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Validation of a Viscoplastic Model for Foam Response Over a Wide Temperature Range

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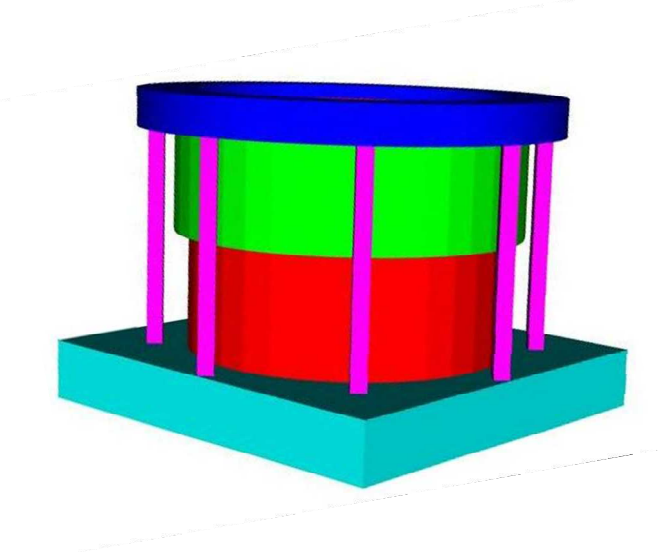
Overview

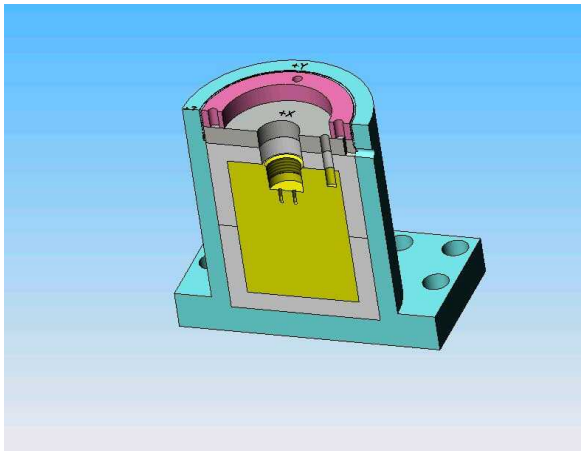
- Validation Strategy
- Viscoplastic Foam Model
- Validation Process
- Validation Results
- Summary

Foam/Component Model Validation Strategy

Max Strain rates > 1000/sec

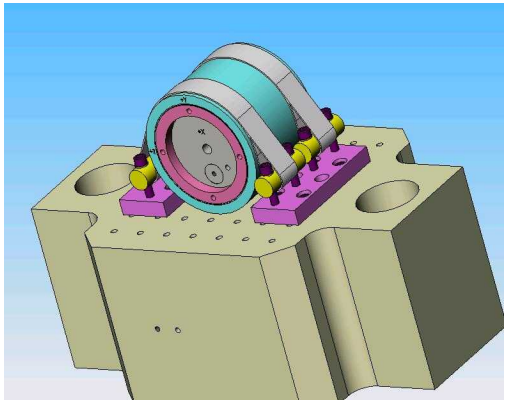
Uni-Stack
(partial confinement)





Axial Impact Fixture

Mini-Stack
(full confinement)



Lateral Impact

Increasing Complexity →

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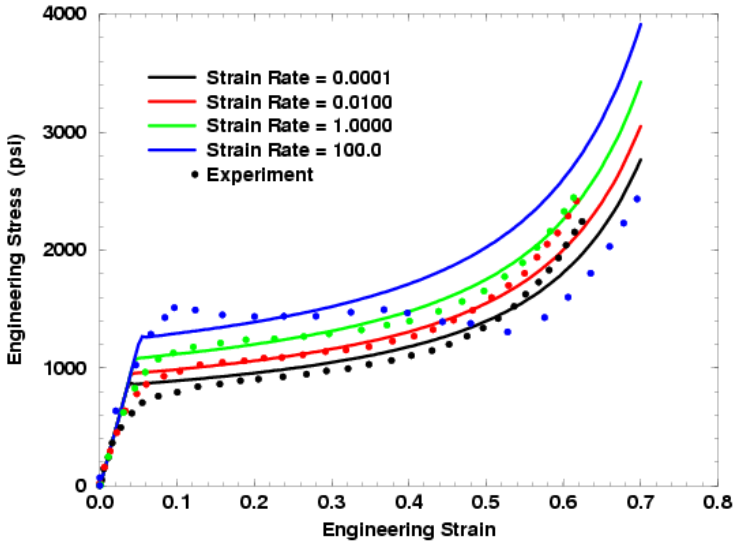
Constitutive Model for PMDI Foam

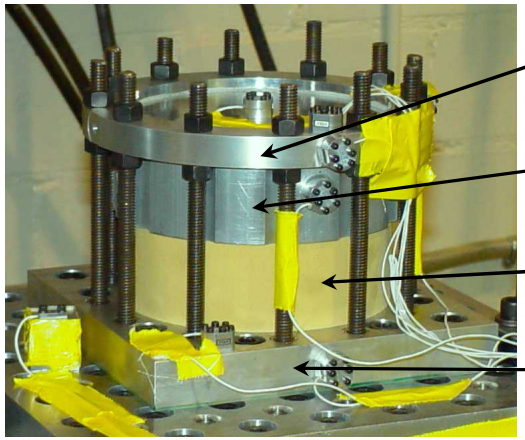
Validation process will use new Viscoplastic Foam Model

- Constitutive experiments performed on PMDI foam by Wei Yang Lu and Bill Olsson, Sandia National Labs.
- Viscoplastic Foam model developed by Neilsen et al.
  - Ref: IMECE2006-14551, Nov 2006, Chicago

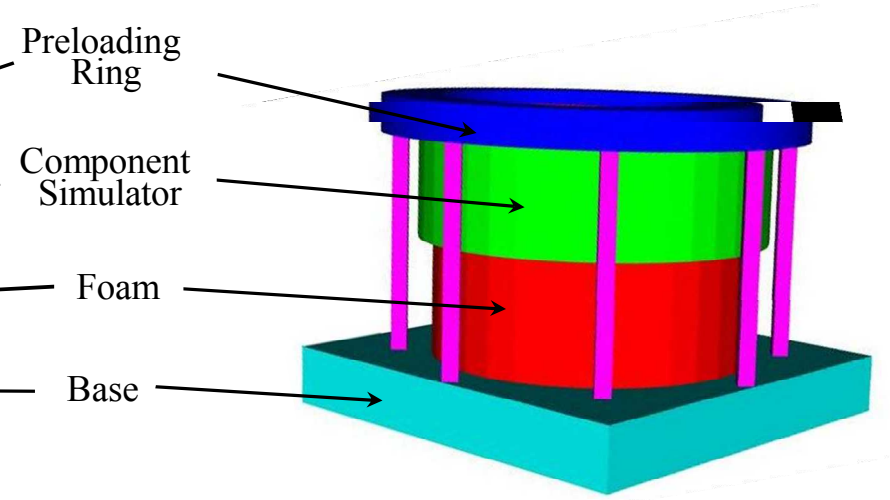


Comparison of uniaxial compression tests at room temperature and strain rates of 10-4 to 100 per second. Note that at the high rate the foam cracks and load carrying capacity decreases. This cracking and reduction in load carrying capacity is not captured by the model.

