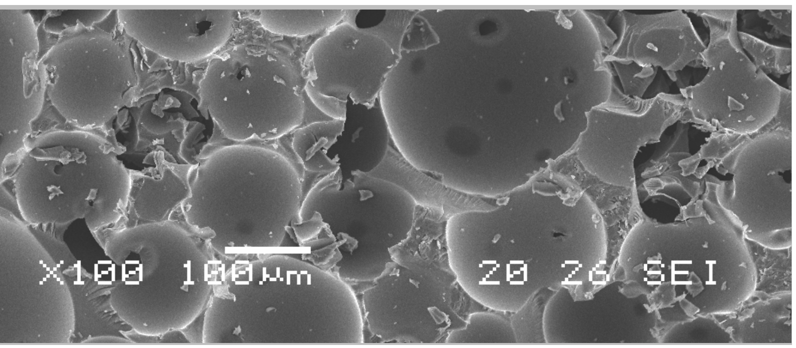
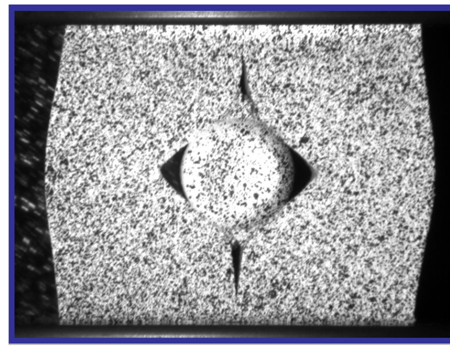
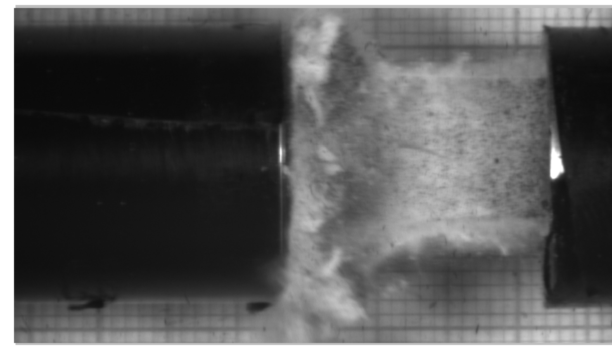
SAND2013-9842C







Confined Compression of Rigid Foams - Experiment

Wei-Yang Lu, Kevin Connelly

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Collaborators

Modeler

Mike Neilsen

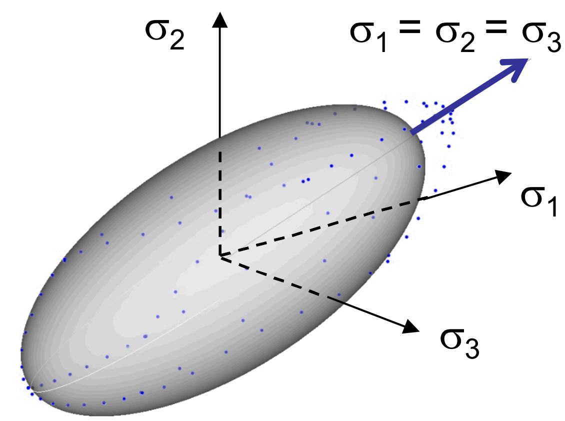
Analyst

Shivonne Haniff, Terry Hinnerichs

Background

Unified Creep Plasticity Model for Foam

Neilsen, M et al (2006),



Yield Function from Plasticity Model

$$\varphi = \sigma^* - a = 0$$

where

$$\sigma^* = \sqrt{\bar{\sigma}^2 + \frac{a^2}{b^2} p^2}$$

Inelastic Rate is Given by

$$\dot{\boldsymbol{\varepsilon}}^{vp} = \begin{cases} h(\theta)\left\langle \frac{\sigma^*}{a} - 1 \right\rangle^{n(\theta)} \mathbf{g} & \text{when } \frac{\sigma^*}{a} - 1 > 0 \\ \mathbf{0} & \text{when } \frac{\sigma^*}{a} - 1 \le 0 \end{cases}$$

Non-associated Flow

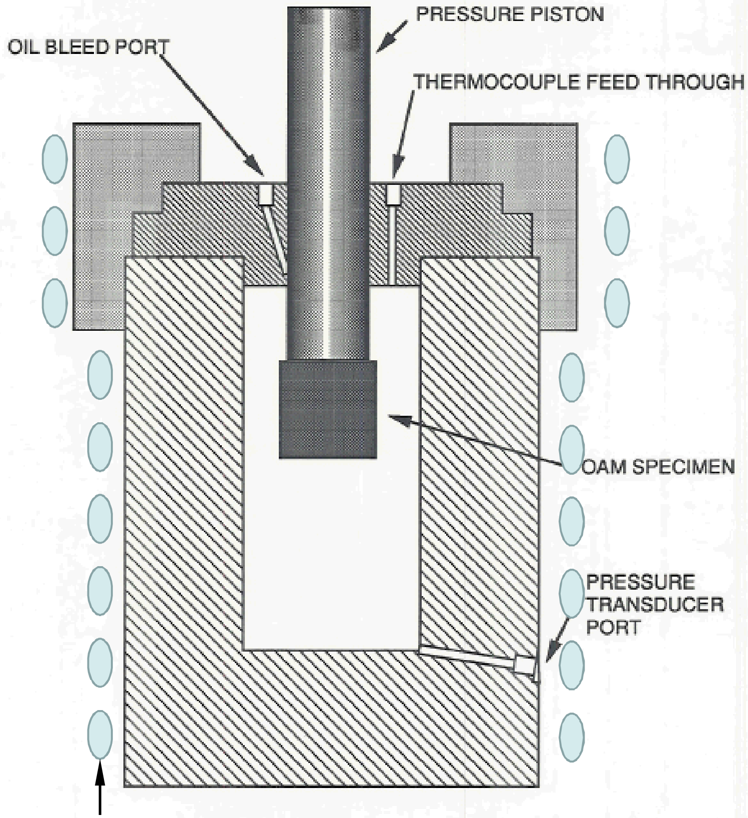
$$\mathbf{g} = (1 - \beta)\mathbf{g}_{associated} + \beta\, \mathbf{g}_{radial}$$

