's structural integrity during gun launch.

- The higher the length to diameter aspect ratio, the higher the stress on the pyrotechnic under confinement (pressure range in this analysis is 2500 psi – 2700 psi).

Summary

- This study has shown that the structural integrity of the pyrotechnic varies with:
  1. **Strain rate (for high temperatures):** Slight increase in strength and stiffness observed in ambient and hot samples
  2. **Temperature:** At higher temperatures the pyrotechnic is more sensitive to the axial load such that the overall axial stress on the material increases.
  3. **Aspect Ratio:** The length to diameter ratio impacts the structural integrity of the pyrotechnic.

- The behavior observed is similar to that of PBX.
  - One goal of this work is to determine if the mechanical behavior is comparable.
  - Based on what we know about PBXs, we can carry the assumption that the behavior of the pyrotechnic is dominated by the binder at low strain rates and dominated by the fuel and oxidizer at high strain rates.

Future Work

- Evolve material model from Linear Elastic/Plastic to an advanced composite model
  - Triaxial compression testing to determine impact of varying confinement pressure
- Evaluate thermomechanical properties of composite and identify similarities to PBXs
  - Thermal analysis to determine impact of inorganics on binder
  - Curing study of binder
- Develop an intricate material model including damage to evaluate crack propagation in illuminant

Acknowledgements

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