UniStack Drop Table Validation Experiment



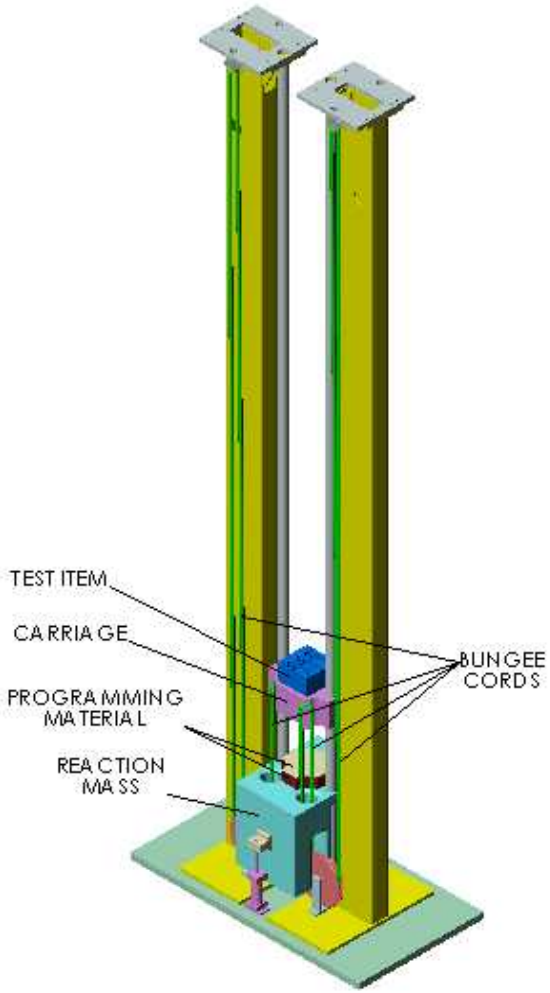
Test Hardware

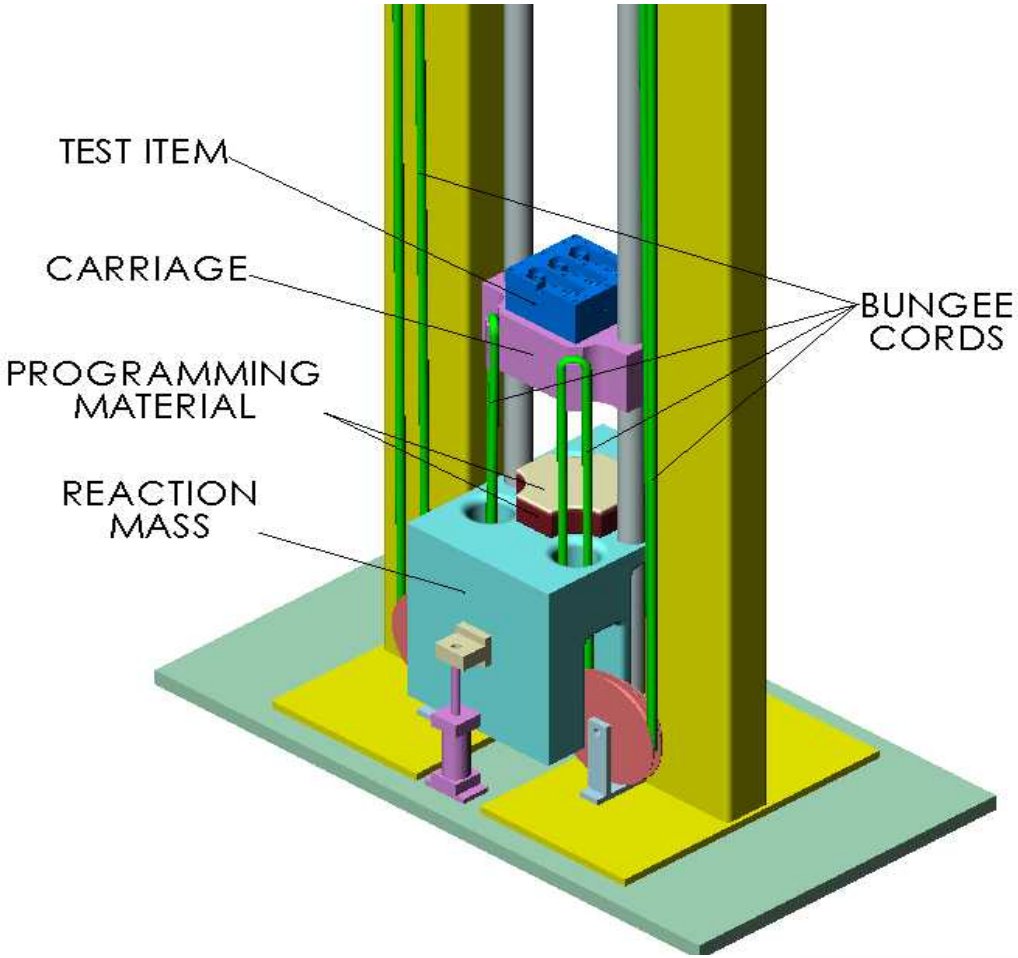


Presto FE Model

Goal: validate model of simplified foam/component configuration for predicting component accelerations with system like loading conditions and uncertainties

Drop Table Testing Rig





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Uni-Stack Drop Table Test Matrix

Table 1. Half inch PMDI foam test matrix.

Number of Tests	Sample Size	Temperature Deg, C	Target G @ Duration (ms)
3	0.5 in	21.1	3400 @ 1.0
3 (2)	0.5 in	21.1	4400 @ 1.0
3	0.5 in	-53.9	3400 @ 1.0
3	0.5 in	-53.9	4400 @ 1.0
3	0.5 in	73.9	3400 @ 1.0
3 (2)	0.5 in	73.9	4400 @ 1.0

Table 2. One inch PMDI foam test matrix.

Number of Tests	Sample Size	Temperature Deg, C	Target G @ Duration (ms)
3	1 in	21.1	3400 @ 1.0
3	1 in	21.1	4200 @ 1.0
3 (2)	1 in	-53.9	3400 @ 1.0
3	1 in	-53.9	4200 @ 1.0
3	1 in	73.9	3400 @ 1.0
3	1 in	73.9	4200 @ 1.0

Table 3. Two inch PMDI foam test matrix.

Number of Tests	Sample Size	Temperature Deg, C	Target G @ Duration (ms)
3	2 in	21.1	3400 @ 1.0
3 (2)	2 in	21.1	4400 @ 1.0
3	2 in	-53.9	3400 @ 1.0
3 (2)	2 in	-53.9	4000 @ 1.0
3	2 in	73.9	3400 @ 1.0
3	2 in	73.9	4000 @ 1.0

(#) actual number of good tests

Test matrix included:

- 3 foam thicknesses
- variable foam densities
- 3 temperatures
- 2 load levels
  -- peak acceleration