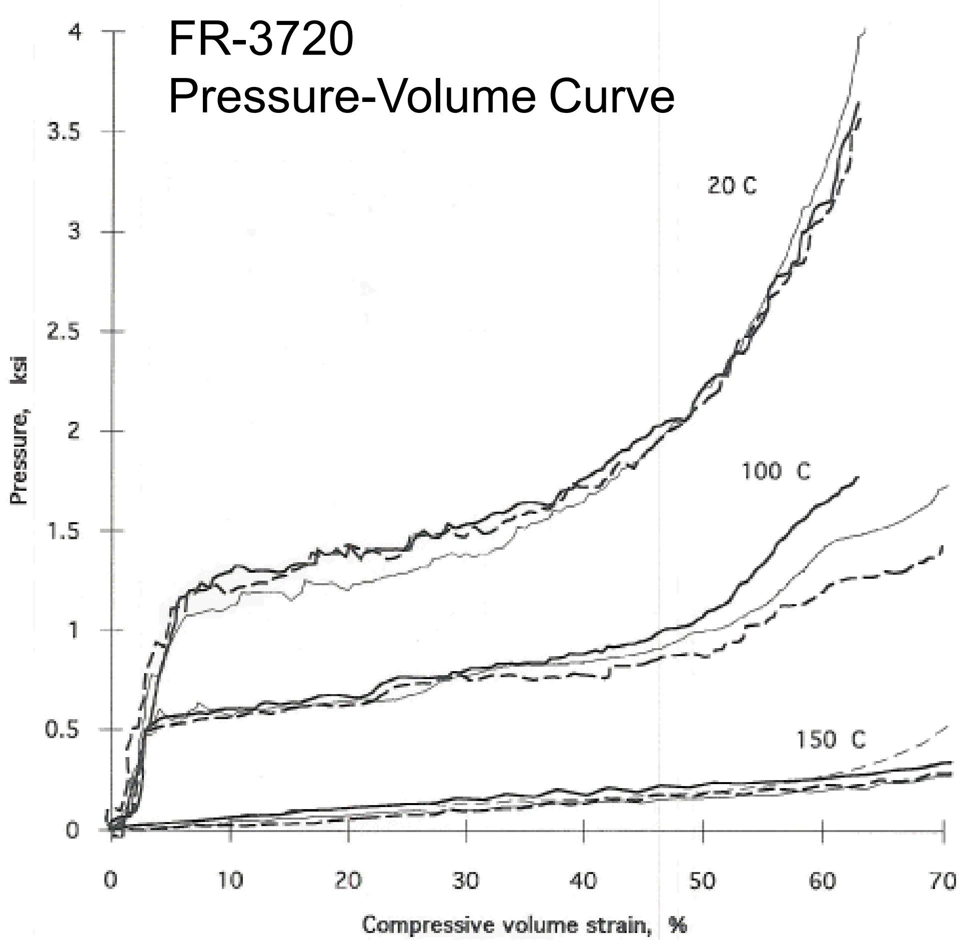
where

$$\mathbf{g}_{radial} = \frac{\boldsymbol{\sigma}}{|\boldsymbol{\sigma}|} = \frac{\boldsymbol{\sigma}}{\sqrt{\boldsymbol{\sigma} : \boldsymbol{\sigma}}}, \quad \mathbf{g}_{associated} = \frac{\dfrac{\partial\varphi}{\partial\boldsymbol{\sigma}}}{\left|\dfrac{\partial\varphi}{\partial\boldsymbol{\sigma}}\right|} = \frac{\dfrac{3}{a^2}\mathbf{s} - \dfrac{2}{3b^2} p\,\mathbf{i}}{\left|\dfrac{3}{a^2}\mathbf{s} - \dfrac{2}{3b^2} p\,\mathbf{i}\right|}$$

References: Perzyna, P (1971) "Thermodynamic theory of viscoplasticity." Advances in Applied Mechanics 11: 313-354.
Zhang, J et al (1998) "Constitutive Modeling of Polymeric Foam ….." Int. J. Impact Engng 21-5: 369-386.
Neilsen, M et al (2006) IMECE2006-14551, Proceedings of IMECE, ASME Press.
Neilsen, M et al (2013) "Unified Creep Plasticity Damage (UCPD) Model for Rigid Polyurethane Foams"

