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Aluminum Honeycomb Characterization and Modeling for Fuze Testing

D. Peairs, M. Worthington, J. Burger, P. Salyers, E. Cooper

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Motivation

- Need: Rapid evaluation of fuze models in impact with honeycomb materials
  - Large expense of fuze testing in actual penetration and launch environments.
  - Airgun testing used to simulate environments
  - Pulse characteristics controlled by honeycomb materials.
  - Shell model of honeycomb is too computationally intensive for many iterations

Aluminum Honeycomb Material

- Primarily two current types used at L3-FOS: “ Mitigator” and “Backstop”

	Foil Layers	Foil Thickness	Density	Crush Strength
Mitgator	>2	.006 in	0.0166 lb/in^3	>80,000 lbs
Backstop	1	.002 in	0.0045 lb/in^3	>1000 lbs

1/8” pre-crush

Mitigator

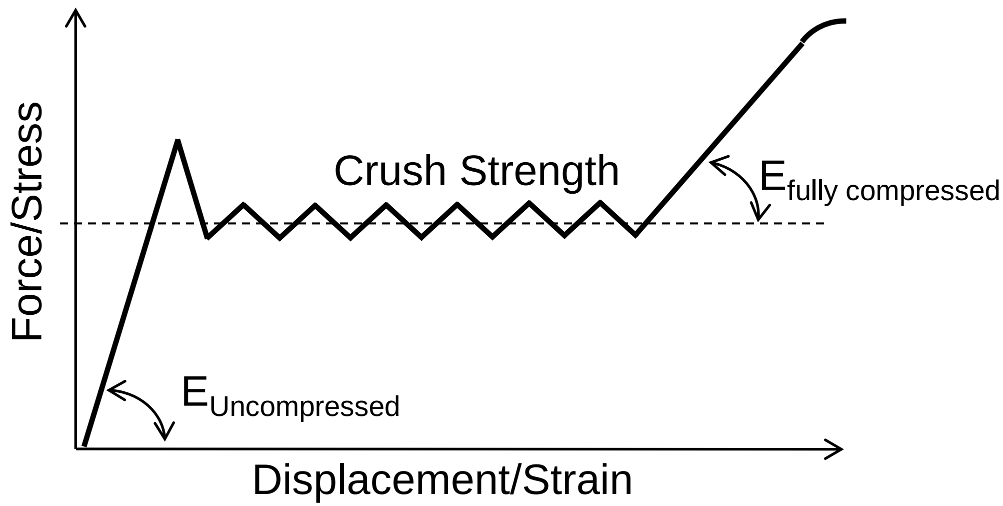
Mitigator after impact

Backstop

Material Model Description

- LS-DYNA Explicit FEA
  - Equilibrium with applied forces not maintained - update stiffness matrix in small steps
  - Timestep controlled by element size and wavespeed

- MAT_026, Mat_126 (honeycomb, modified honeycomb) options
  - Separate stress-relative volume curves allowed for normal and shear stress direction (3 normal, 3 shear directions)
  - Mat_026 uncoupled, nonlinear behavior for normal and shear stresses
  - Mat_126 can model off axis loading, shear and normal curves can be coupled
  - Two almost independent phases: Not Compacted, Fully Compacted
  - Extrapolated yield stresses should not be negative

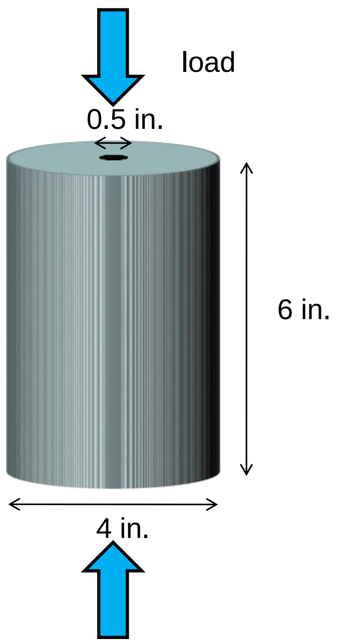


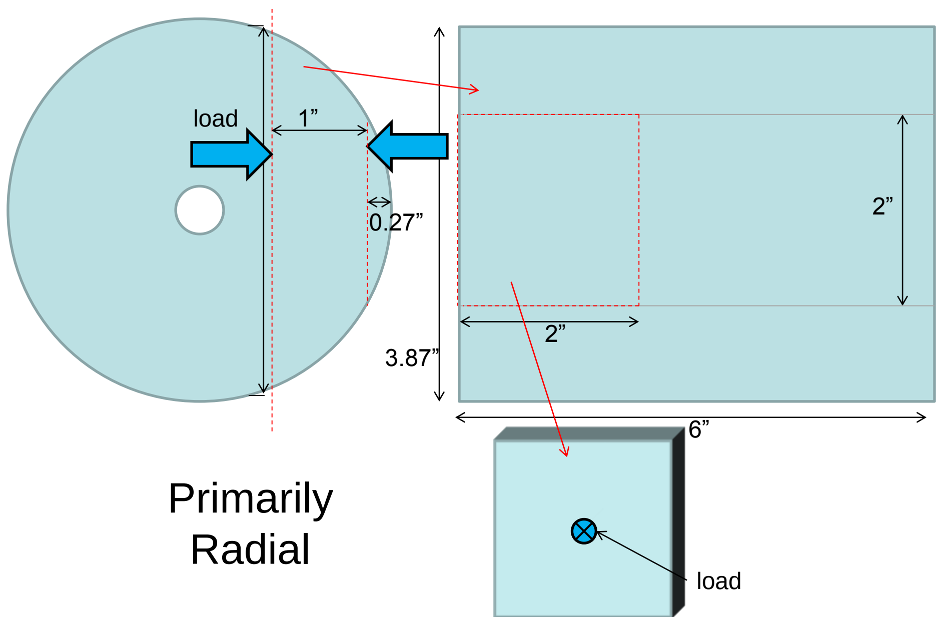
Shkolnikov, 7th International LS-DYNA Users Conference

Sample Preparation

- Cylindrical mitigator sectioned to determine compressive, shear properties in primarily axial, theta, radial directions
- Samples bonded to rigid face plates for shear.