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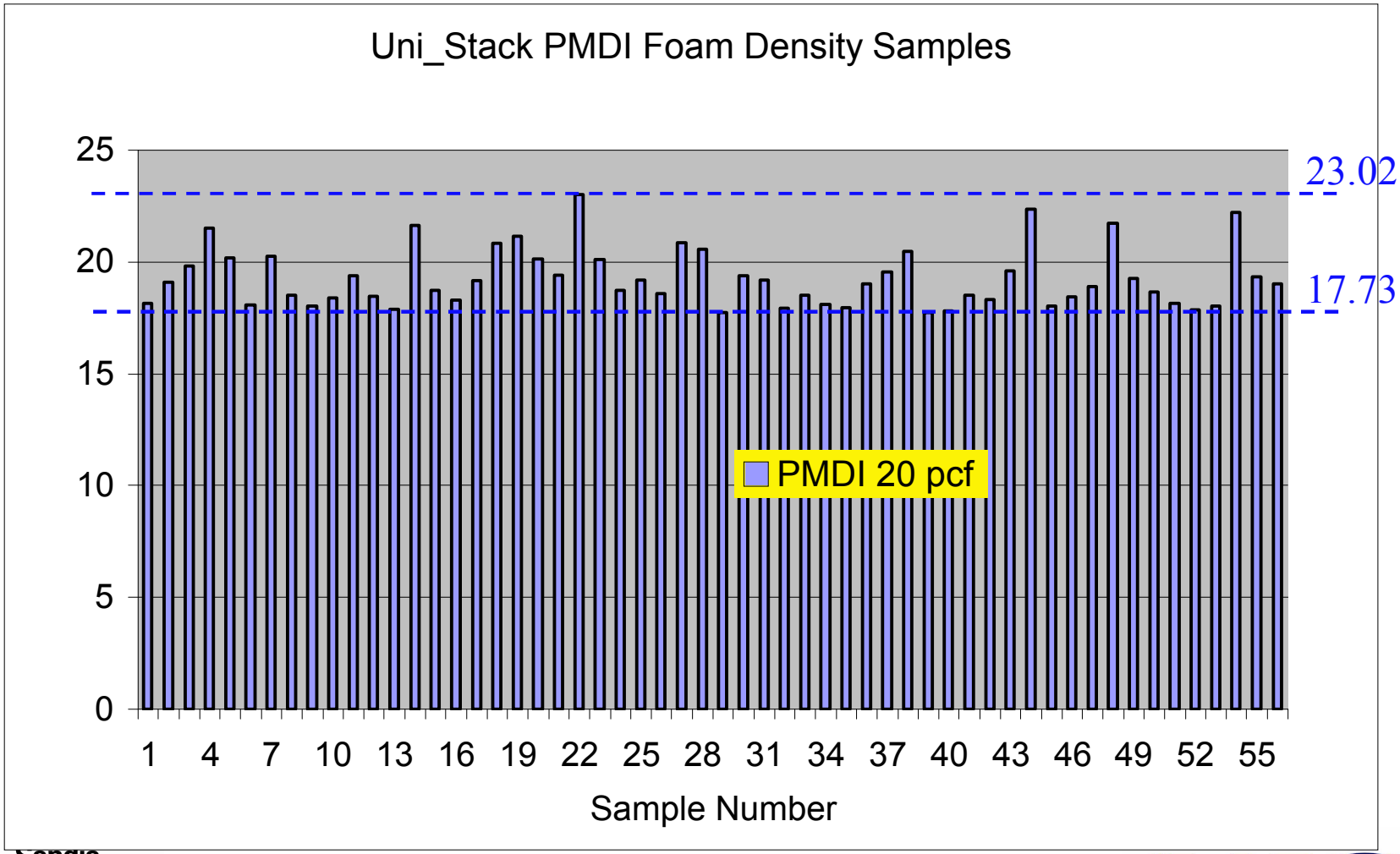
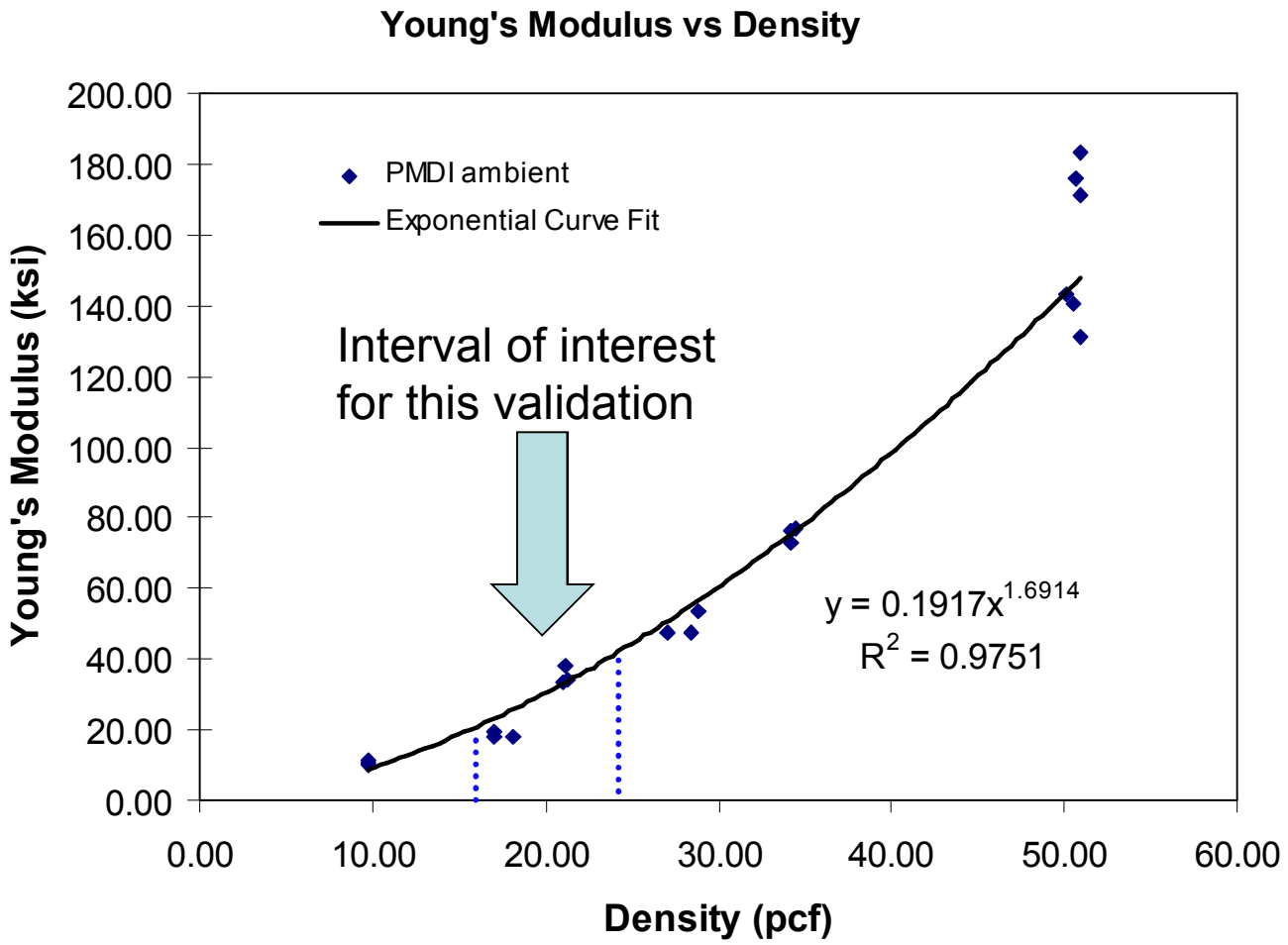
Model Uncertainties or Variabilities

- Foam Density – see next slide
- Temperature range: -65 F, ambient, and 165 deg F
- Friction – foam/component interface
- Preload - ~50 psi

