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Calibration and Validation of a Ductile Failure Model Against Aluminum Axial Torsion Experiments

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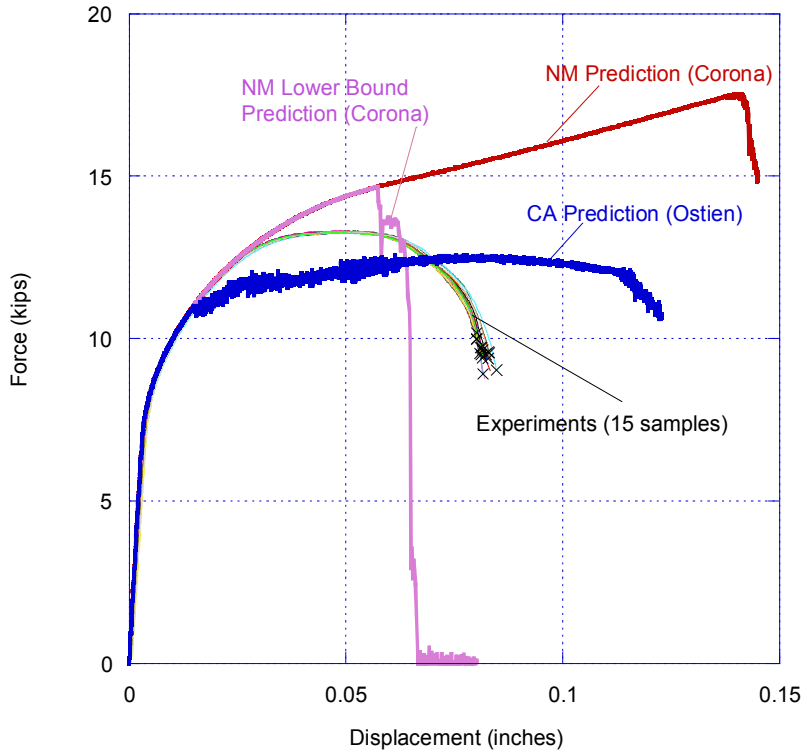
Motivation

- Past history of poor predictions in shear-dominated failure



J. Koester and E. Corona. 2013 Shear-dominated failure x-prize, post challenge investigations. Technical report, Sandia National Laboratories, September 2013. Internal Sandia Memo.

- Compare two approaches
  - Uncoupled model: modified Johnson-Cook model
  - Coupled model: modified Gurson model

Modeling Approach

- Attempt to calibrate against simple experiments and validate against more complex experiments.
- Finite Element Code: Sierra/SM Implicit Quasi-Statics
- Element Type: q1p0
- Simulations were run up to the initiation of failure.

Calibration / Validation Specimens

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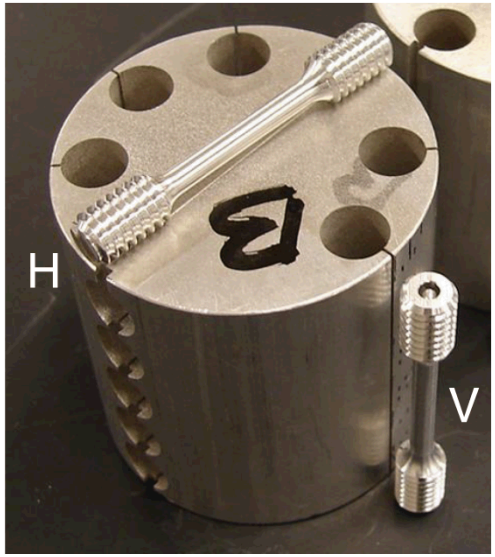
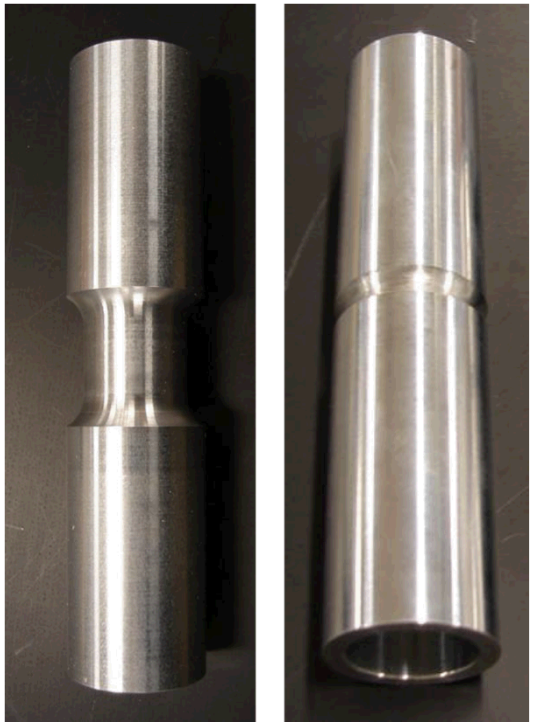
Smooth Bars