Axial

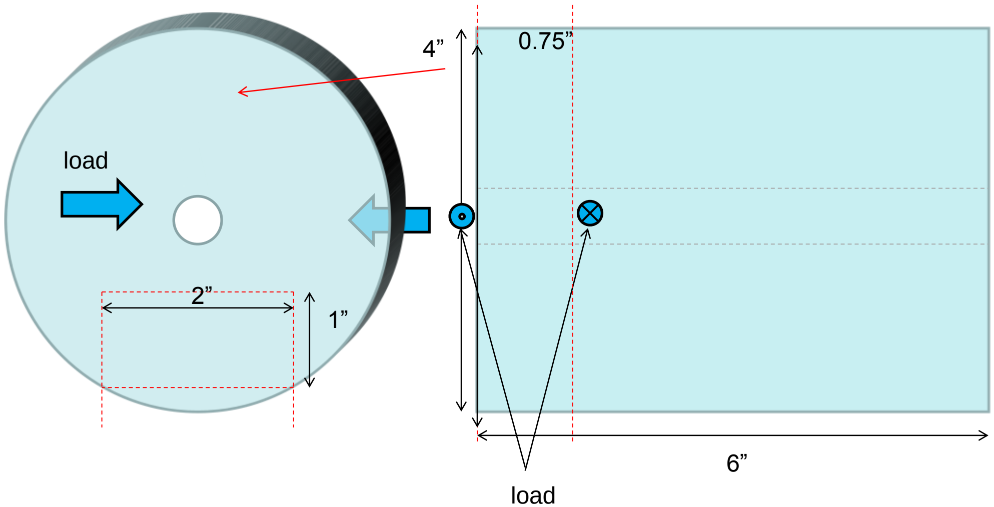




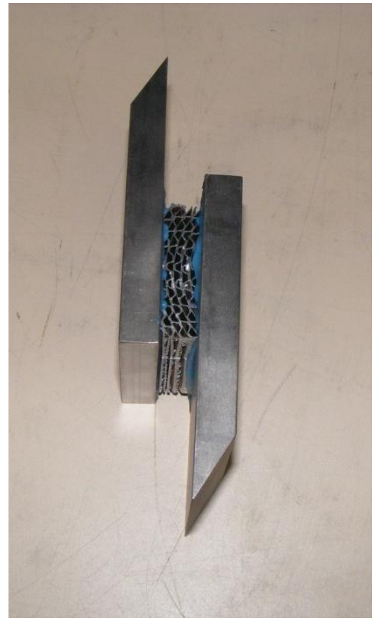
Primarily Radial

Shear Sample Preparation

- Steel face plates
- Hysol EA 9360 adhesive
  - 5000 psi lap shear strength



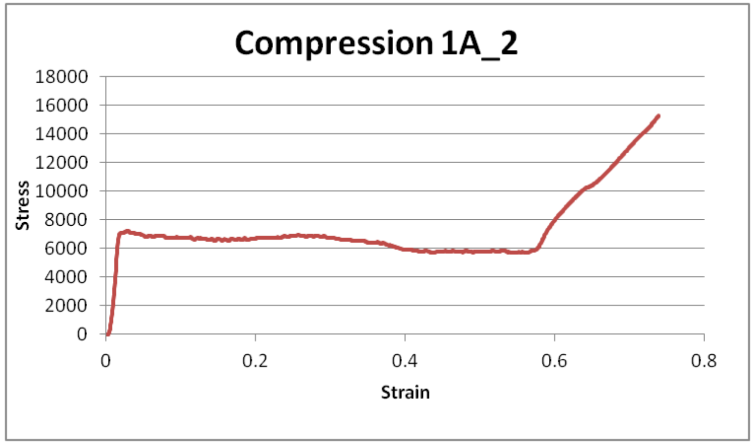
Example sectioning for shear (primarily circumferential-axial direction)



Example shear specimen(primarily axial-circumferential direction)

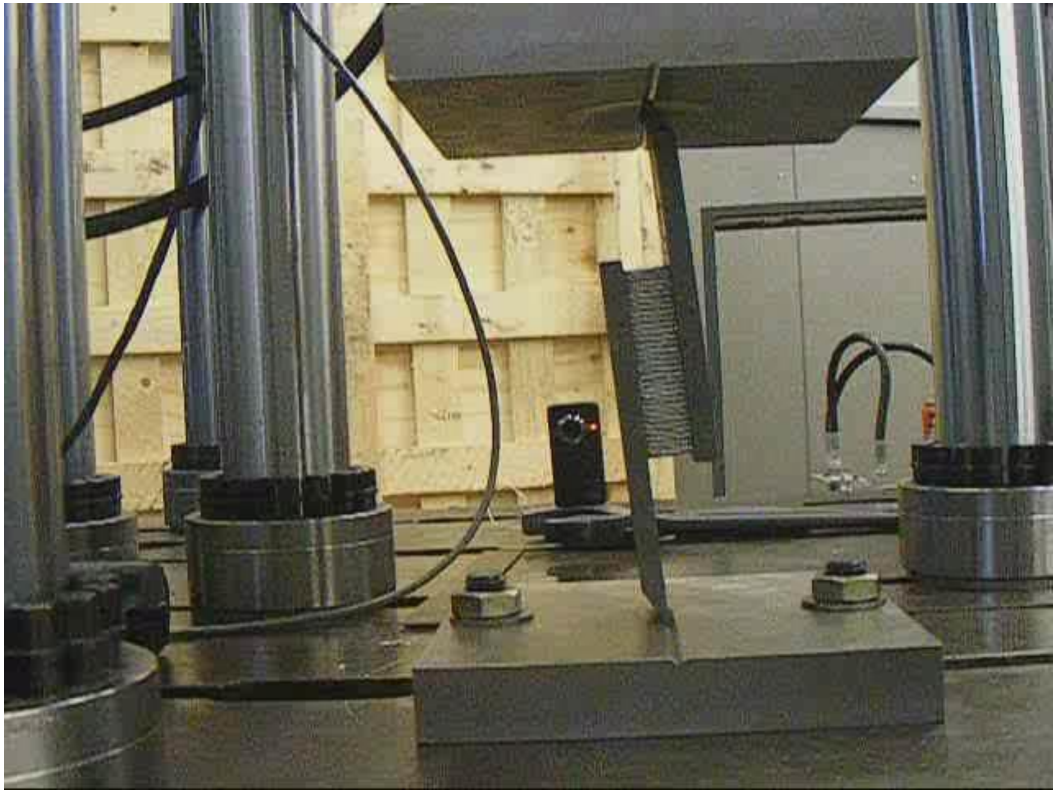
Testing

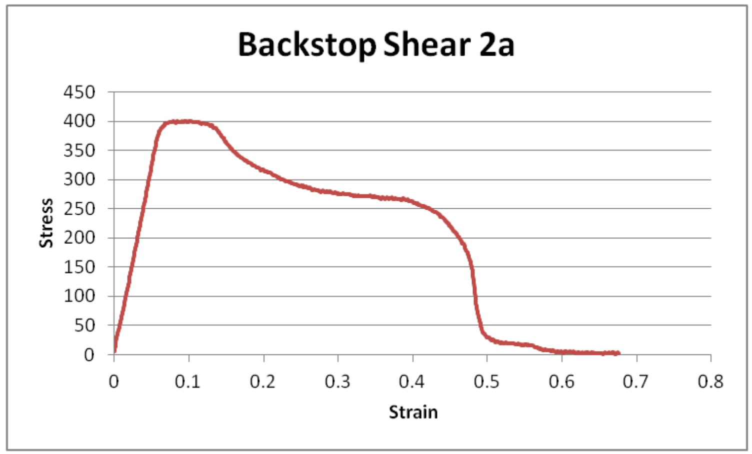
- Quasistatic loading
  - 6 Mitigator specimens, 2 Backstop specimens