Density Variation in Foam Samples



Effect of Density on Young's Modulus



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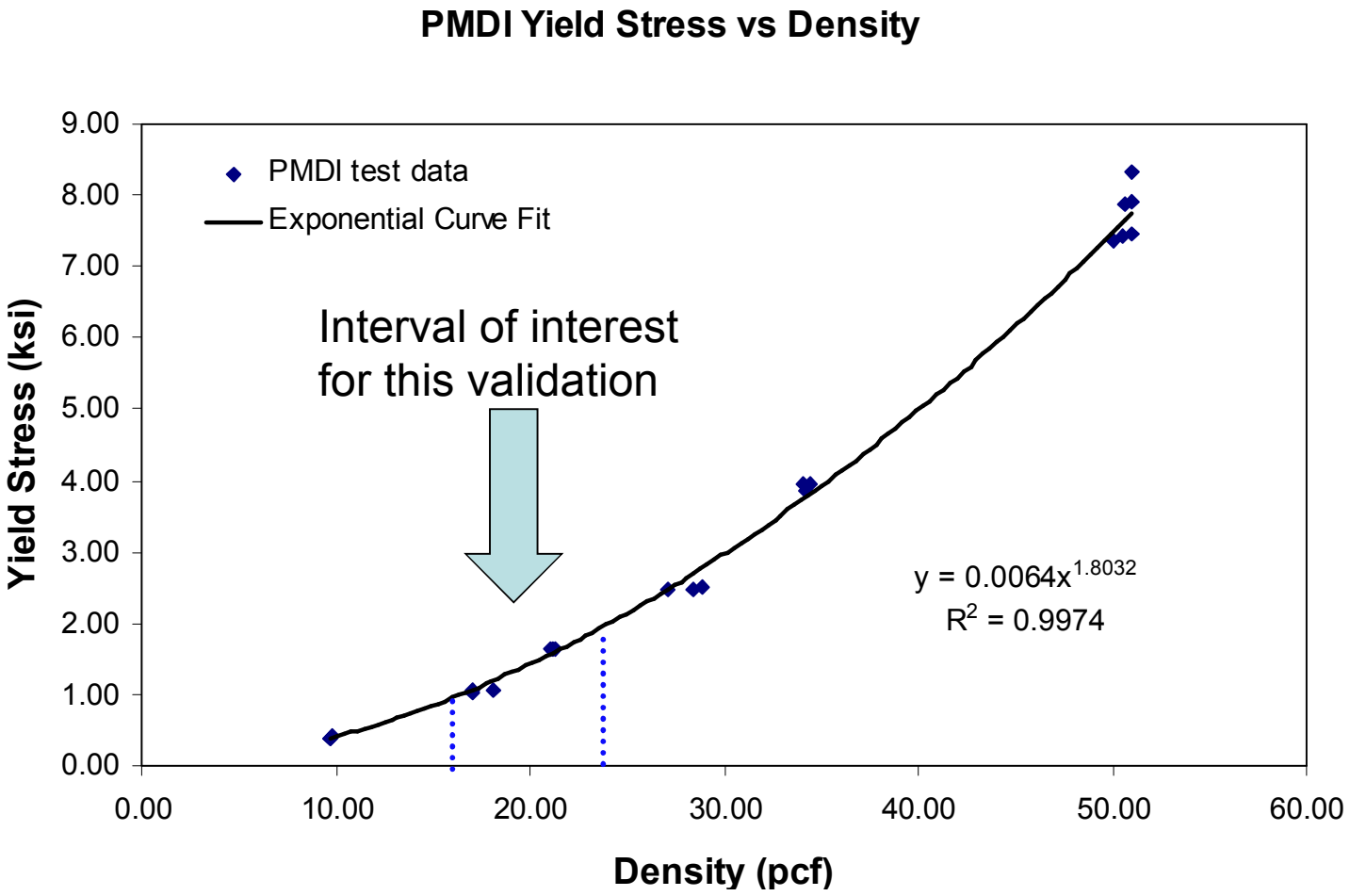
Effect of Density on Yield Stress



Applied to shear and hydrostatic yield stress values

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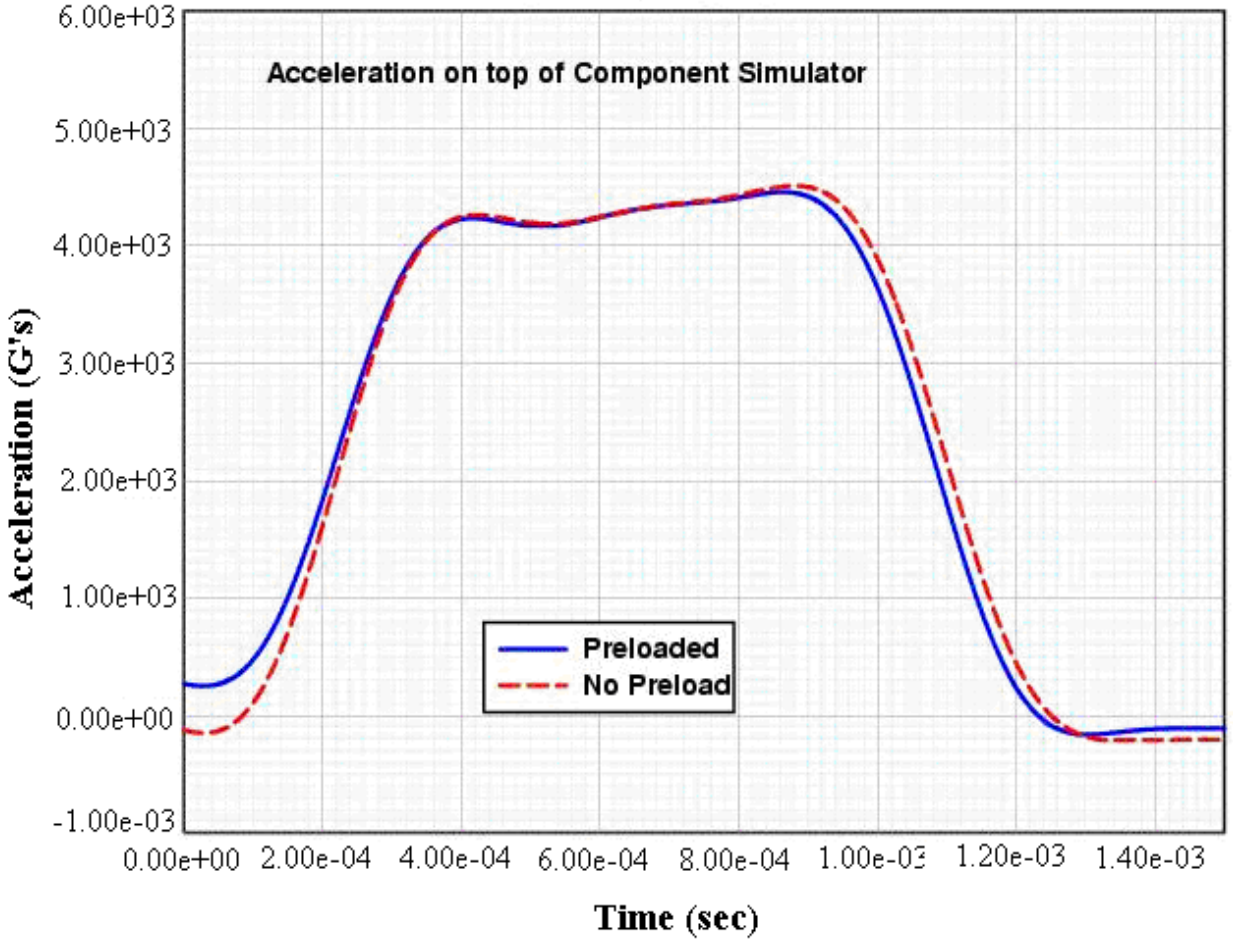
Preload Sensitivity Assessment



