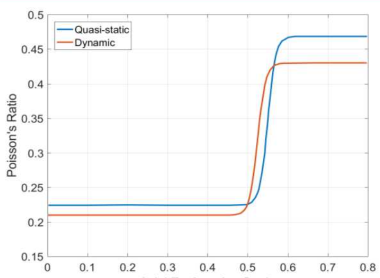
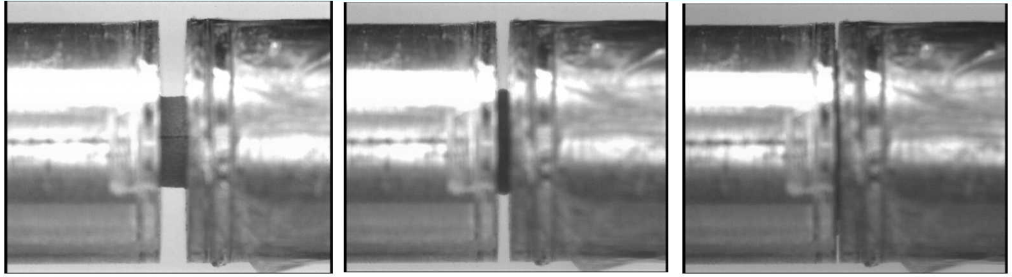
SAND2018-5560C

Quasi-Static and Dynamic Poisson's Ratio Evolution of Hyperelastic Foams





PRESENTED BY

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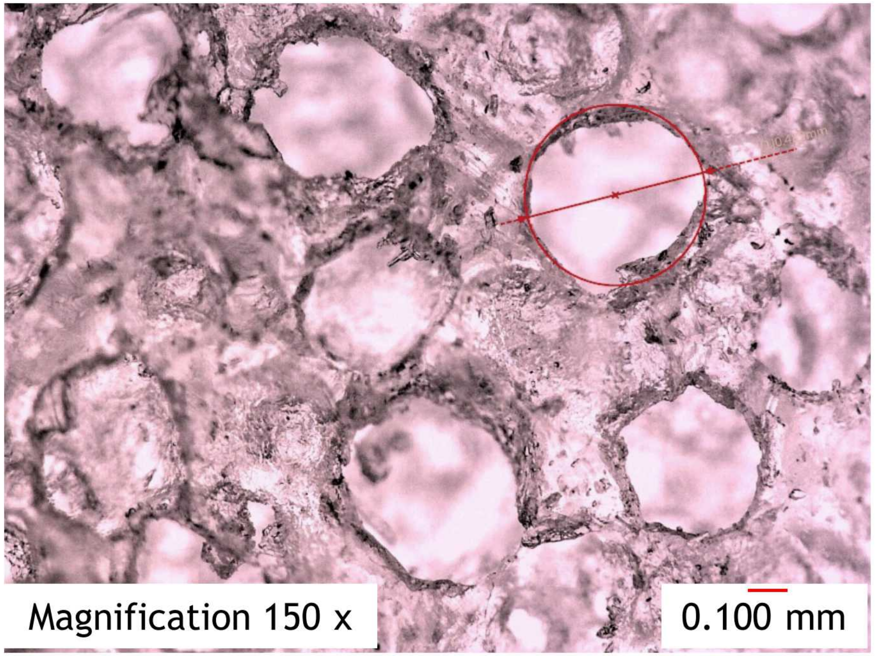
Silicone Foam Background

Shock Vibration Isolation and Reduction

- Light weight
- Excellent energy absorption
- Full recovery after impact loading



Open-Cell Silicone foam

Density: 608 ± 21.85 kg/m^3

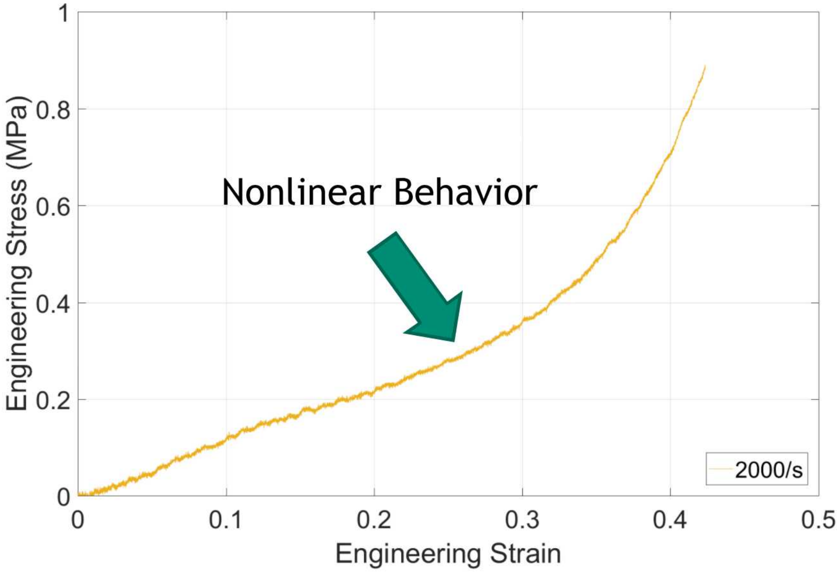
Average cell size: ~0.5 mm

At first glance, it may seem OK to neglect Poisson's Ratio or assume a small number near zero due to apparent compressibility

Silicone Foam

Mechanical response of silicone foam may be altered by…

- Strain rate
- Stress-state
- Temperature



Shock or vibration isolation pads can undergo

- High strain rate
- High densification state

Past densification, material may lose compressibility

How does Poisson's Ratio change with strain rate and densification?