Shear testing

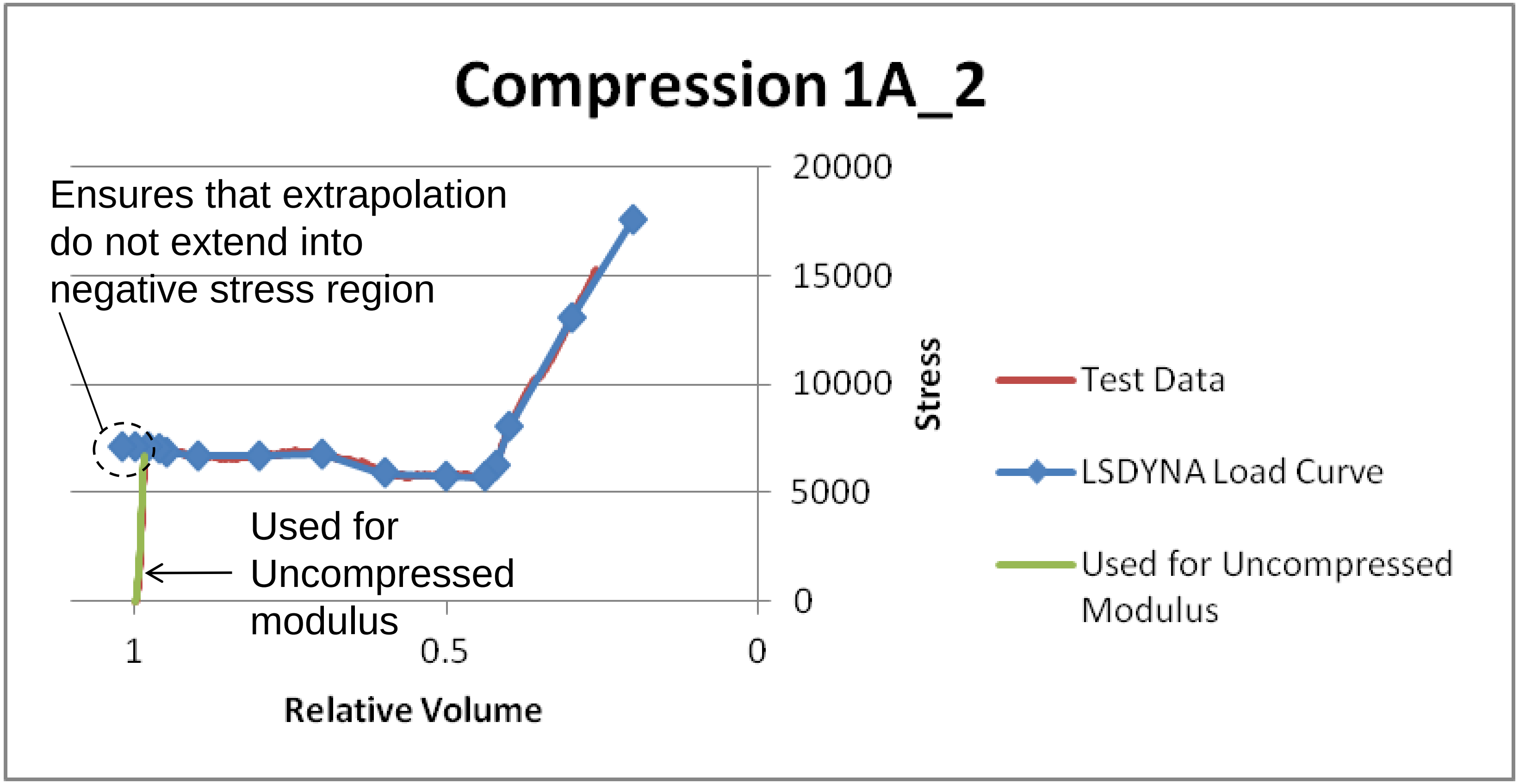
- No mitigator shear tests reached crushing portion of response
- Backstop shear test did not reach fully compressed response