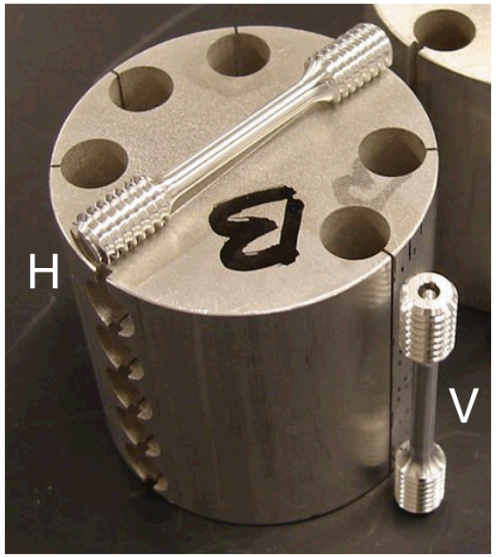
Notched Bars

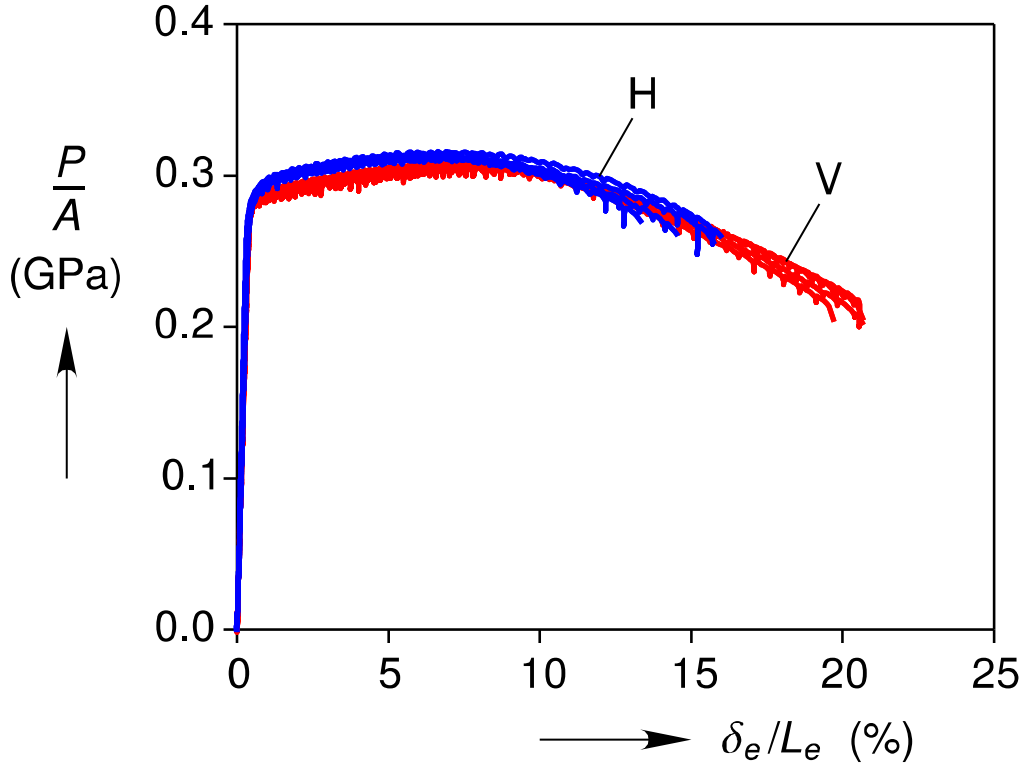
Tubes



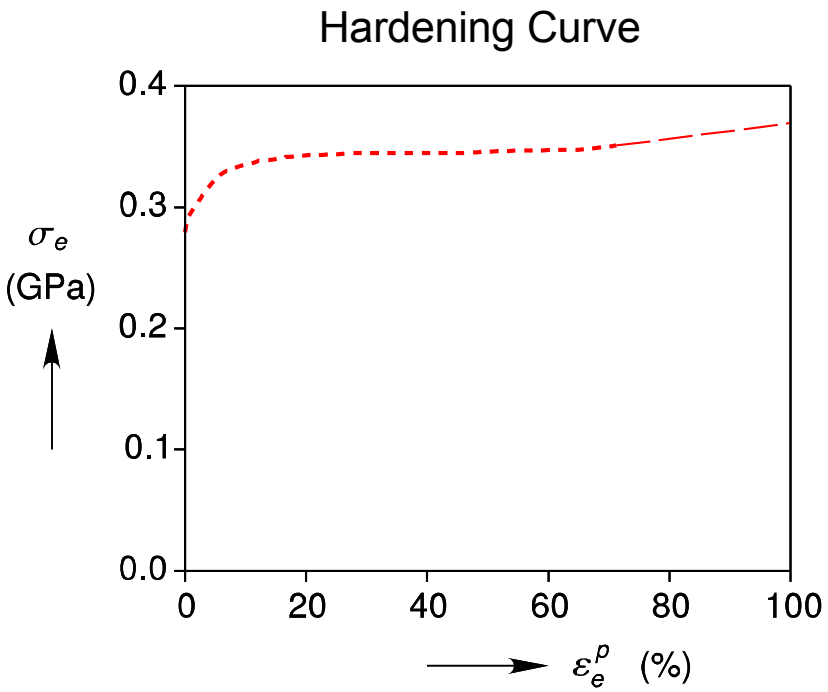
All specimens were machined from the same large diameter bar of Al 6061-T651