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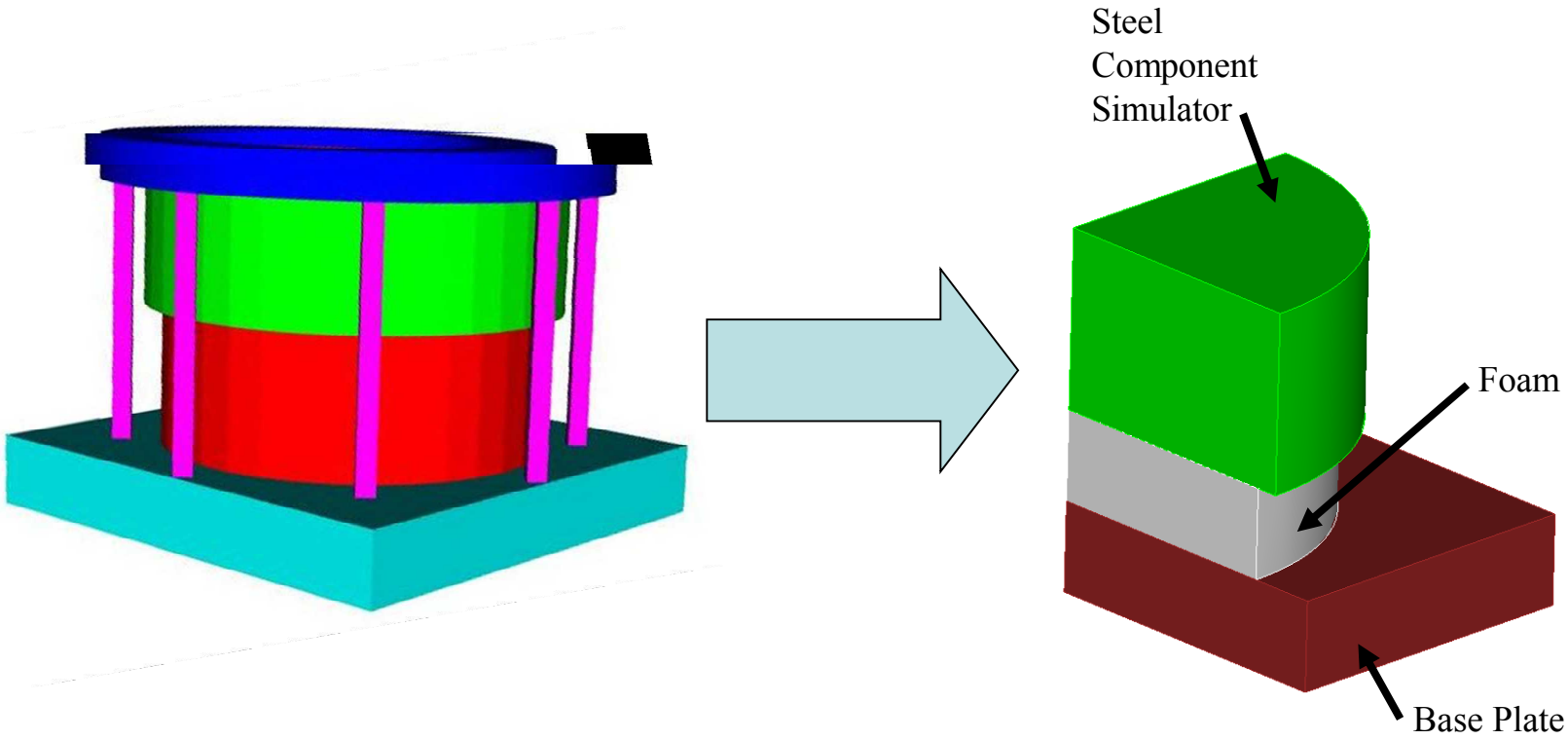
Model Simplification after neglecting Preload



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Analysis Model Convergence Assessment

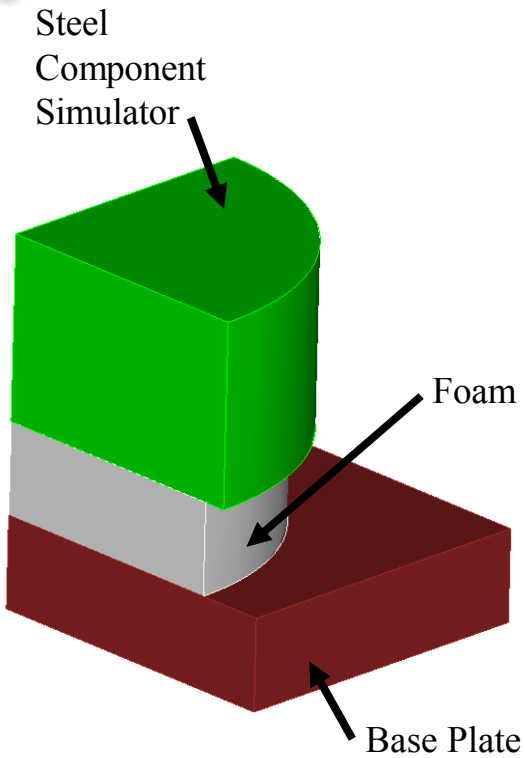
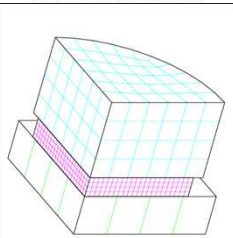
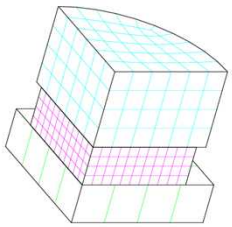
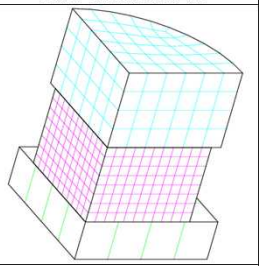
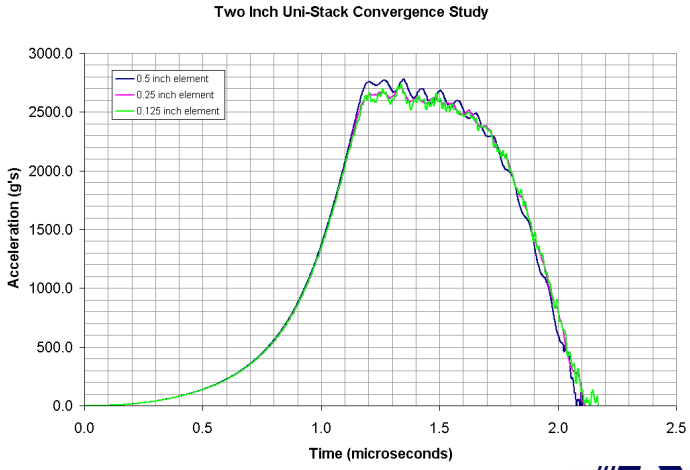


Table 1 – Convergence Models

	Half Inch Model	One Inch Model	Two Inch Model
Model			
Element Size	0.25 inch	0.5 inch	0.5 inch
Element Size	0.125 inch	0.25 inch	0.25 inch
Element Size	0.0625 inch	0.125 inch	0.125 inch