Poisson's Ratio

Poisson's Ratio is typically regarded as a material *constant*

$$\nu = -\frac{e_r}{e_x}$$

Good for metals in Elasticity

Small strains

Materials such as foams are undergo large deformation

$$\nu = -\frac{\ln \lambda_r}{\ln \lambda_x} = -\frac{\varepsilon_r}{\varepsilon_x}$$

True strains along axial and radial directions

Secant Poisson's Ratio

Applicable to Linear Response Only

In the case of nonlinear large deformation, ***tangent Poisson's ratio*** with true strains represents actual Poisson's ratio

$$\nu = -\frac{d\varepsilon_r}{d\varepsilon_x}$$

Literature

Most available studies on Poisson’s ratio…

Conducted at quasi-static strain rates → **Response might not apply to high strain rates**

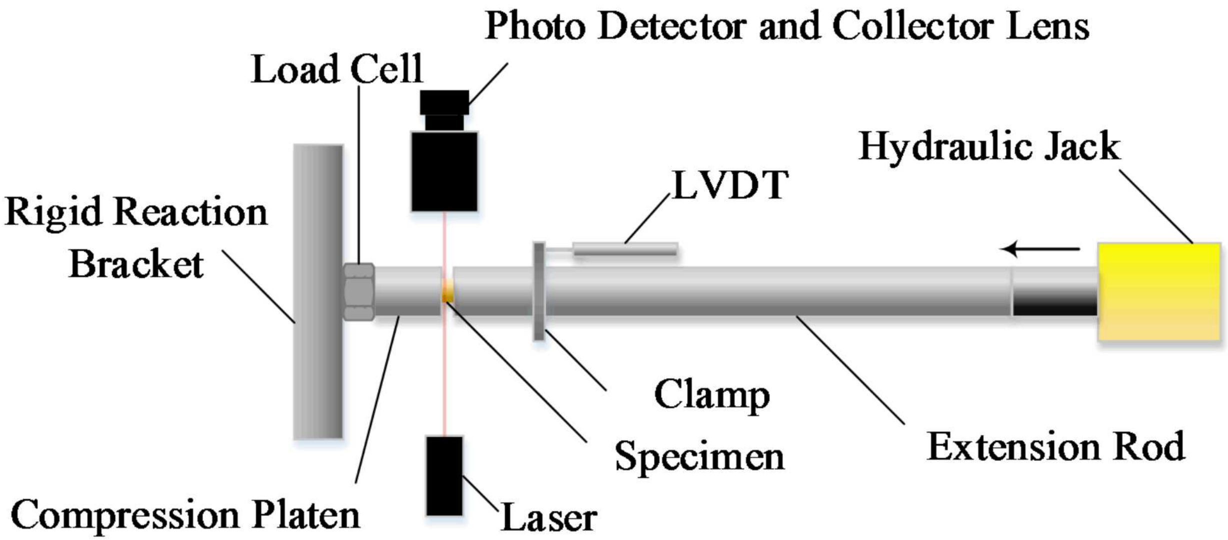
Limited to small deformations → **Material can undergo large deformation during use**

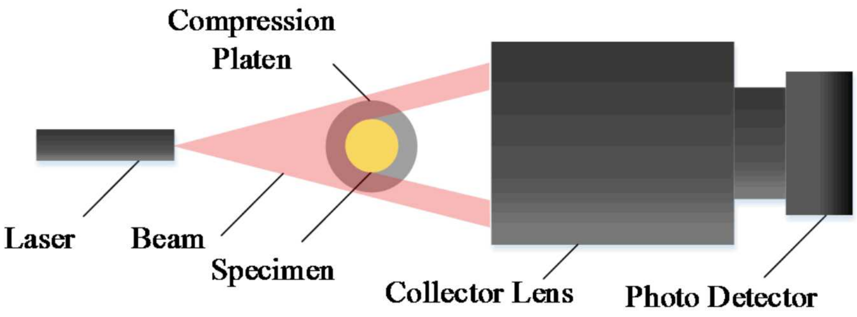
Some measure large deformation, use secant ratio to calculate → **Tangent method must be used for accurate results**

Our Approach: Measure Poisson’s ratio at **high rate***, **large deformation**, and calculated using **tangent ratio** for best results