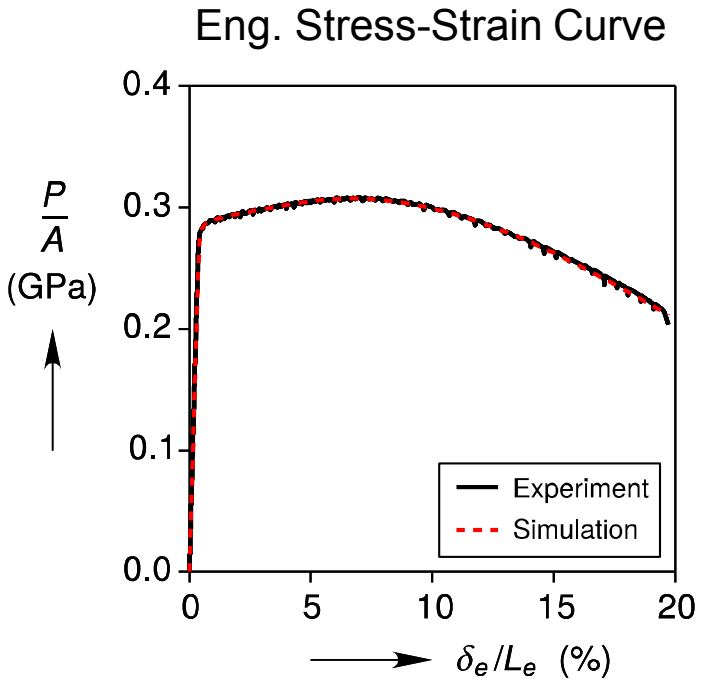
Smooth Bar Tensile Experiments





Hardening Curve Calibration





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