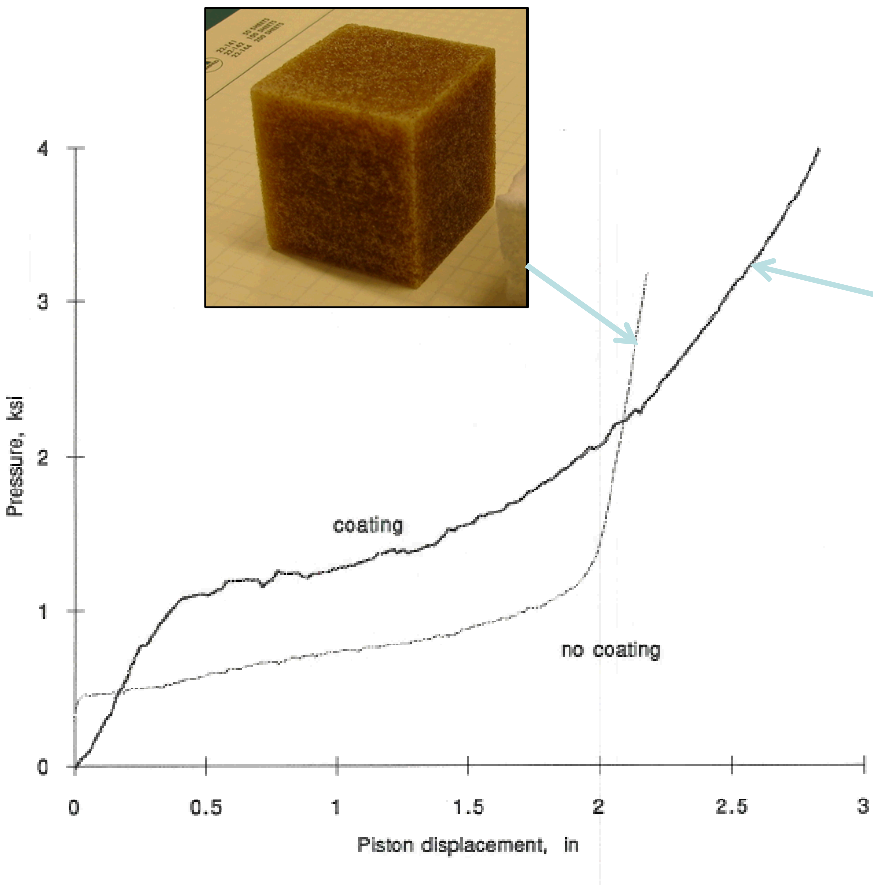
Hydrostatic Compression

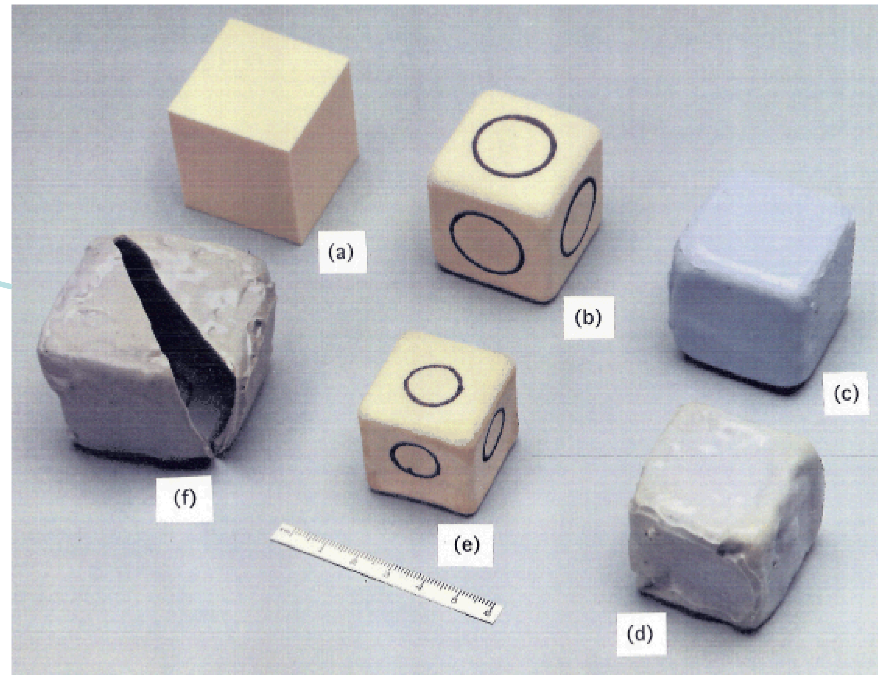




W-Y Lu ; J Korellis ; K Lee ; R Grishaber, "Hydrostatic and uniaxial behavior of a high density polyurethane foam (FR-3720) at various temperatures," SAND93-8227, March 1993.