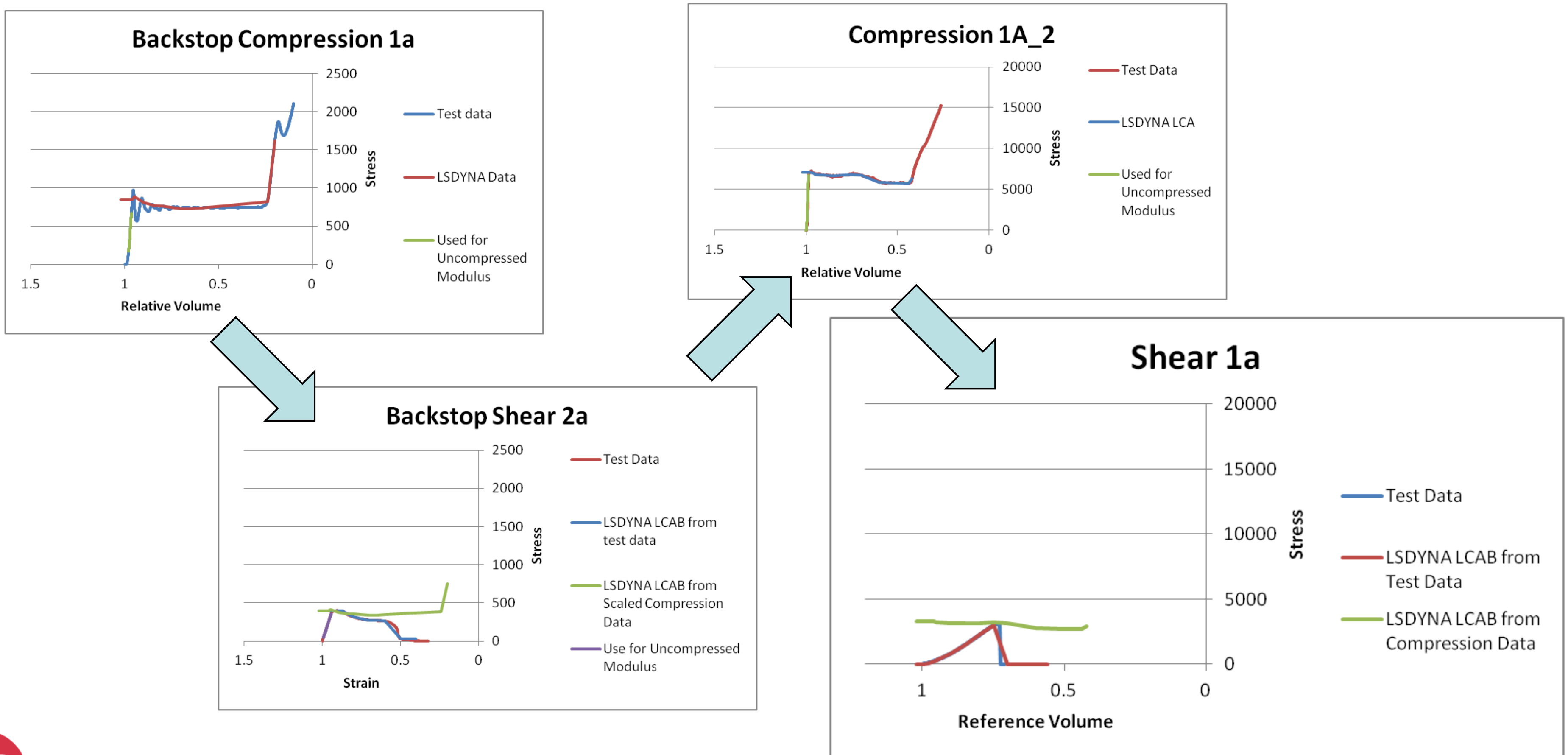
Test Data Reduction

- Same number of data points desired for each load/relative volume relationship



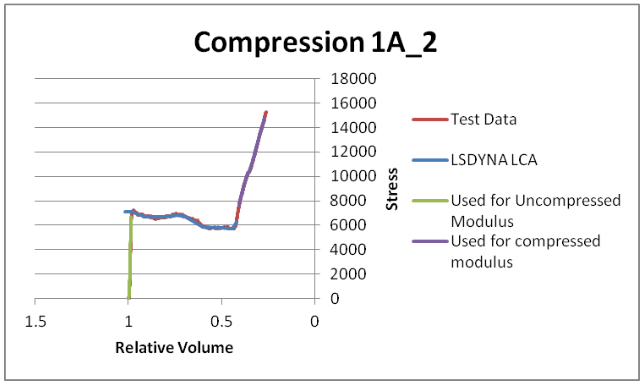
Shear Data Estimation

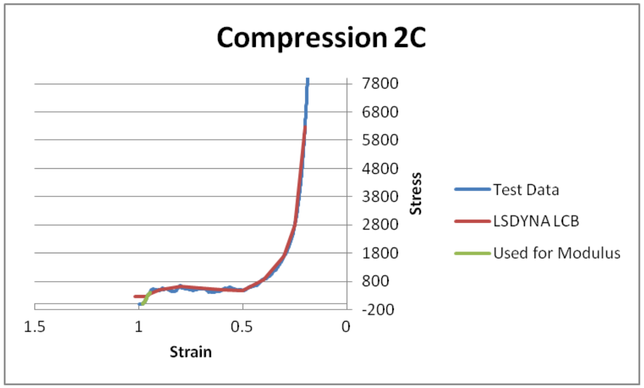
- Ratio of Backstop shear/compressive properties used to estimate Mitigator Shear/compressive properties

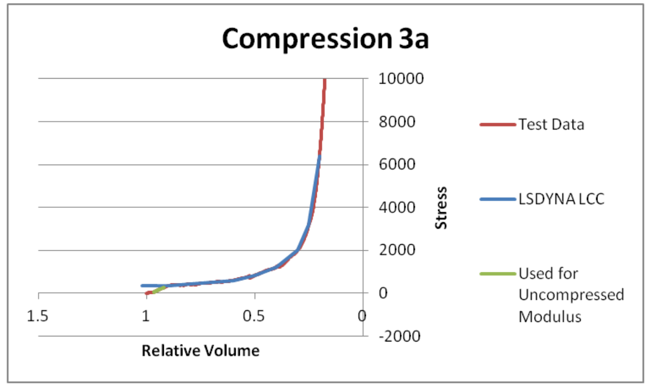


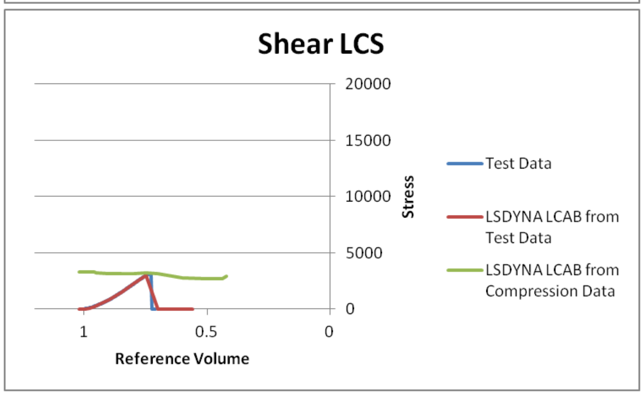
Material Model Input

- 4 curves used to describe crush strength
  - Axial
  - Primarily radial
  - Primarily circumferential
  - Shear (1 instead of maximum of 3)
- 4 uncompacted Moduli
- Compressive modulus and Poisson's Ratio from Aluminum for fully compacted condition



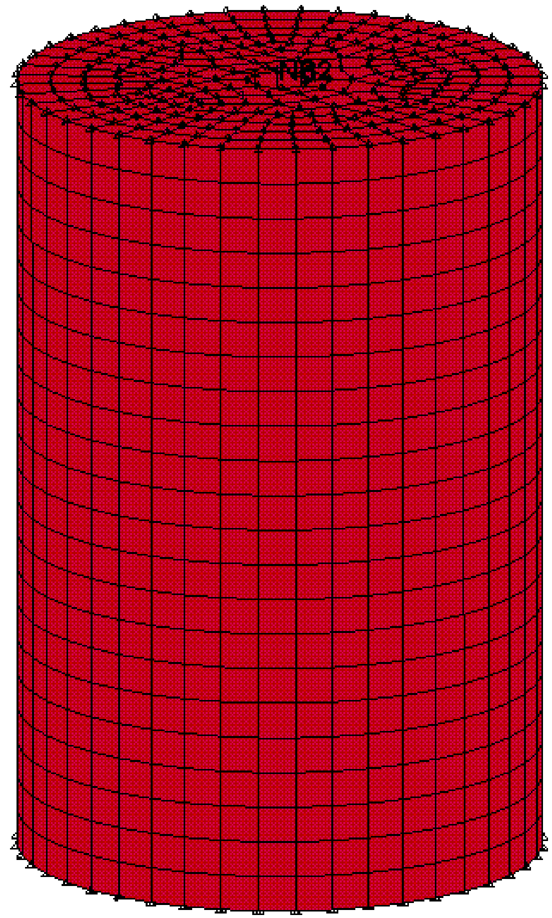






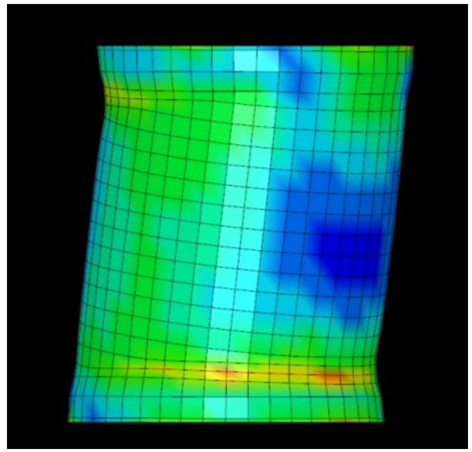
FEA Model Set-up

- Solid elements
- Applied axial displacement applied to top surface
    - 5 in. at constant rate
- BC's
    - Nodes around center hole at top and bottom fixed in transverse direction
    - Bottom face fixed in axial direction