* Shaded blocks in blue indicate convergence models



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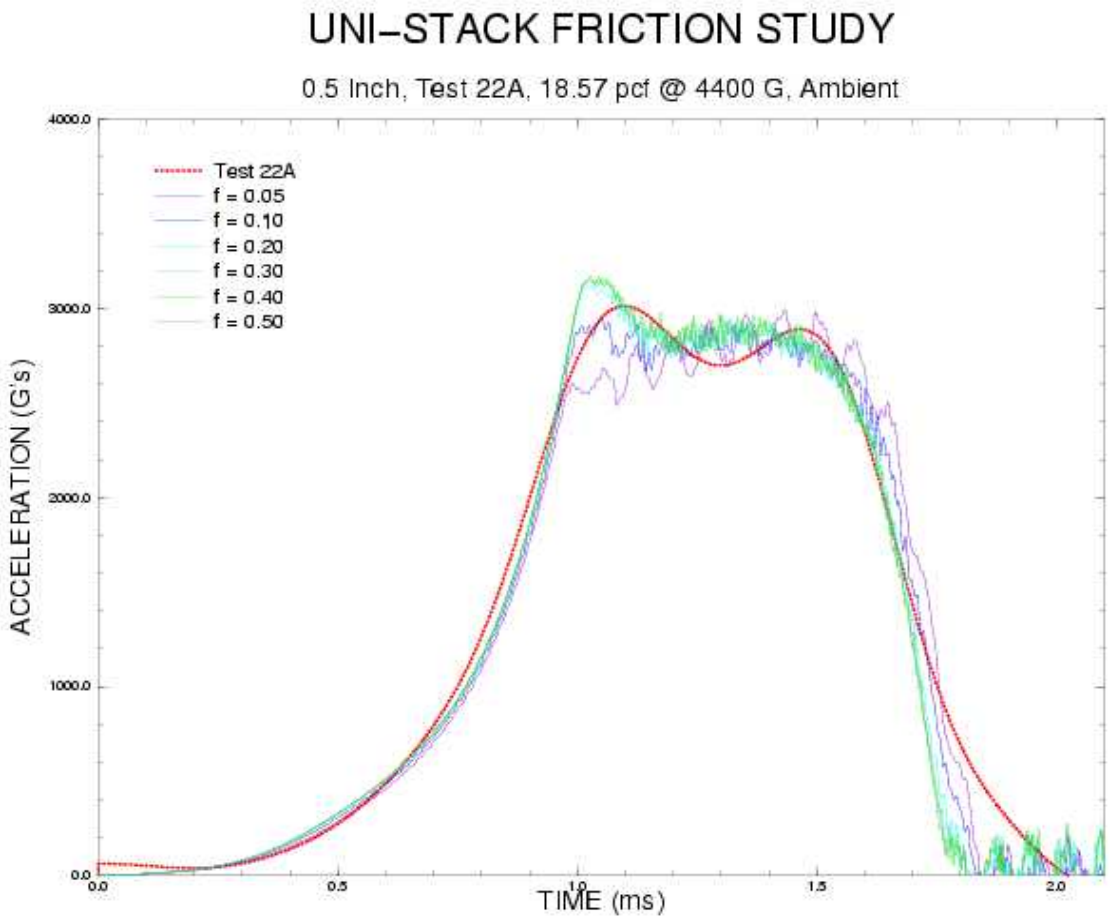
Friction Sensitivity



Friction Tests of foam on steel resulted in a Static Coef.of Friction = 0.26

Short-Stack model Simulations indicated Foam/component lockup at approximately a Coef. of Friction = 0.2

Chose a dynamic Coef. of Friction = 0.2 for the model

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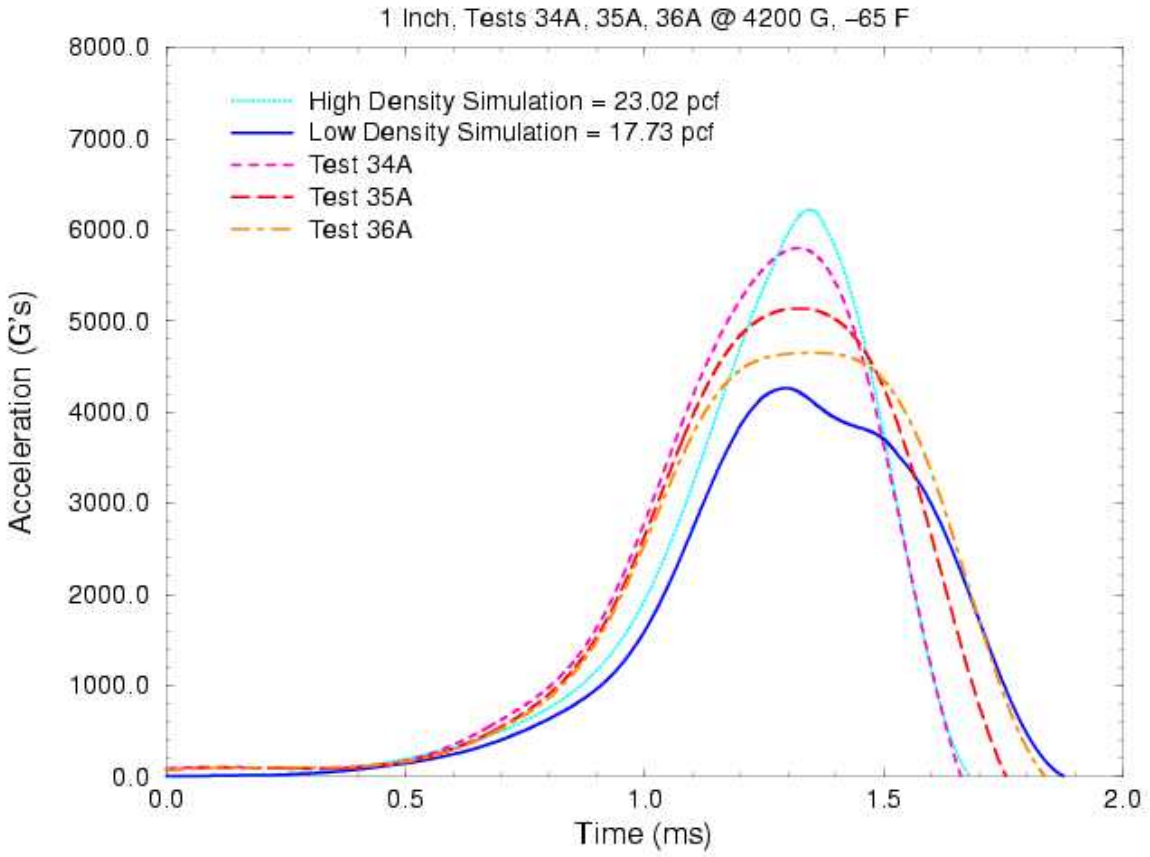
Bounding Model Validation Predictions for 1 inch Uni-Stack sample