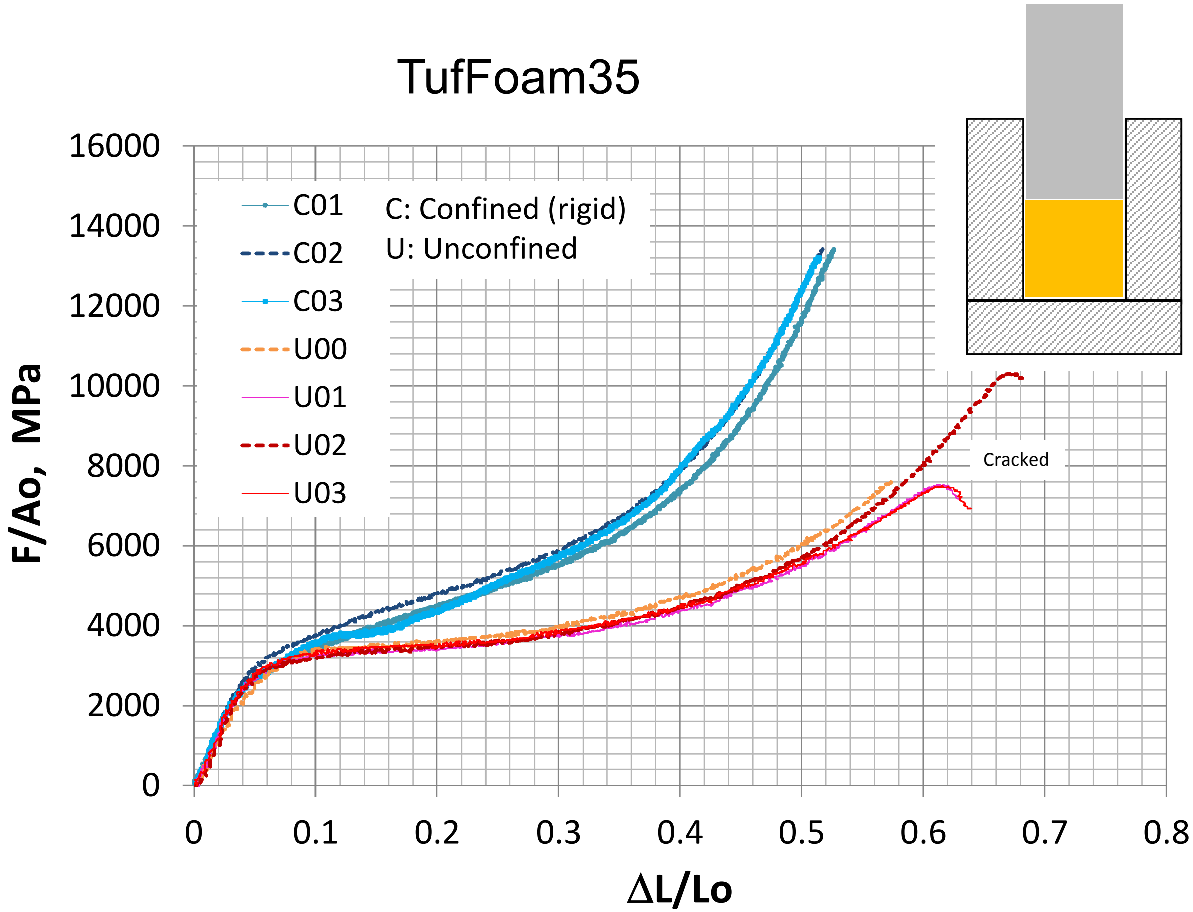
Specimen Coating



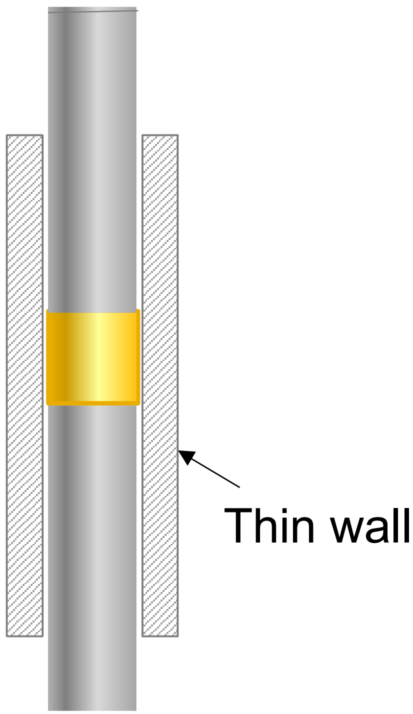


Triaxial Compression

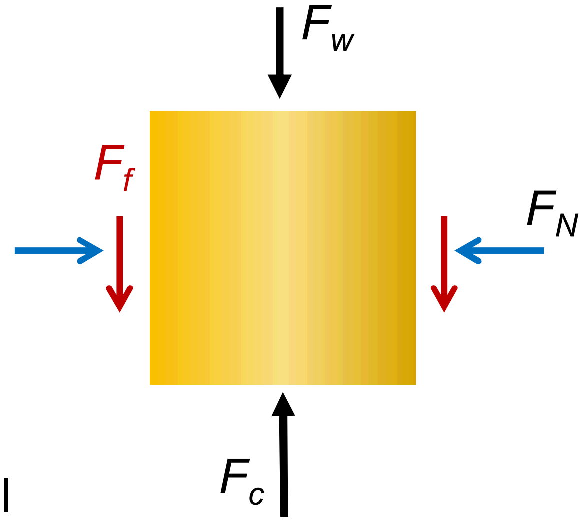
Thick wall for rigid confinement.



Elastic Confinement



Foam specimen

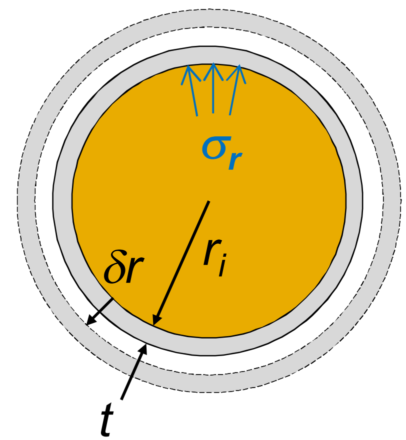


$$F_c = F_w + F_f$$

$$\sigma_z = F_w/(\pi r_i^2)$$

$$\sigma_r = F_N/(2\pi r_i h)$$

2D Thin tube



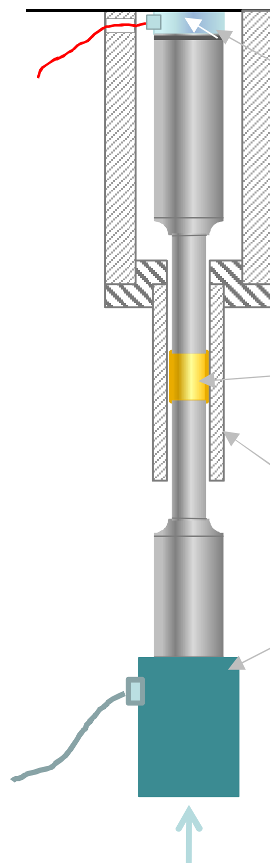
$$\delta_r = \frac{\sigma_r r_i^2}{tE}\left(1 + \frac{t}{2ri}\right)$$