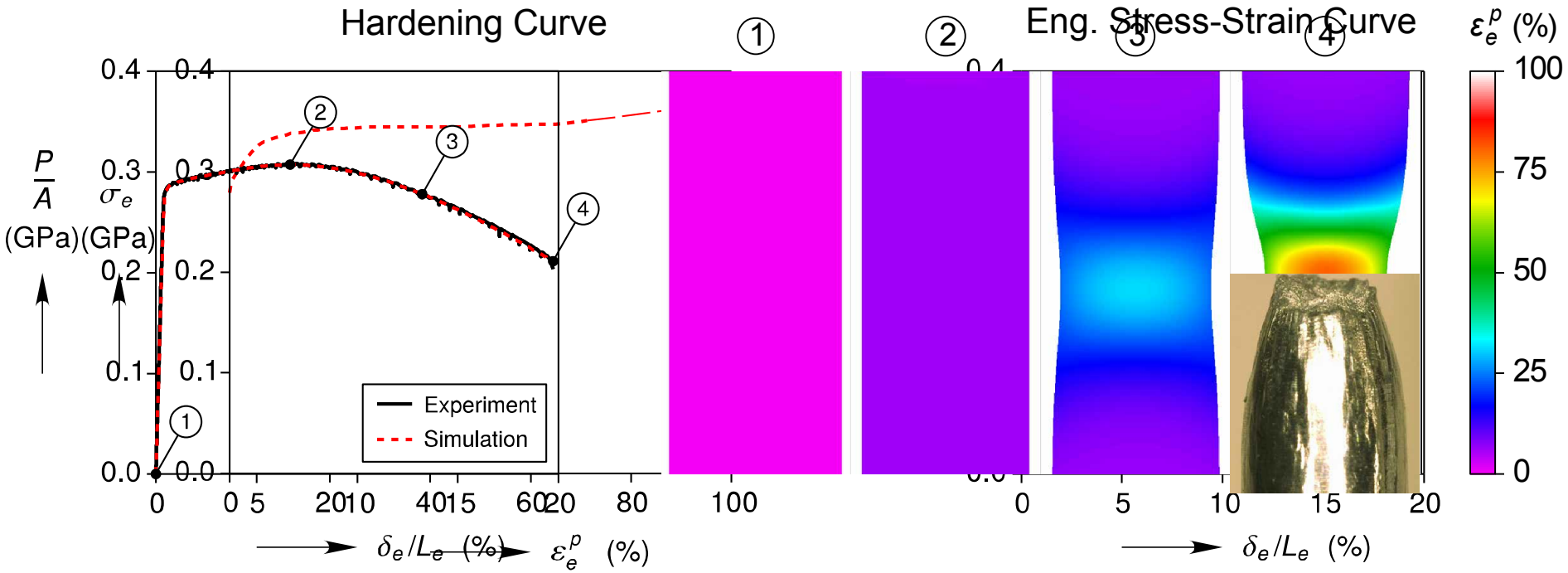
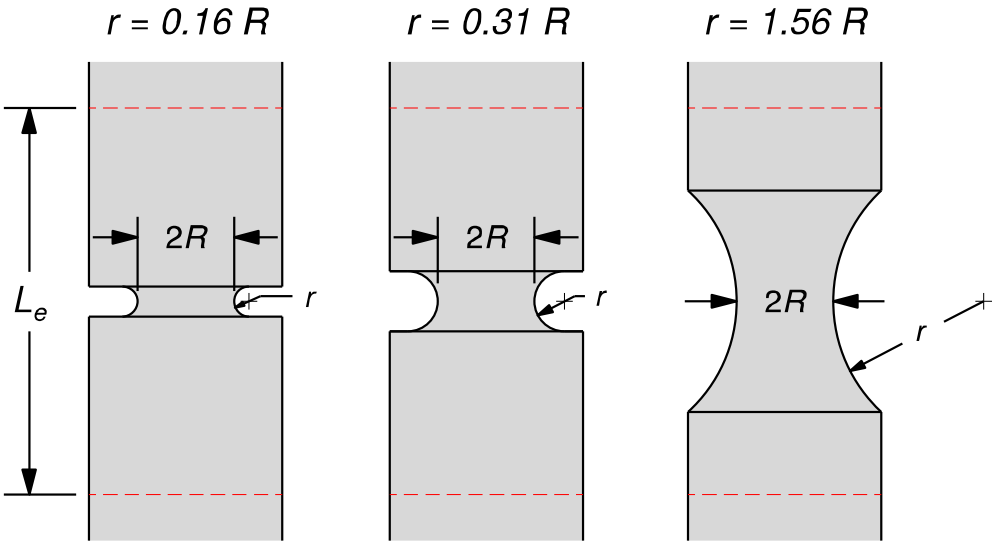
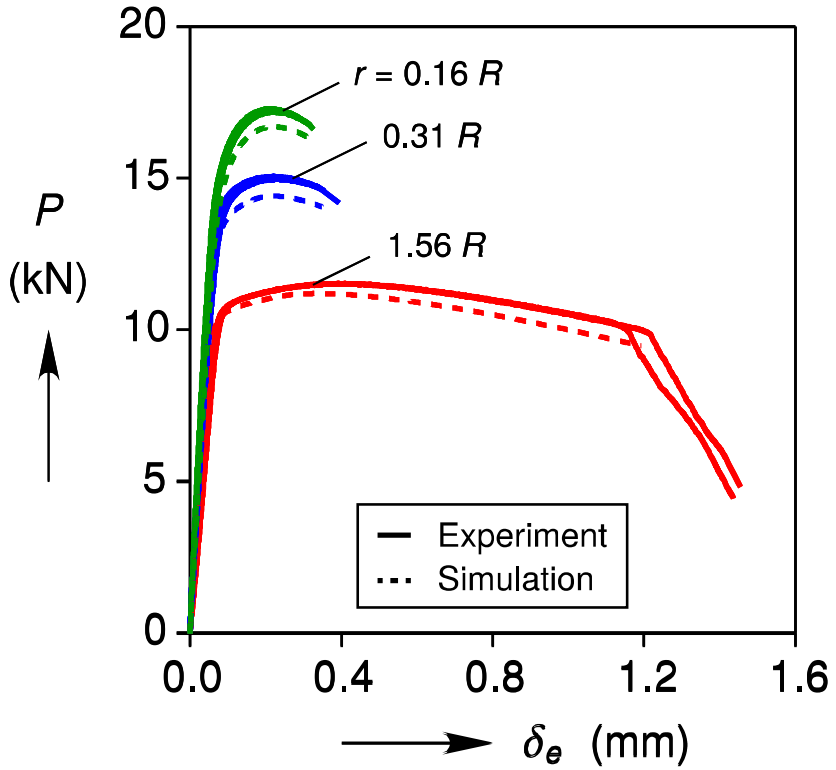