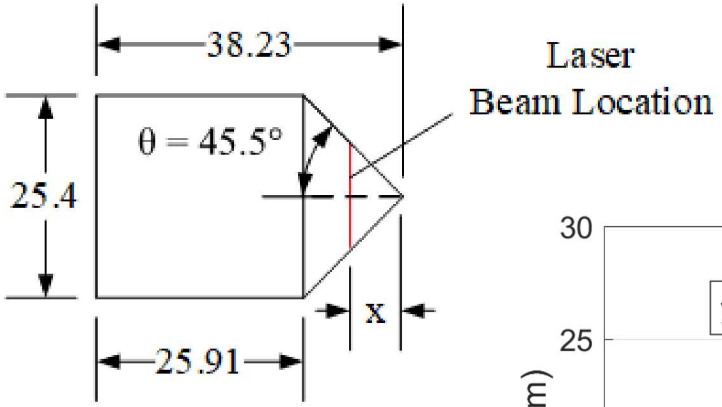
*quasi-static also included as a check

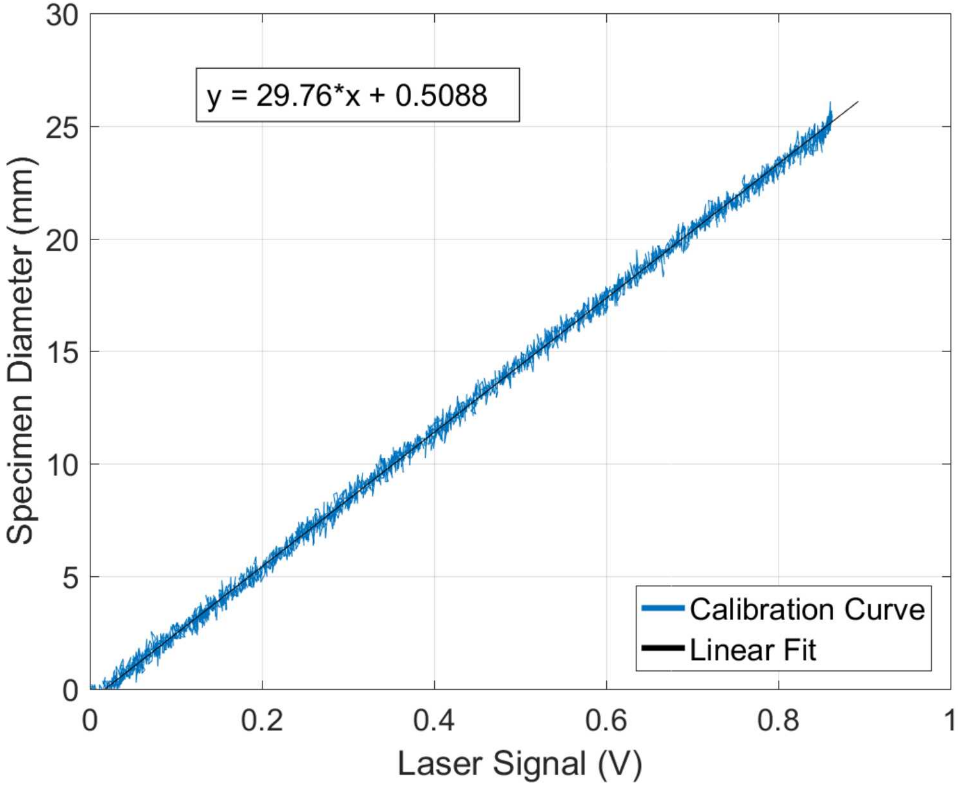
Quasi-static experiments