(if σ_r is uniform)

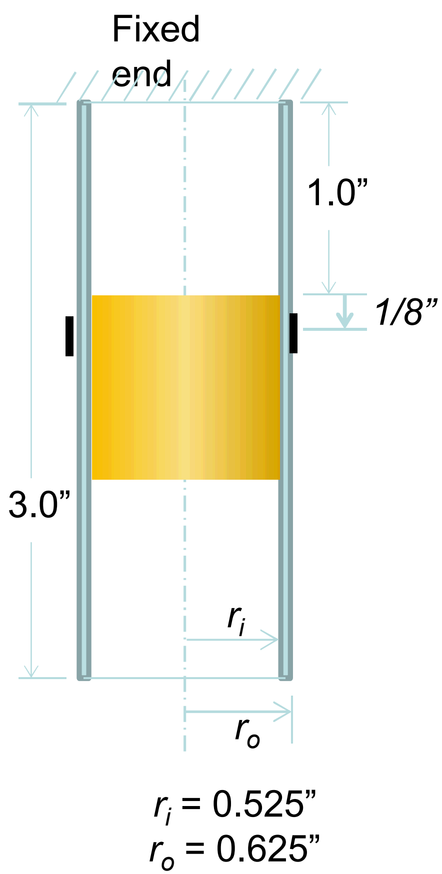
New Confined Compression of Foams

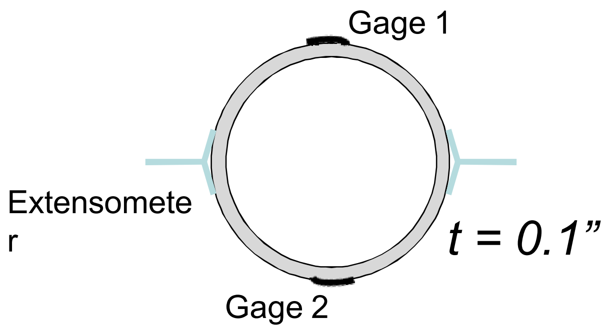
Setup

Schematics



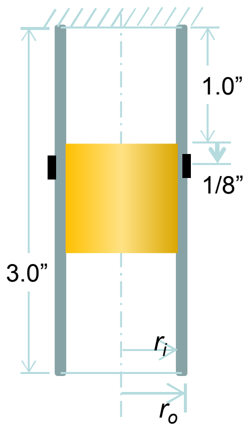
Thin Tube 1

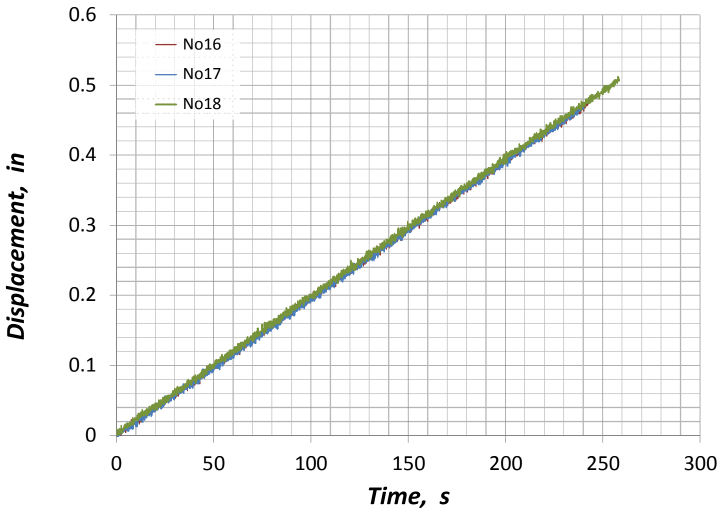


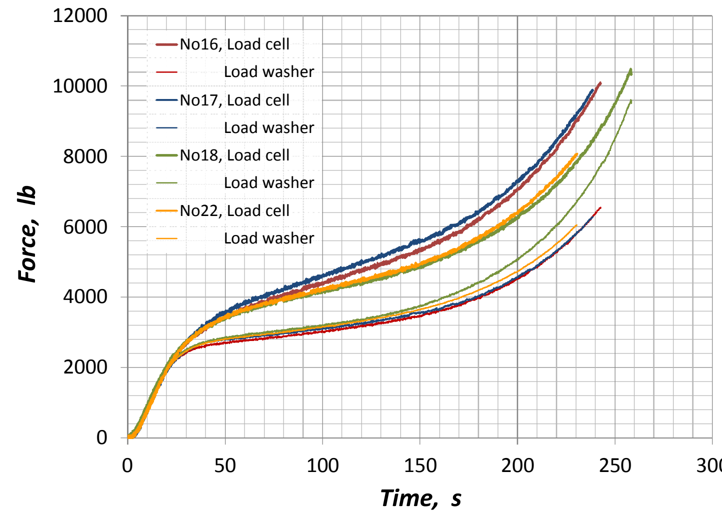


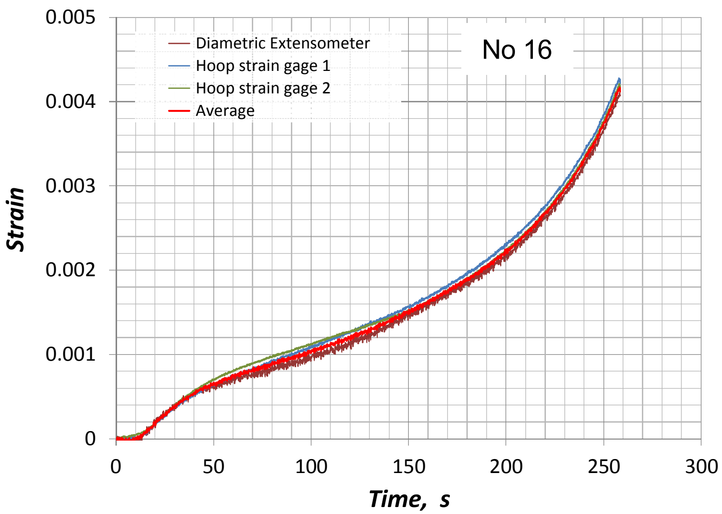
- Al7075-T7351
- $\sigma_y \approx 70$ ksi