Notched Bar Tensile Experiments



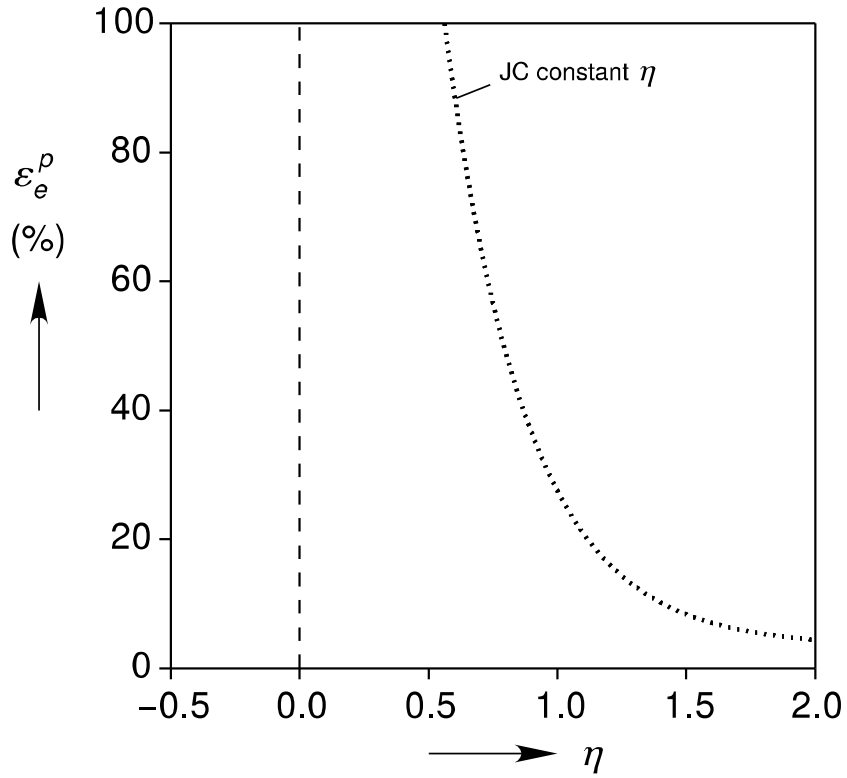


Failure Model Calibration

$$\varepsilon_{ef}^{p} = d_1 + d_2 \exp\left[d_3\, \eta\right]$$

$$D = \int_0^{\varepsilon_e^p} \frac{\dot{\varepsilon}_e^p}{\varepsilon_{ef}^p\,(\eta)}\, \mathrm{d}t$$