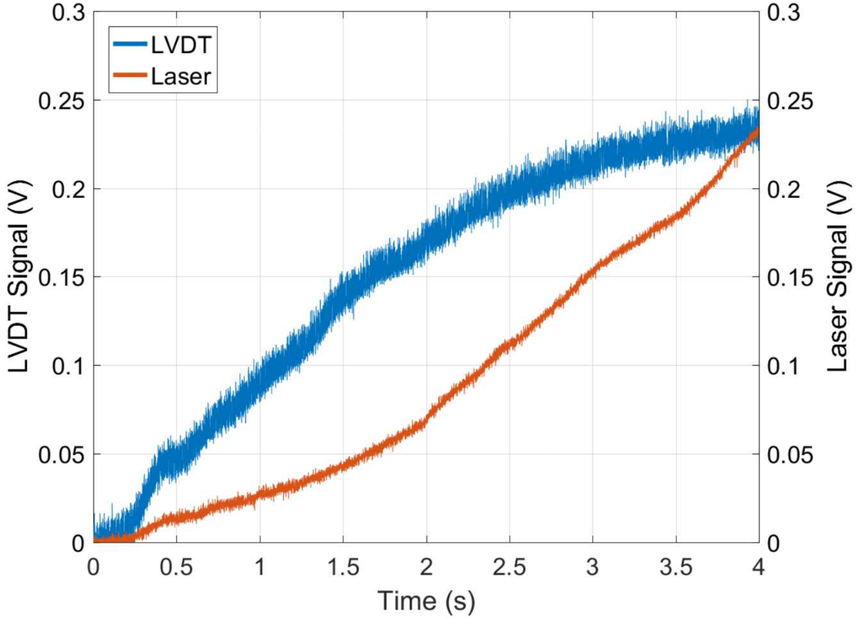


Laser Calibration

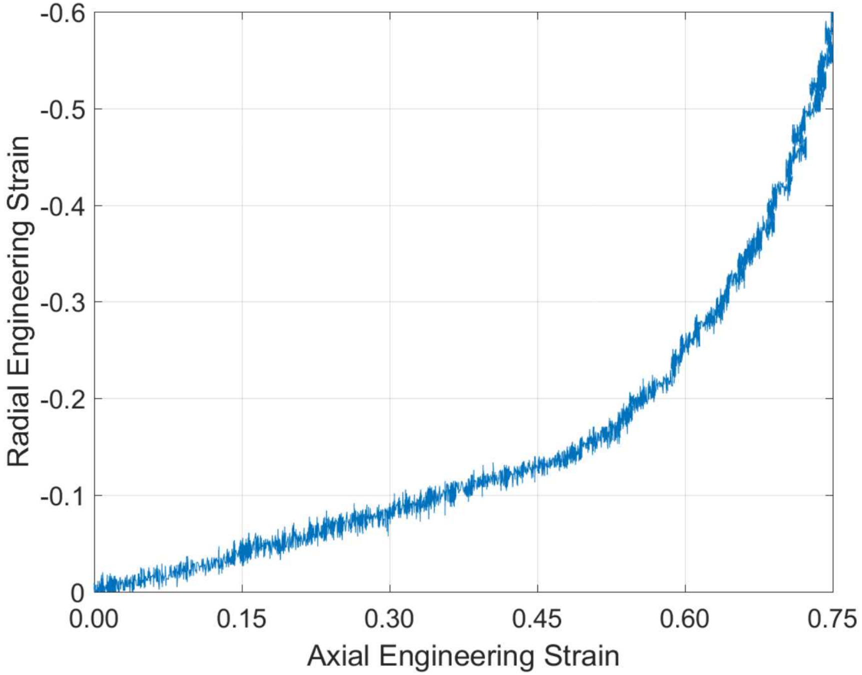




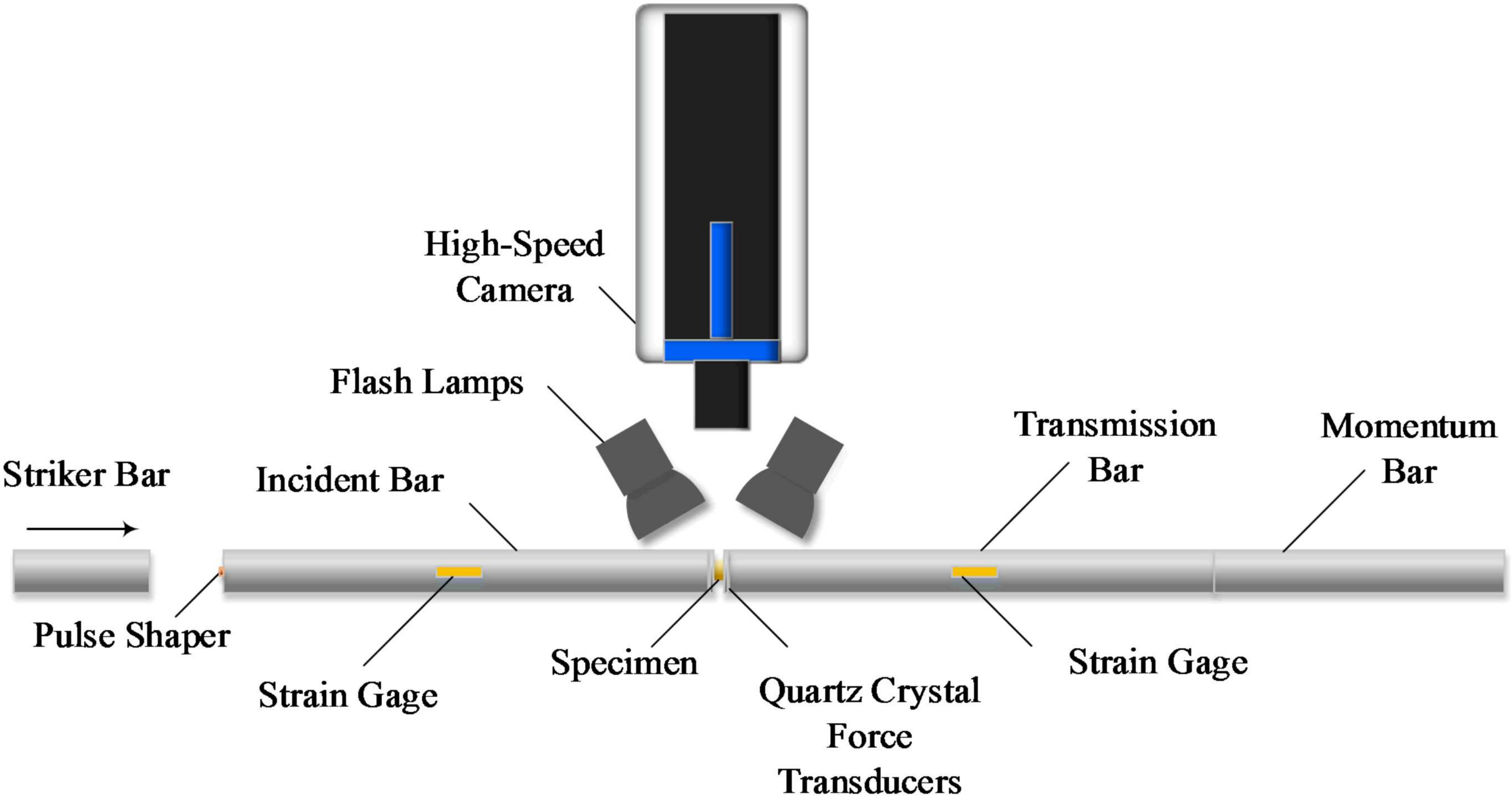