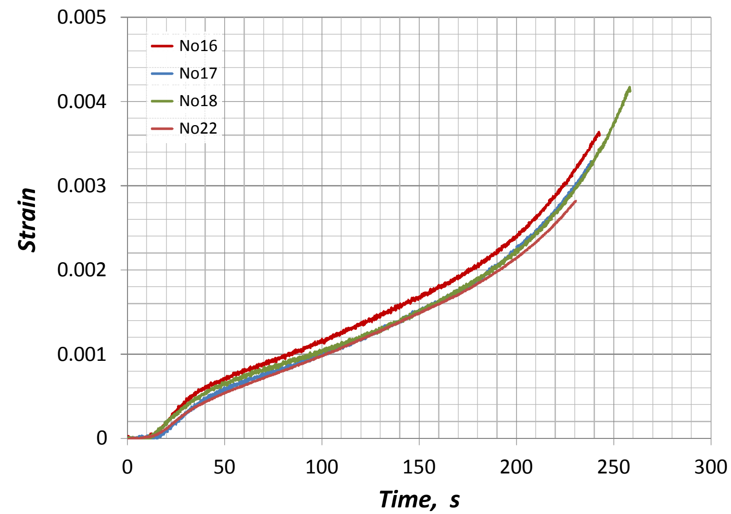
TufFoam 35


1.0”
1/8”
3.0”
r_i
r_o


No16
No17
No18
Displacement, in
Time, s
0.6
0.5
0.4
0.3
0.2
0.1
0
0
50
100
150
200
250
300


No16, Load cell
Load washer
No17, Load cell
Load washer
No18, Load cell
Load washer
No22, Load cell
Load washer
Force, lb
Time, s
12000
10000
8000
6000
4000
2000
0
0
50
100
150
200
250
300


Diametric Extensometer
Hoop strain gage 1
Hoop strain gage 2
Average
No 16
Strain
Time, s
0.005
0.004
0.003
0.002
0.001
0
0
50
100
150
200
250
300

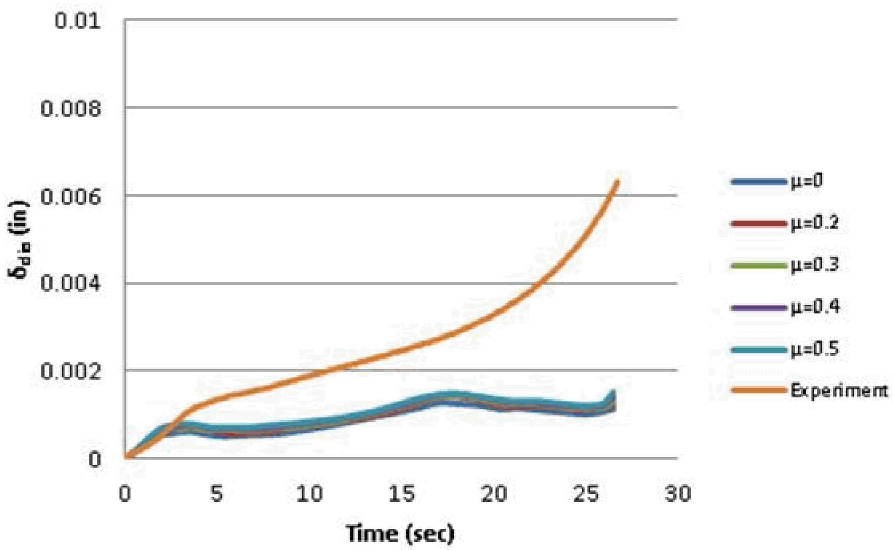

No16
No17
No18
No22
Strain
Time, s
0.005
0.004
0.003
0.002
0.001
0
0
50
100
150
200
250
300