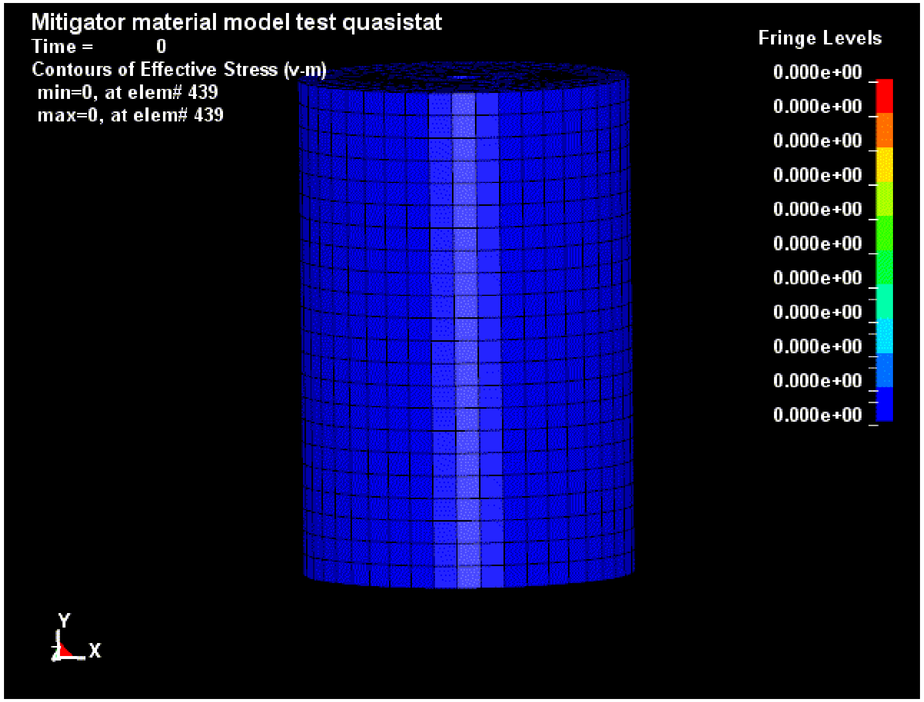
Initial Modeling Results MAT_26

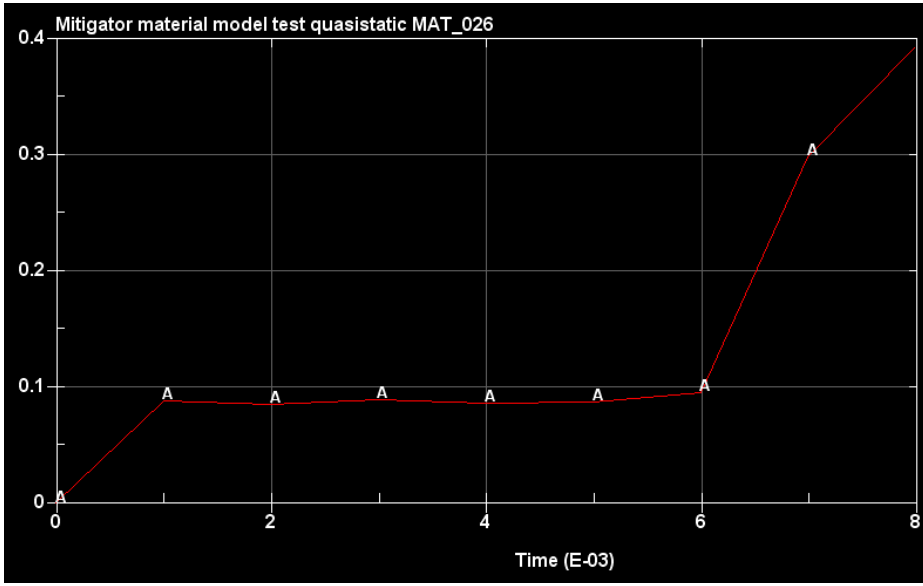
- No precrushed section causes crushing to initiate in multiple layers
  - Precrushed layer not modeled
- Insufficient face constraints and multiple crushing locations can cause bending/buckling
- No strain rate dependence included



Initial Modeling Results MAT_26

- Initial stress increase in entire structure similar to test results
- Early termination because of poor model stability



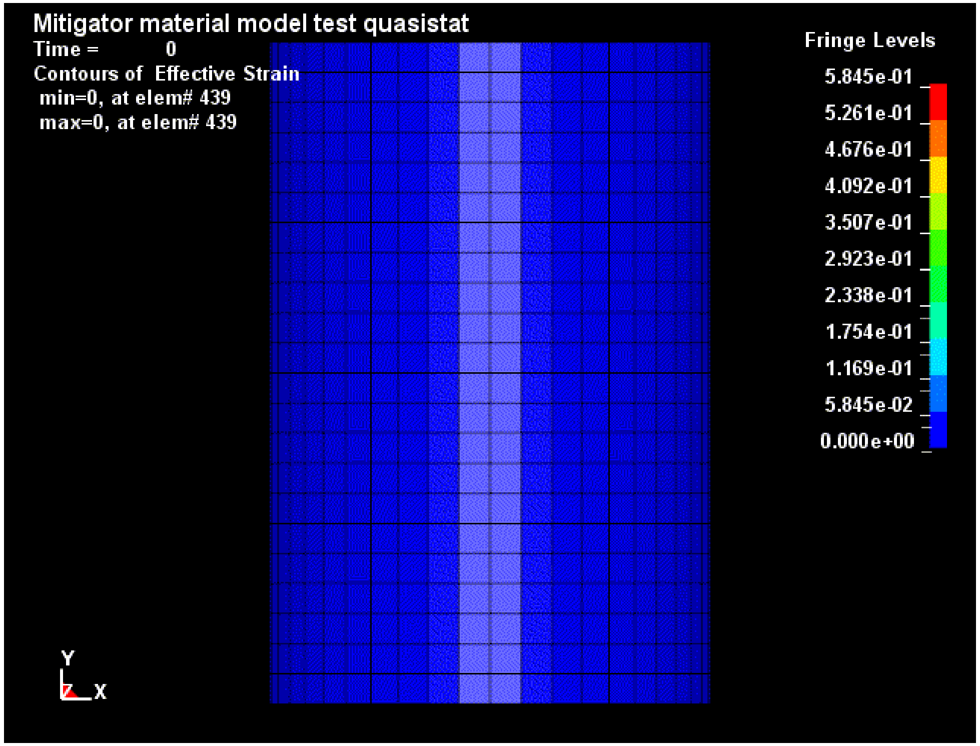


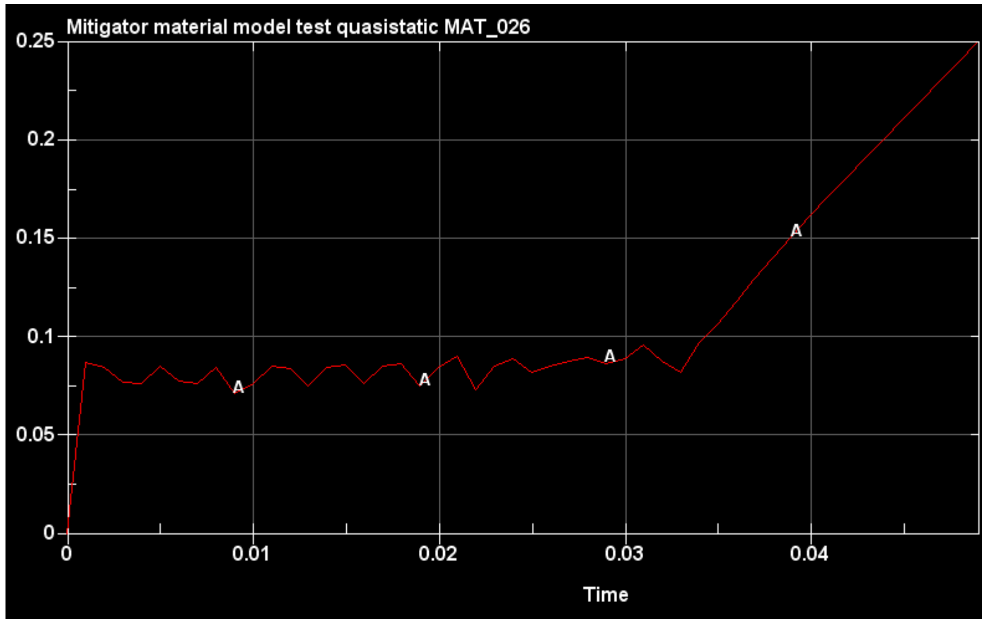
MAT_126 (Modified Honeycomb) Model

- Switch to nonlinear spring element (type 0)
    - Allows large deformations
- Increased stability
- Load curves input in strain instead of relative volume
- Material response during and after crushing follows load curve
    - Post crush material properties ignored