Quasi-static Output



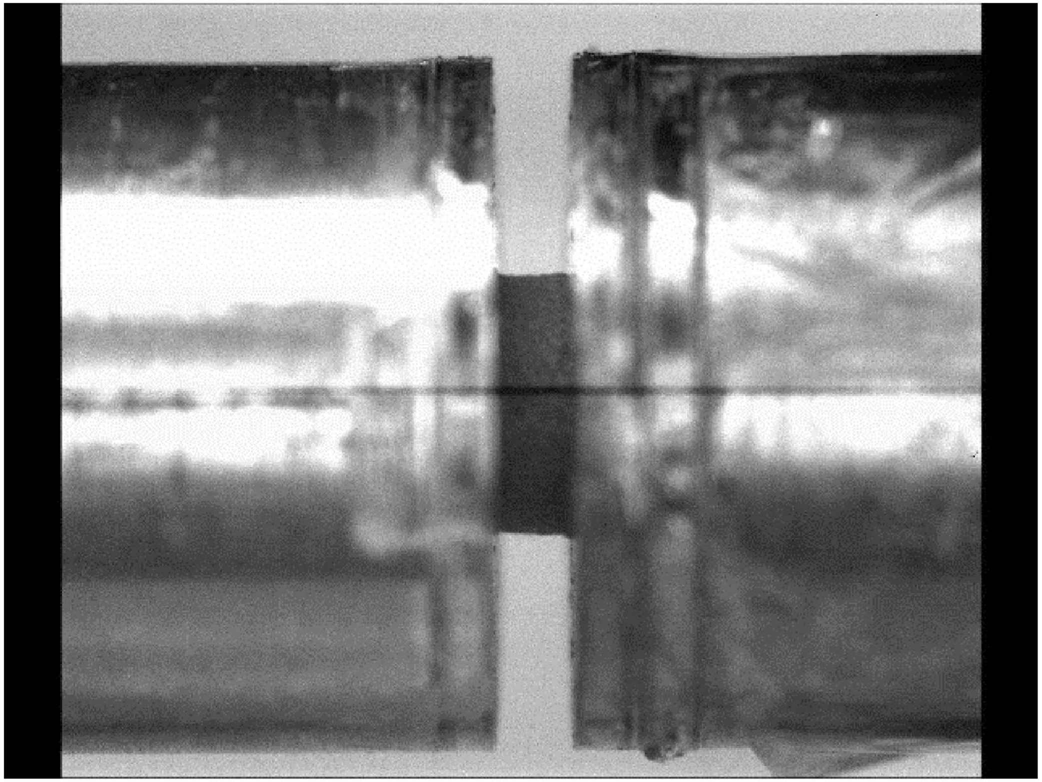
$$e_x = 1 - \frac{l_1}{l_0} \quad e_r = 1 - \frac{d_1}{d_0}$$