Model Parameters

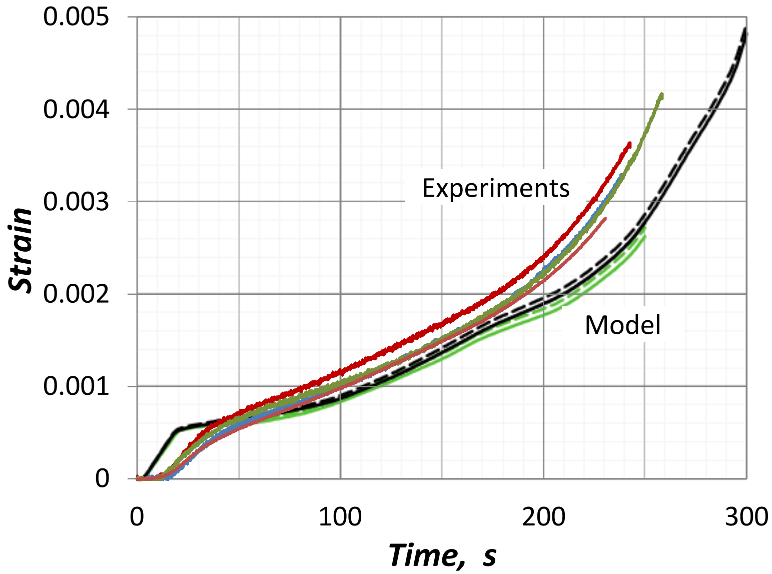
Flow direction

$$\mathbf{g} = (1-\beta)\,\mathbf{g}_{associated} + \beta\,\mathbf{g}_{radial}$$

Initial prediction with $\beta = 0.9$

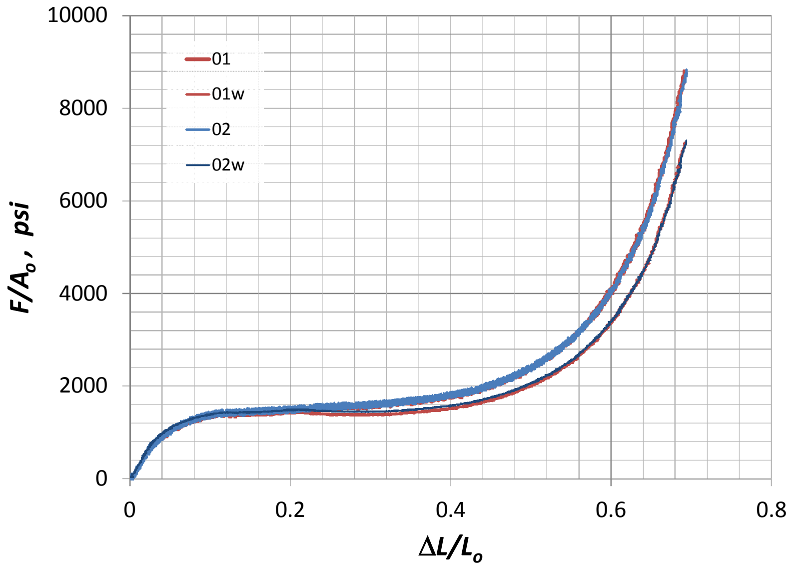


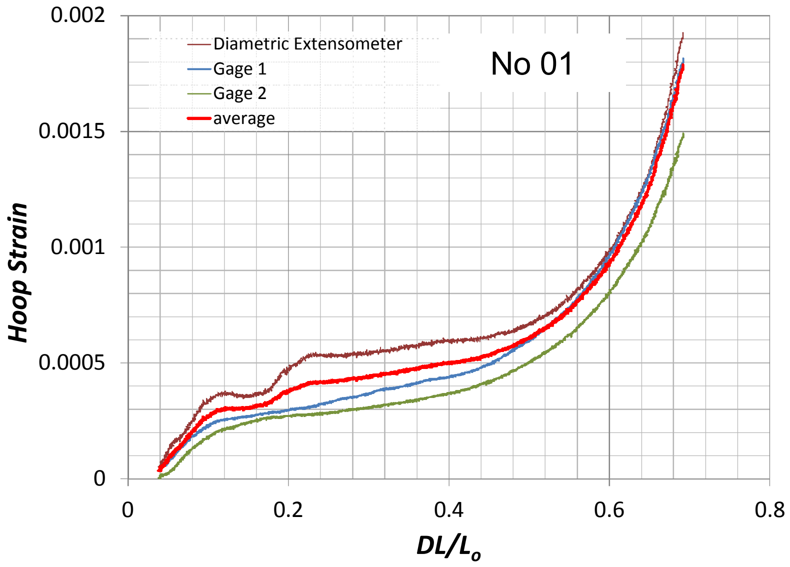
Simulation with $\beta = 0$



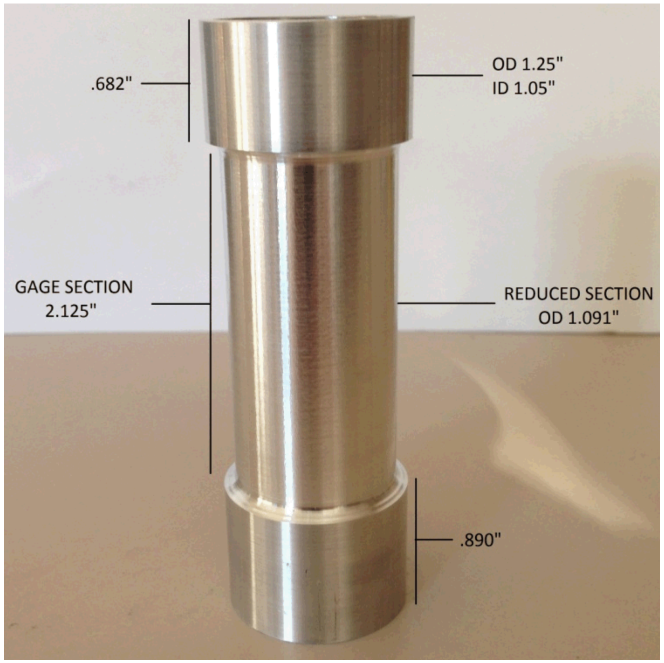
PMDI20

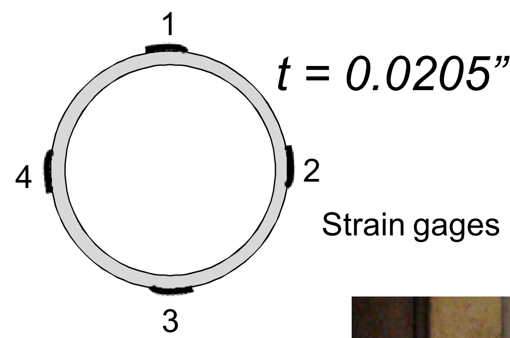
- Constant loading speed is about 0.002 in/s.
- Large scatter in hoop strain for lower density foams.