MAT_126 Model Results

- Response matches test curve (as expected)





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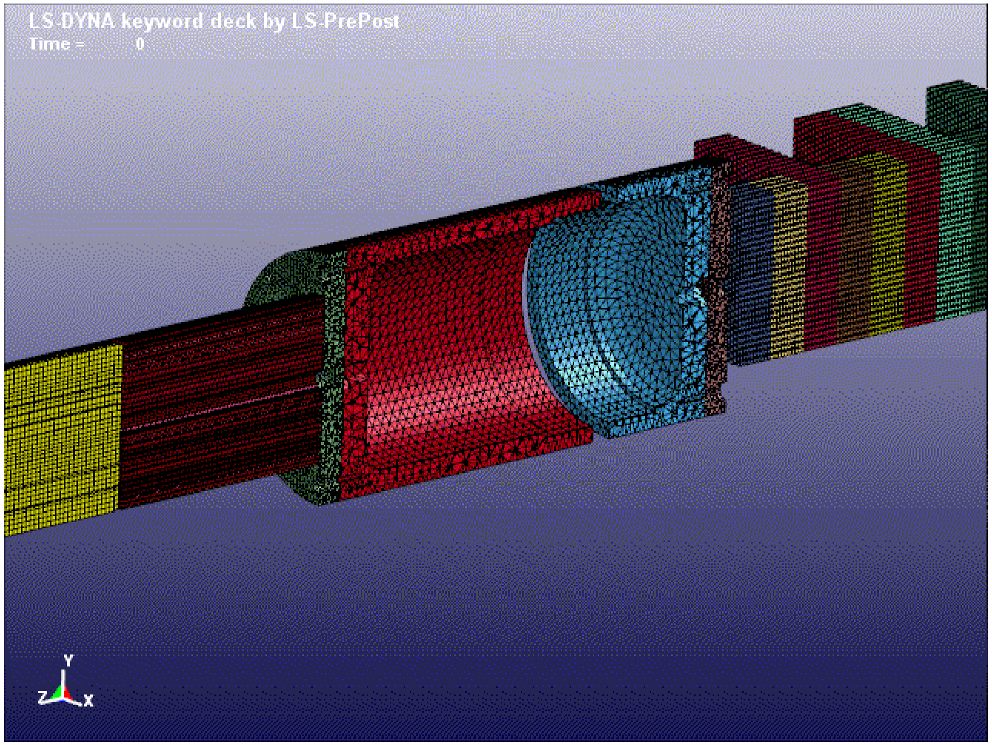
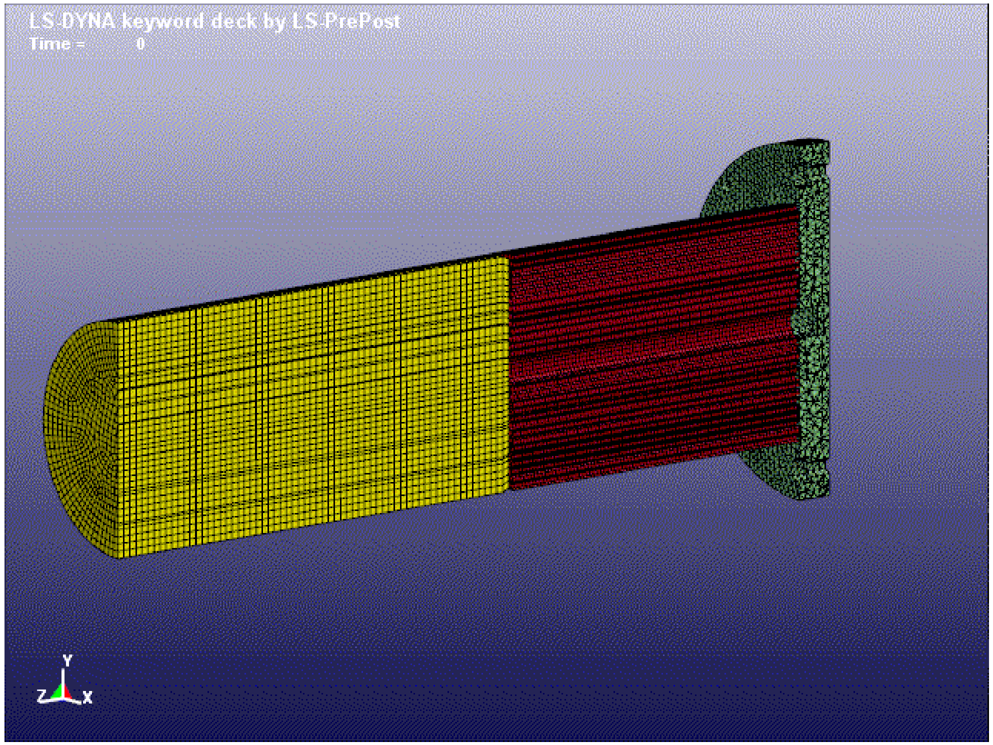
High Speed Impact