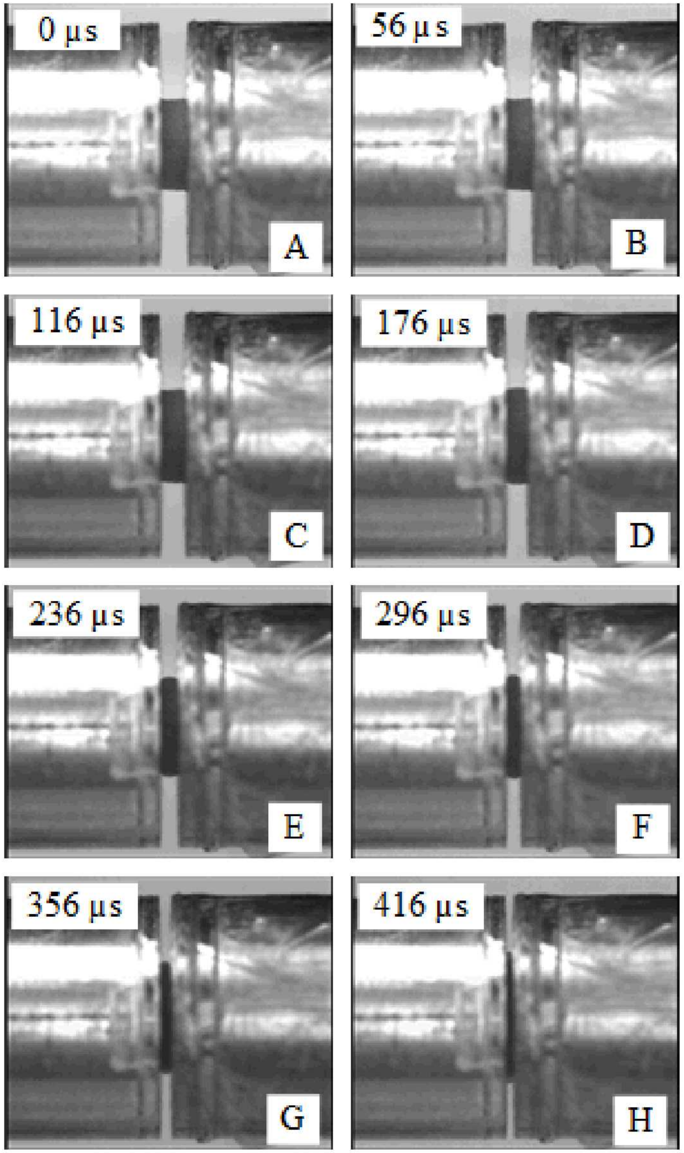
High Rate Experiments

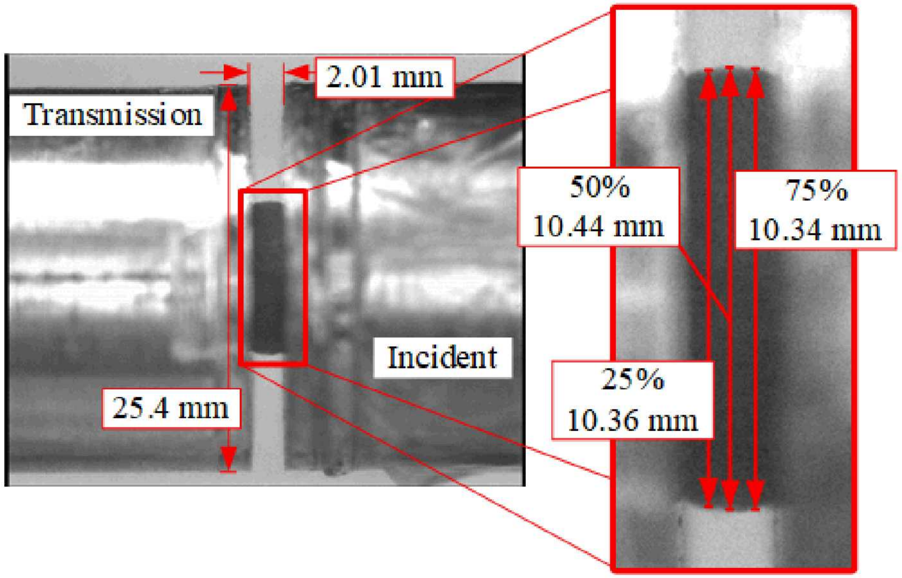


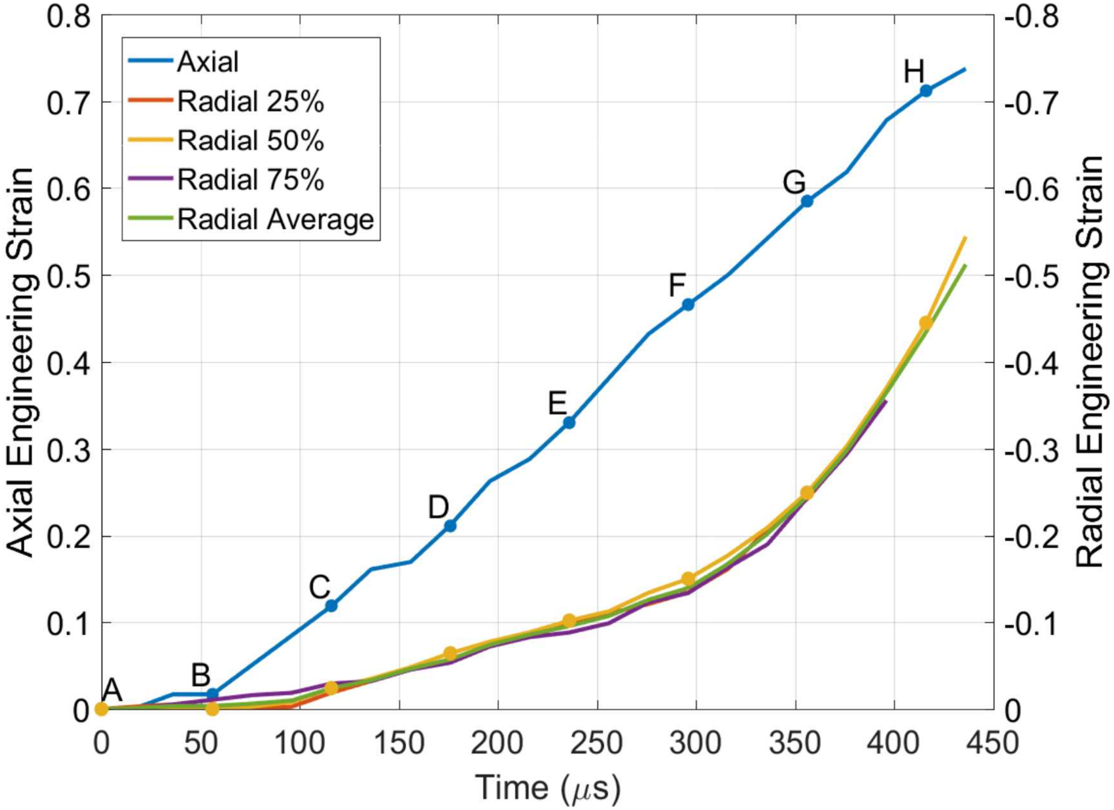
High Rate Deformation



High Rate Deformation







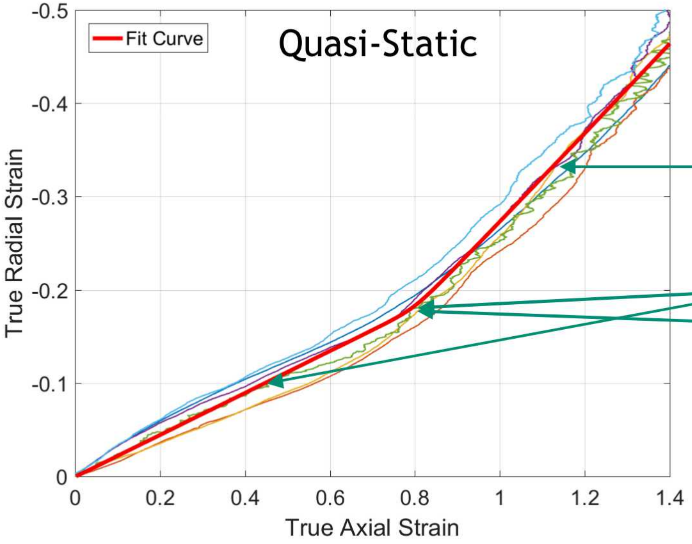
Poisson’s Ratio Calculation

$$\nu = -\frac{d\varepsilon_r}{d\varepsilon_x}$$

Tangent Poisson’s Ratio for large, nonlinear deformation

$$\varepsilon = -\ln\left(1 - e\right)$$