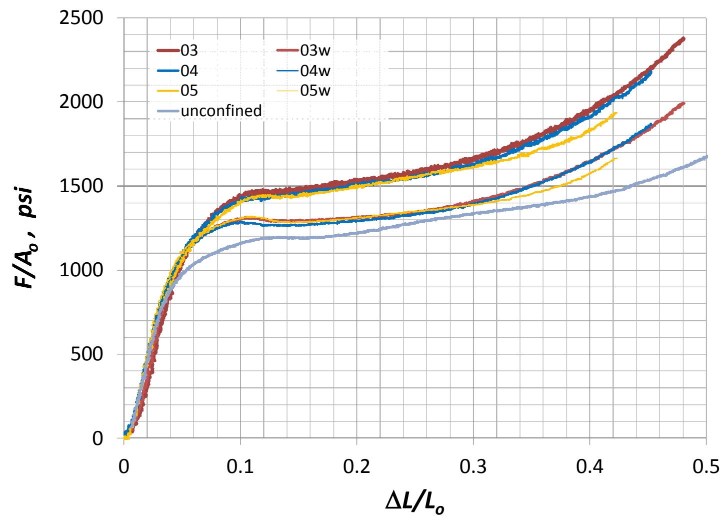
Thin Tube 2

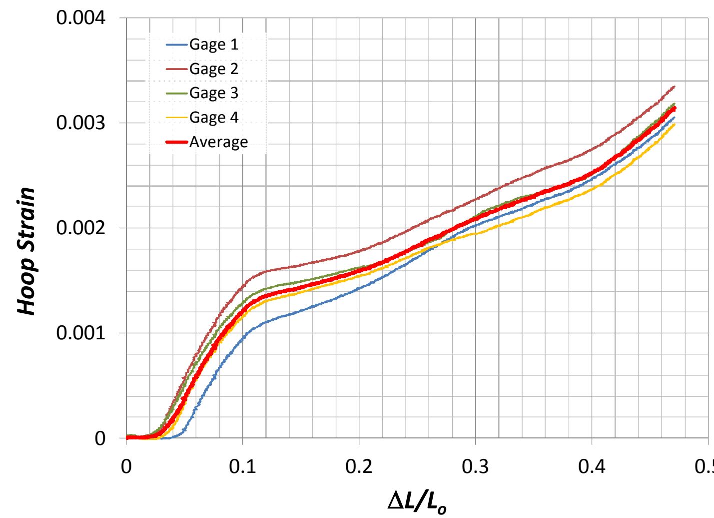

.682"
OD 1.25"
ID 1.05"
GAGE SECTION
2.125"
REDUCED SECTION
OD 1.091"
.890"

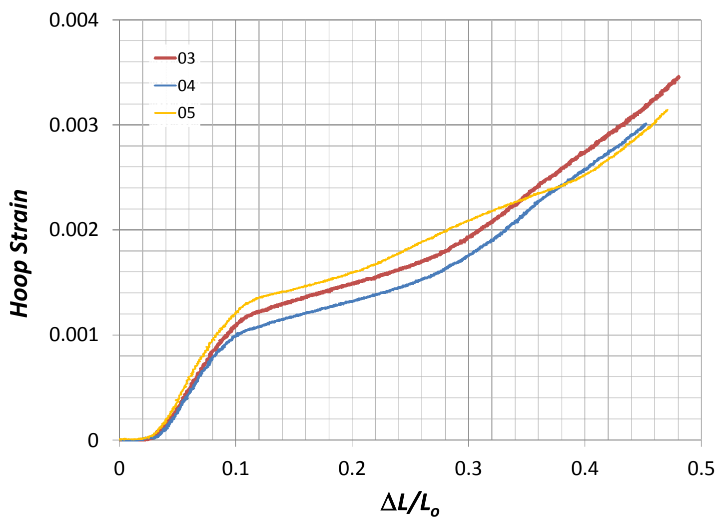

1
2
3
4
t = 0.0205"
Strain gages

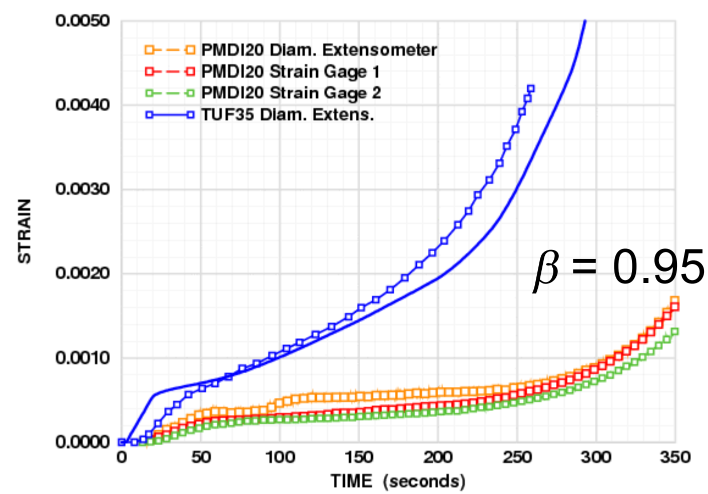
PMDI20

Sandia National Laboratories









Summary

- Elastically confined compression provides critical data for calibrating foam model parameters.
- The data show the flow direction depends on the foam density: associate flow for high density foams (35 pcf) and non-associate flow for lower density foams (20 pcf).
- Confined compressions at different temperatures and loading rates are under investigation.