Shell Model

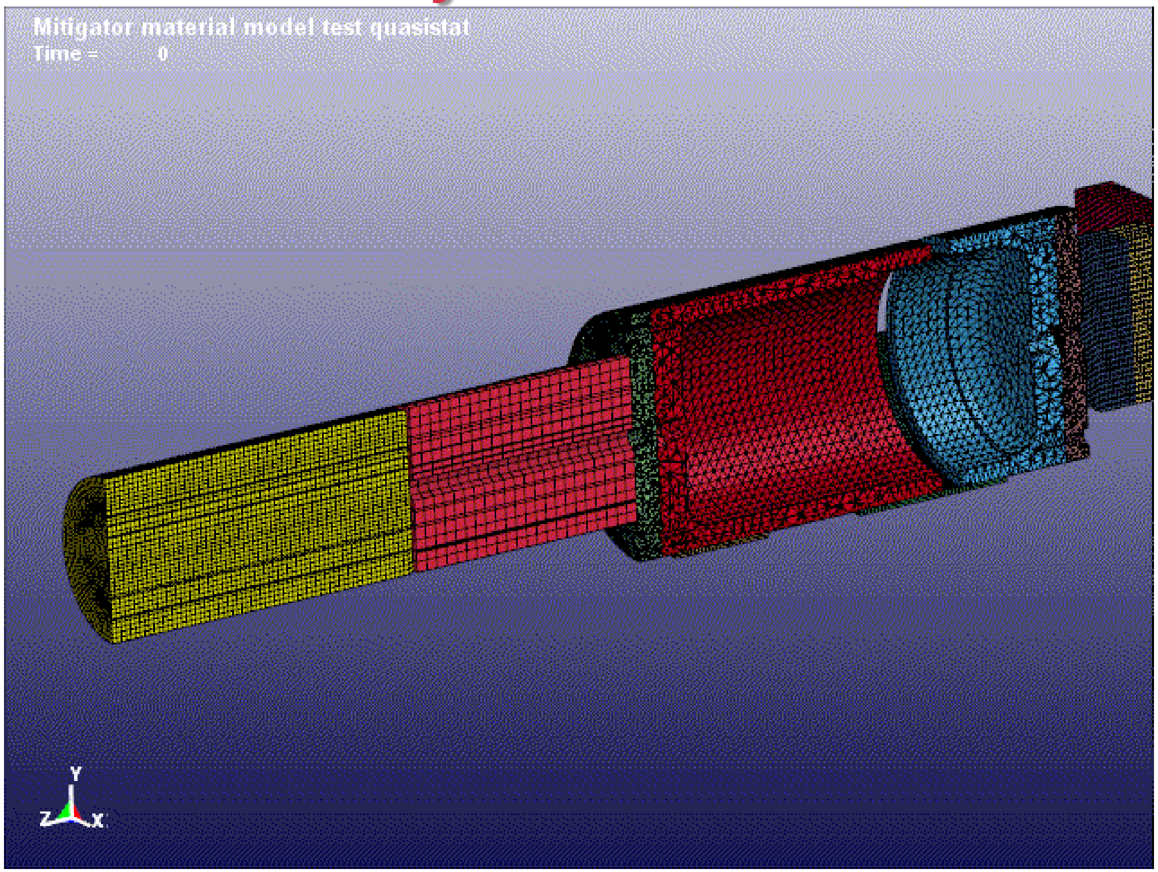
- Very good correlation to test results
  - Computationally intensive



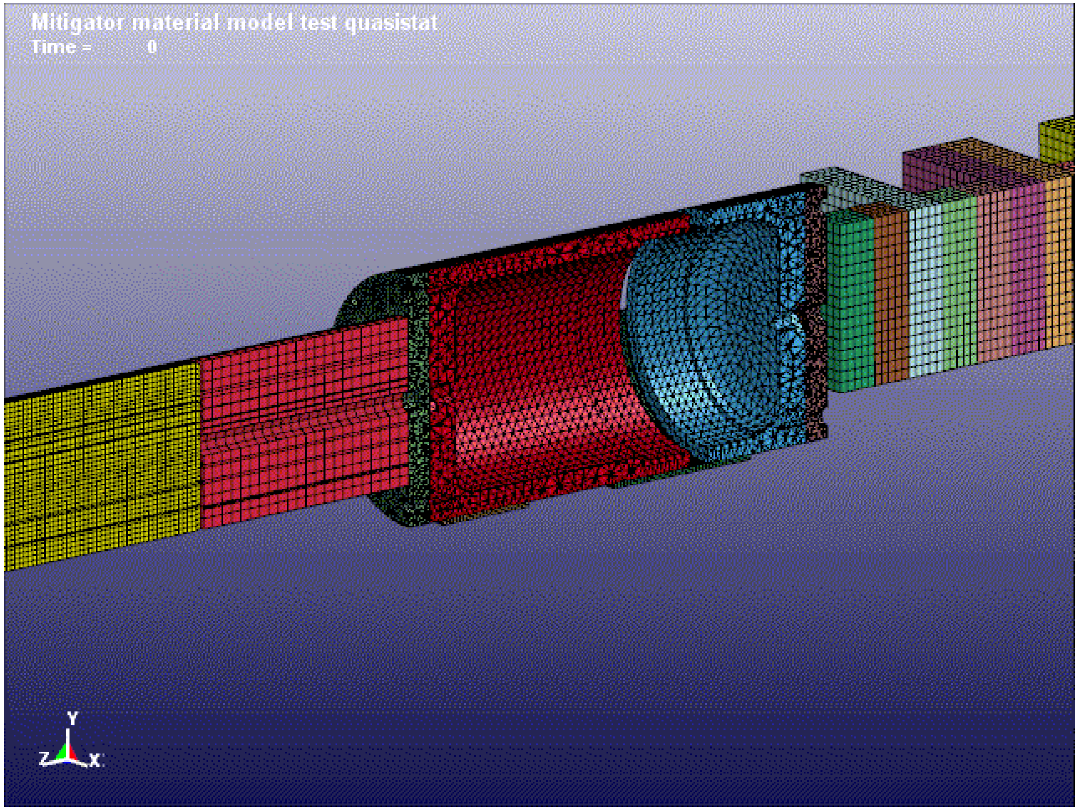


MAT_126 results

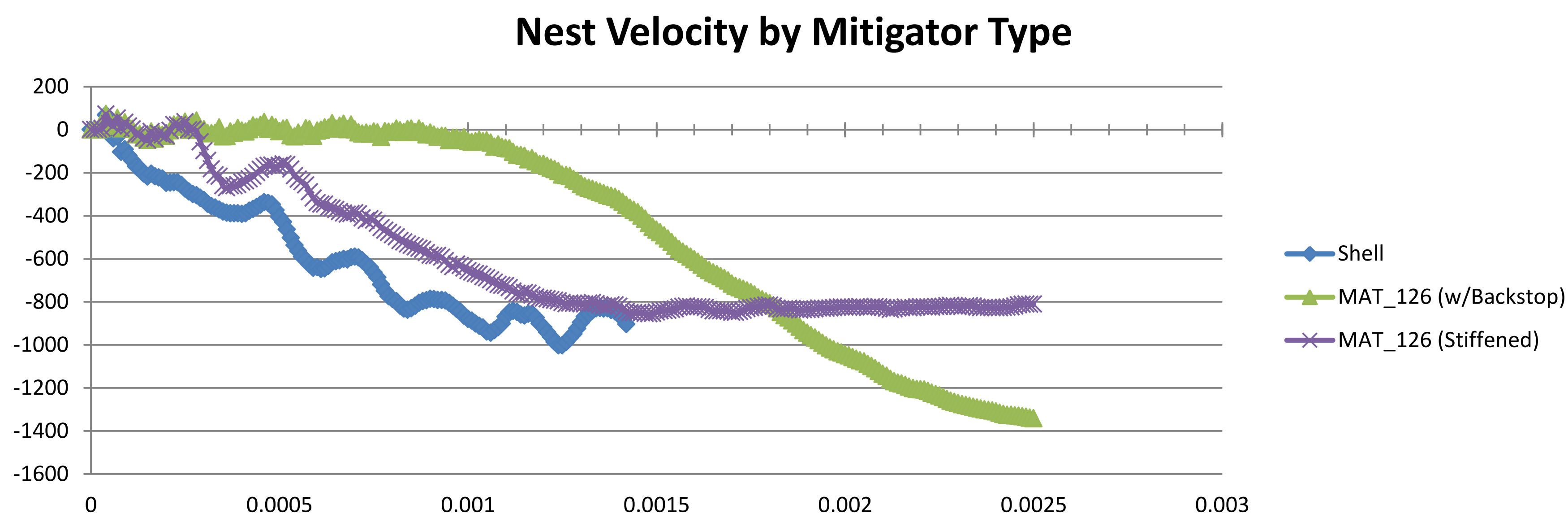
- ~85% reduction in run time from shell element mitigator model
  - Run time now controlled by elements in device under test
- Honeycomb on honeycomb contact modeled