True strain: Axial compression (+) and Radial Tension (-)



Boltzmann Sigmoidal Function

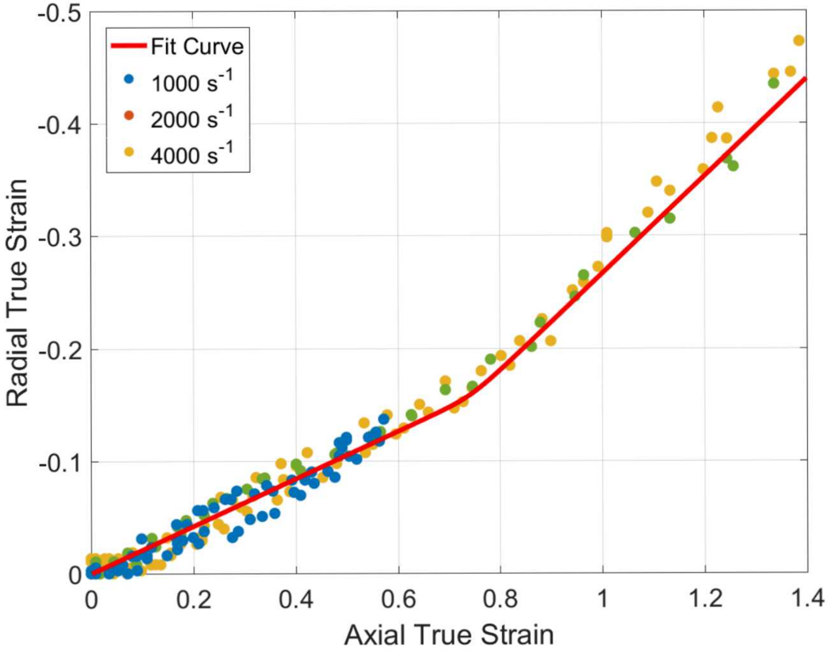
Bilinear

$$\nu\left(e_x\right) = \frac{\nu_1 - \nu_2}{1 + \exp\left(\frac{e_x - e_{x0}}{\delta}\right)} + \nu_2$$

High Rate Poisson’s Ratio

Radial-axial relationship is similar to QS results

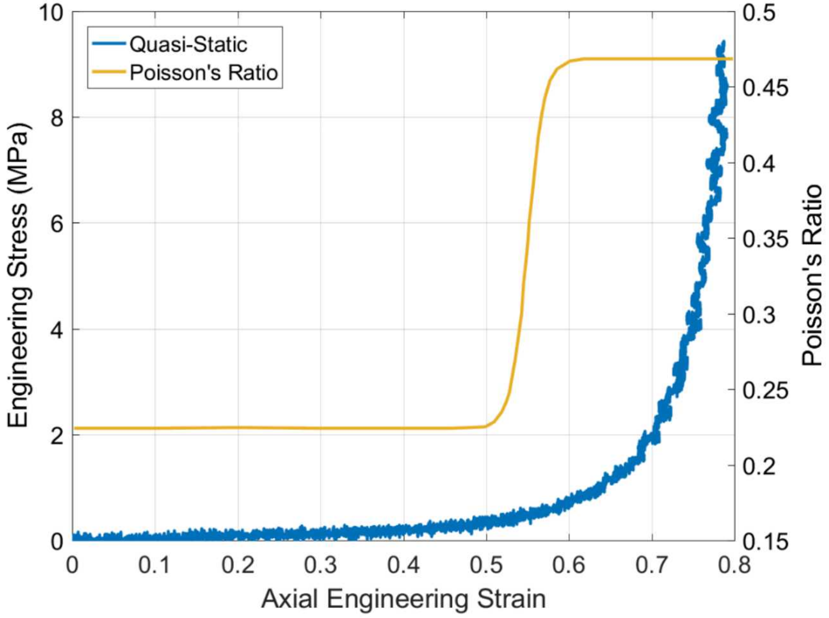
No strain rate effect is evident for radial-axial true strain relationship from 1000-4000 s^{-1}