Validation metrics:
1) Peak Acceleration
2) Impulse
   - Area under curve

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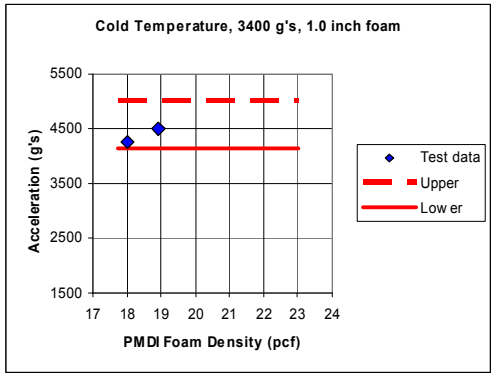
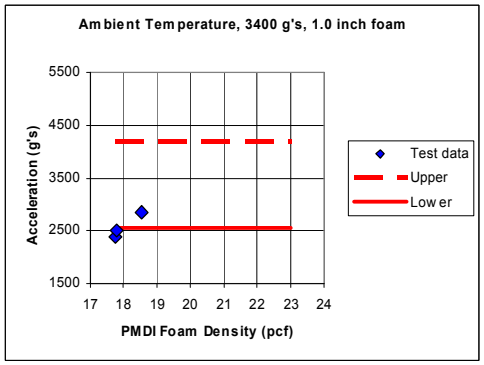
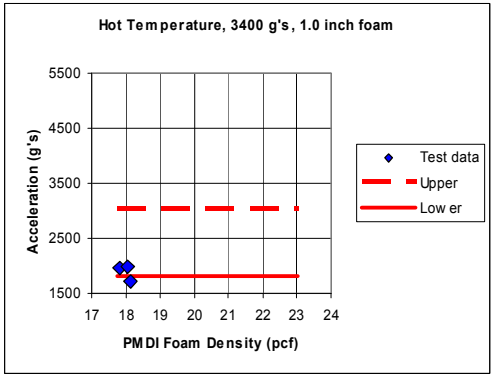
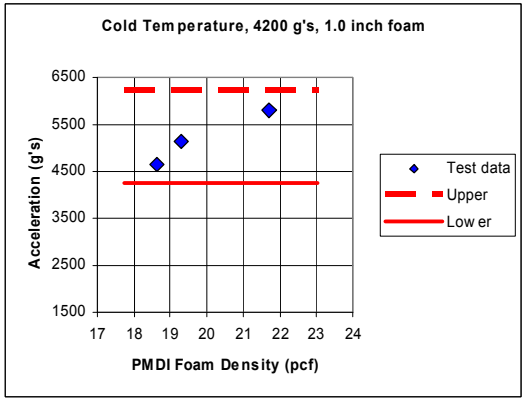
Bounding Model Validation Predictions for 1 inch Uni-Stack samples

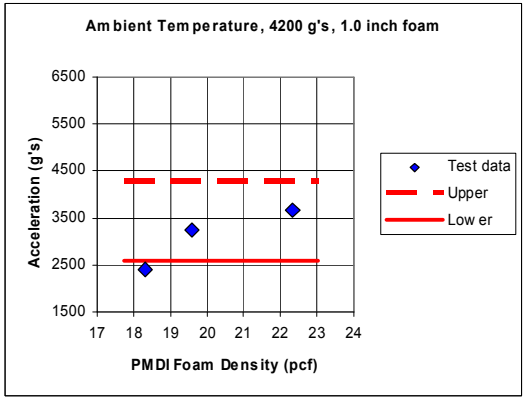


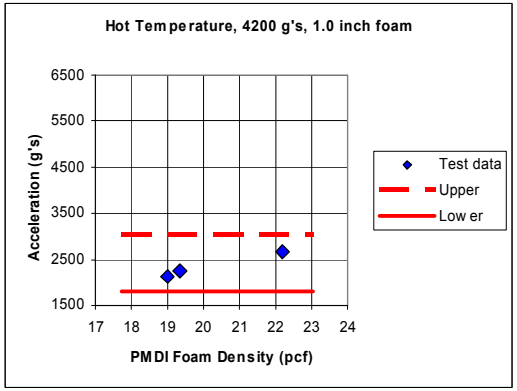




Bounding peak acceleration predictions versus test data for 3400 G and one inch foam (left to right is cold, ambient and hot temperature data).







Bounding peak acceleration predictions versus test data for 4200 G and one inch foam (right is cold, ambient and hot temperature data).

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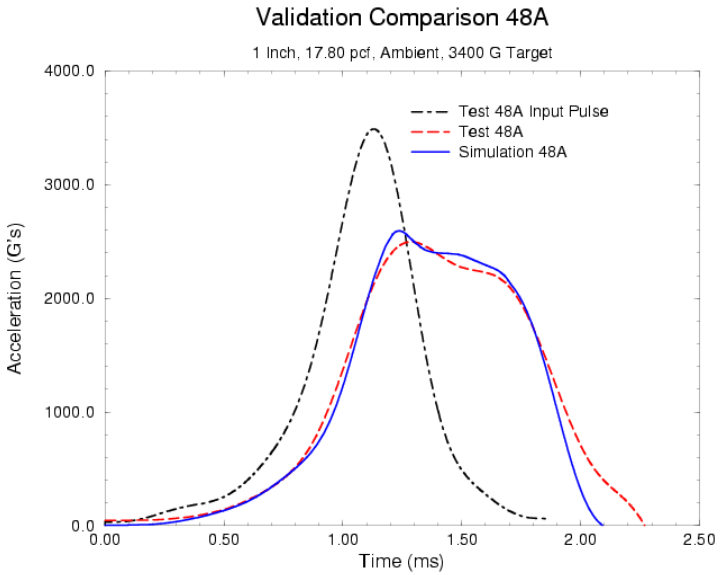
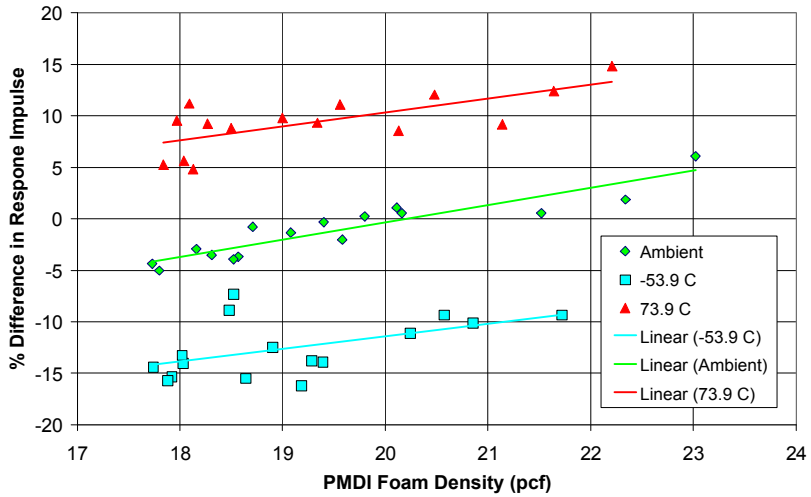
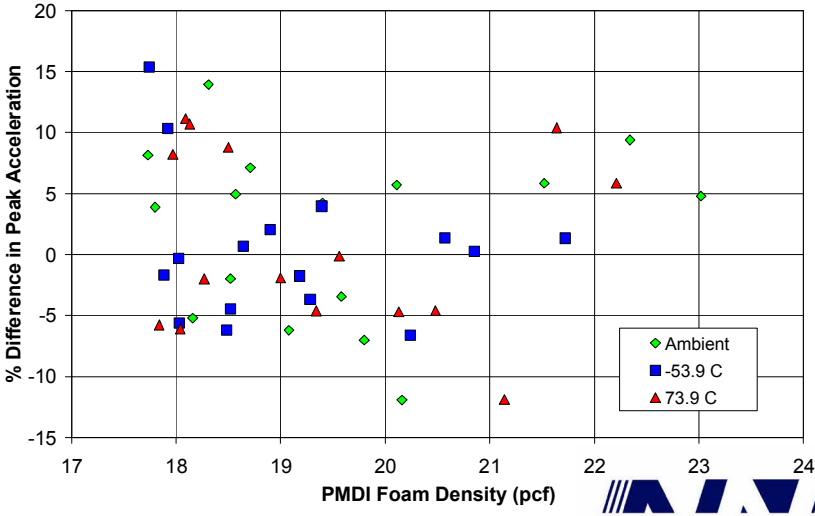
Deterministic Assessment of Uni-Stack Model Validation