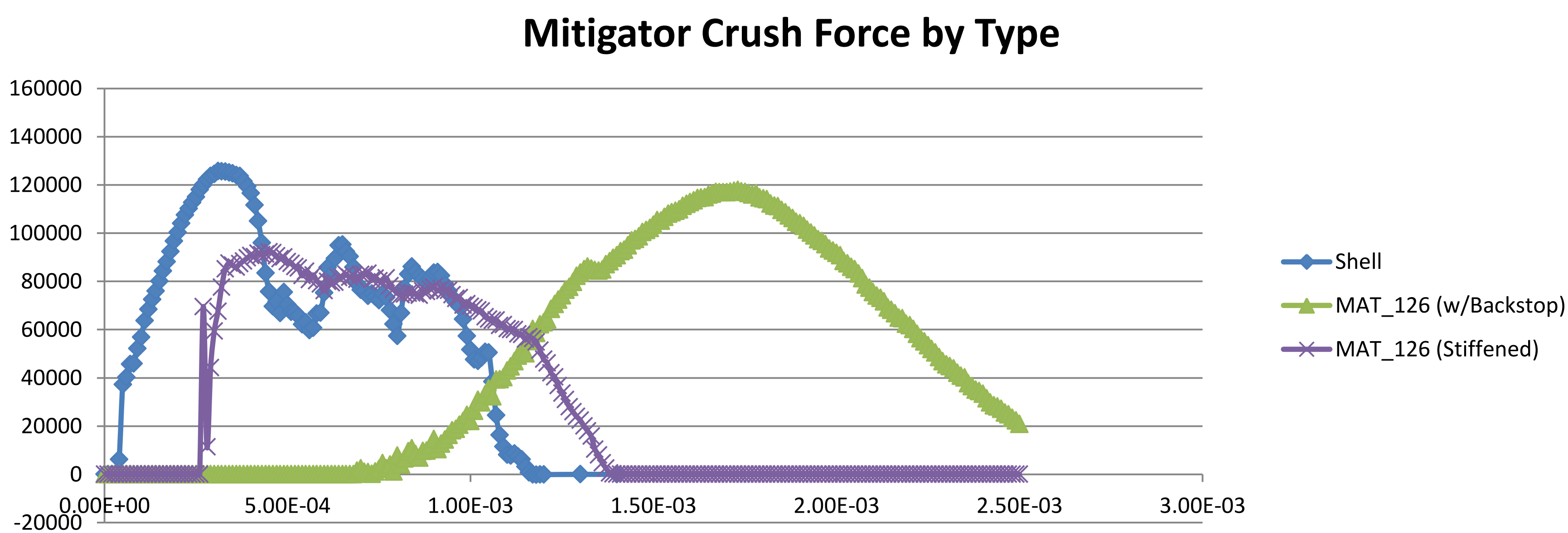


Stiffened Mat_126

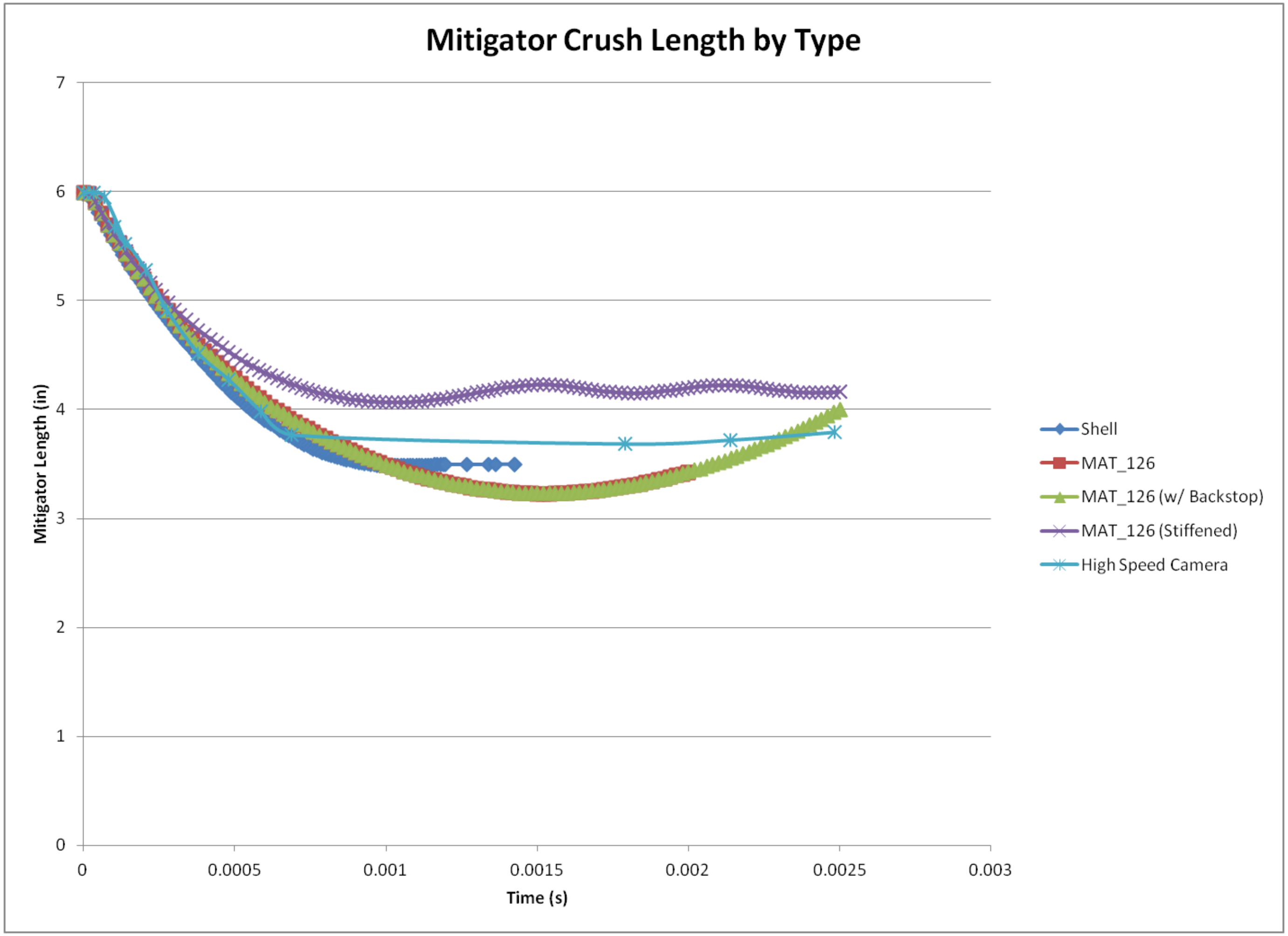


Model Results Comparison





Comparison with Test Data



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Conclusion

- Honeycomb material model is part of ongoing efforts at L-3 FOS to continuously improve modeling capabilities of all factors affecting fuze survivability.
- Material model significantly reduces runtime while maintaining acceptable accuracy.
- Reduced run time allows **increased model iteration** and **increased understanding of response**.