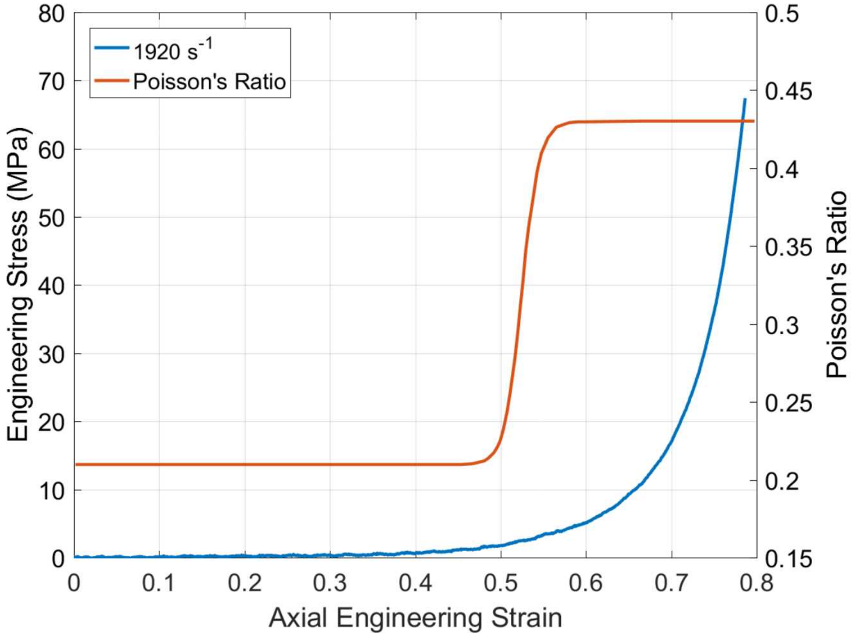
Boltzmann

Parameter	Quasi-static	Dynamic
v_1	0.22	0.21
v_2	0.47	0.43
e_{x0}	0.550	0.525
δ	0.01	0.01

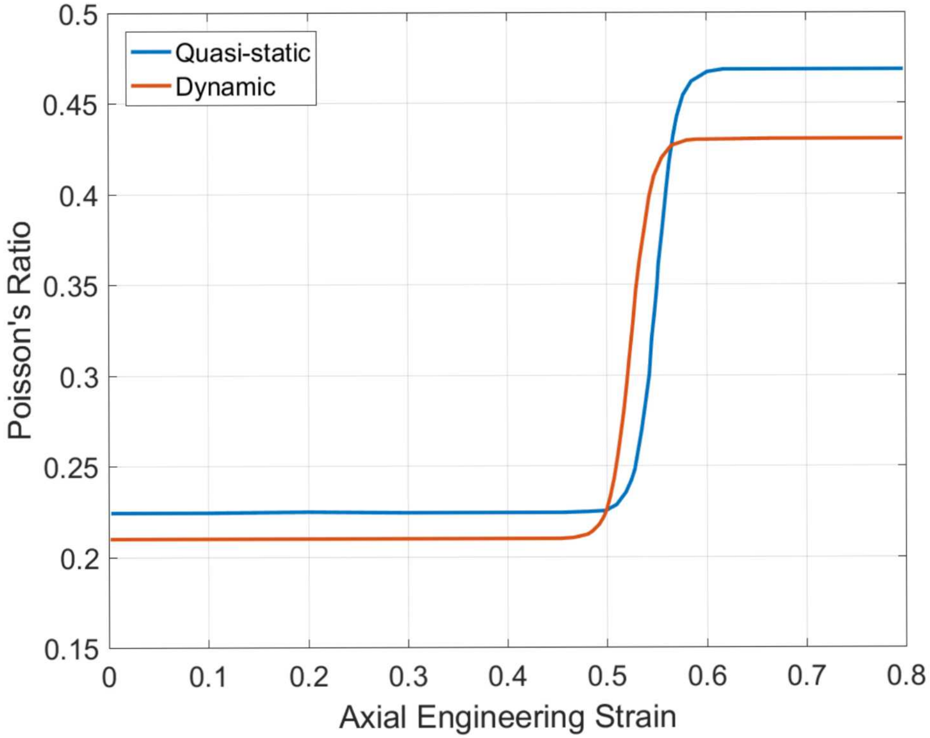
QS and High Rate Poisson's Ratio



Change in v coincided with densification for both rate regimes



QS and High Rate Poisson’s Ratio



Conclusion

- Optical methods were used to measure deformation of silicone foam along axial and radial directions
  - Quasi-static (laser)
  - Dynamic (high-speed camera)
- Radial-axial strains were collected
- Tangent method to calculate Poisson’s ratio for large strain, nonlinear deformation
- Radial-axial behavior fit using Botlzmann sigmoid function
- No major strain rate sensitivity in radial-axial strain behavior at high rate
- Quasi-static and dynamic Poisson’s ratios were slightly different
- Overall, foam transitioned from being compressible to nearly incompressible with densification

Models should include this transition for most accurate results