Model validates within +/-15% of test data

Test data has +/- 10% uncertainty

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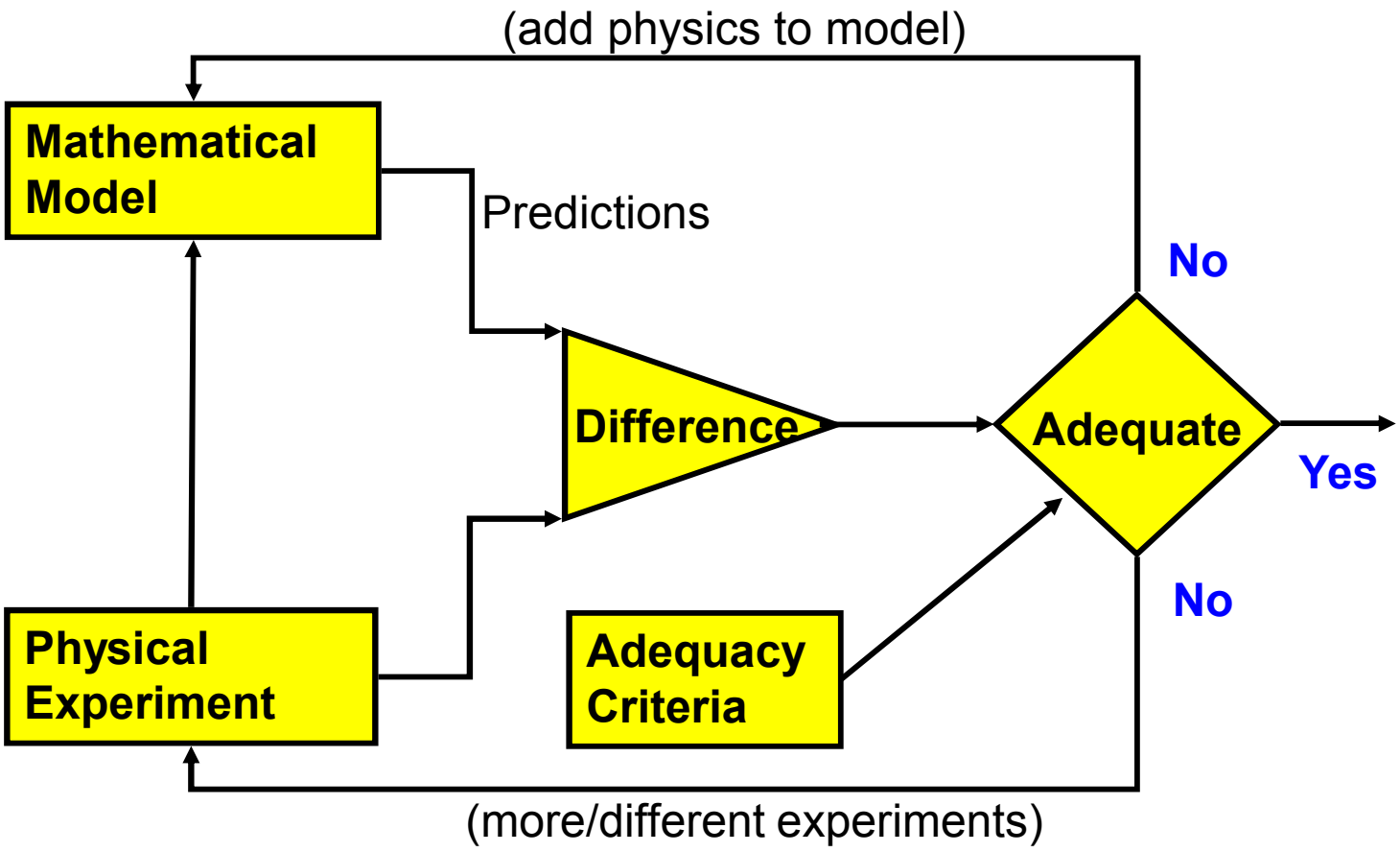
Summary

- Conducted a double blind model validation process
- High strain rate (>1000/sec) drop table tests used for validation experiments
- New Viscoplastic foam model applied
- Uncertainties of foam density,temperature, preload, friction incorporated
- First stage of foam/component model validation completed

Backup Slides

Calibration/Validation Process



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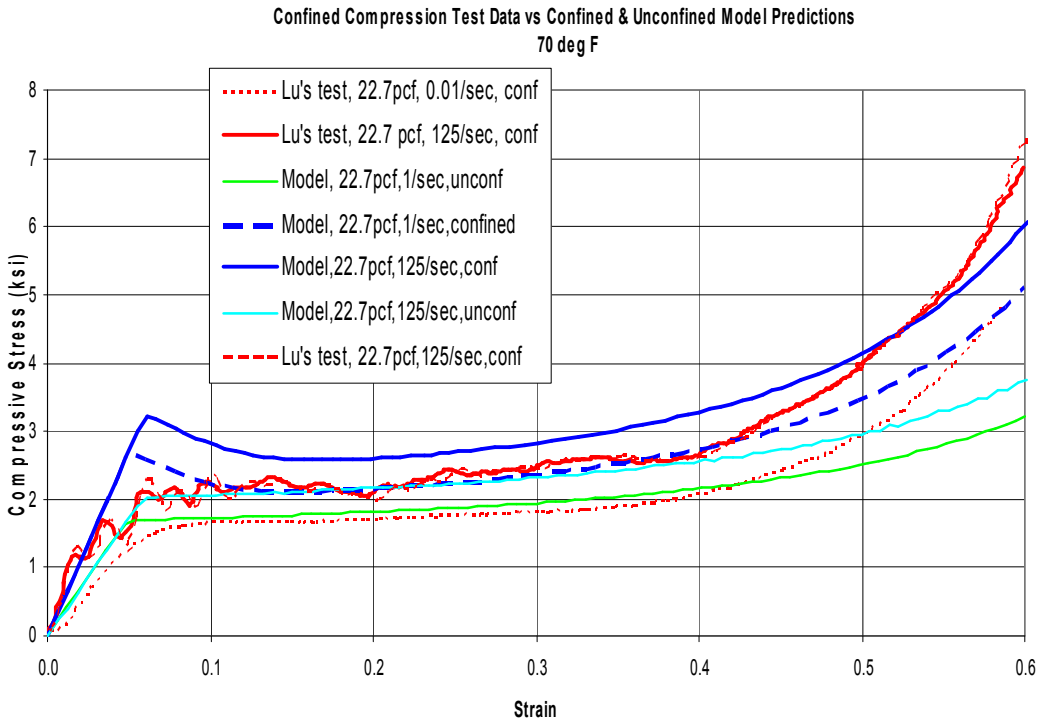
Viscoplastic Foam Model fit to Lu's Confined Compression Tests



Initial yield behavior of model is high vs. test data
- may be due to approx. test confinement

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