$$D \geq 1 \;\Rightarrow\; \text{Failure}$$



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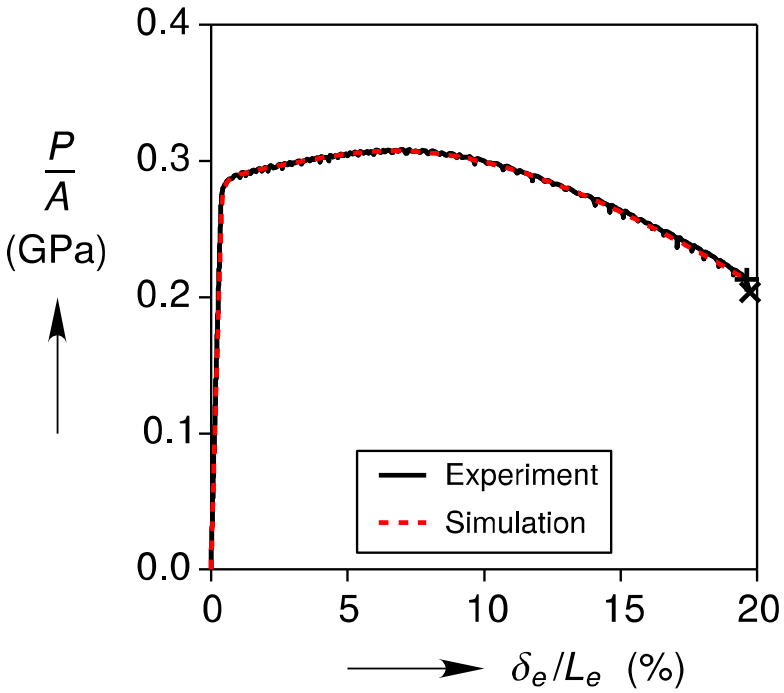

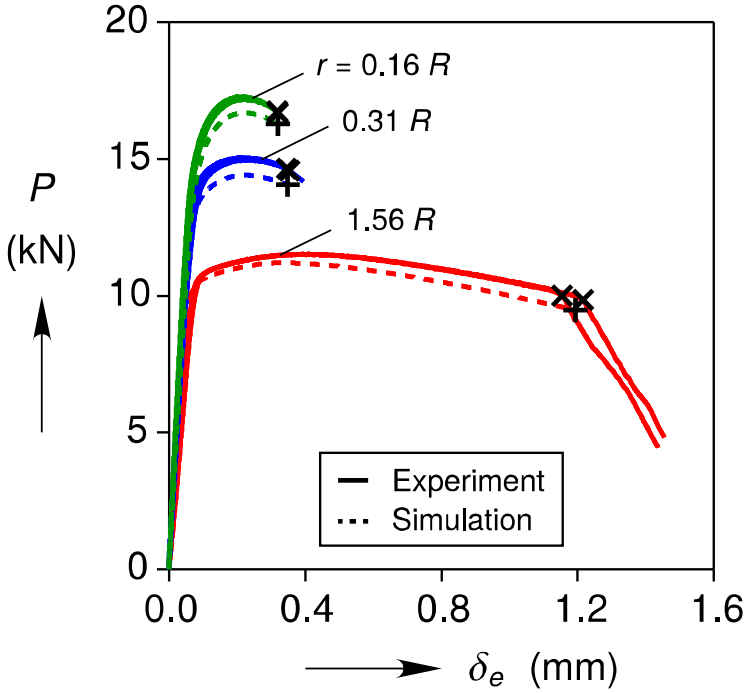

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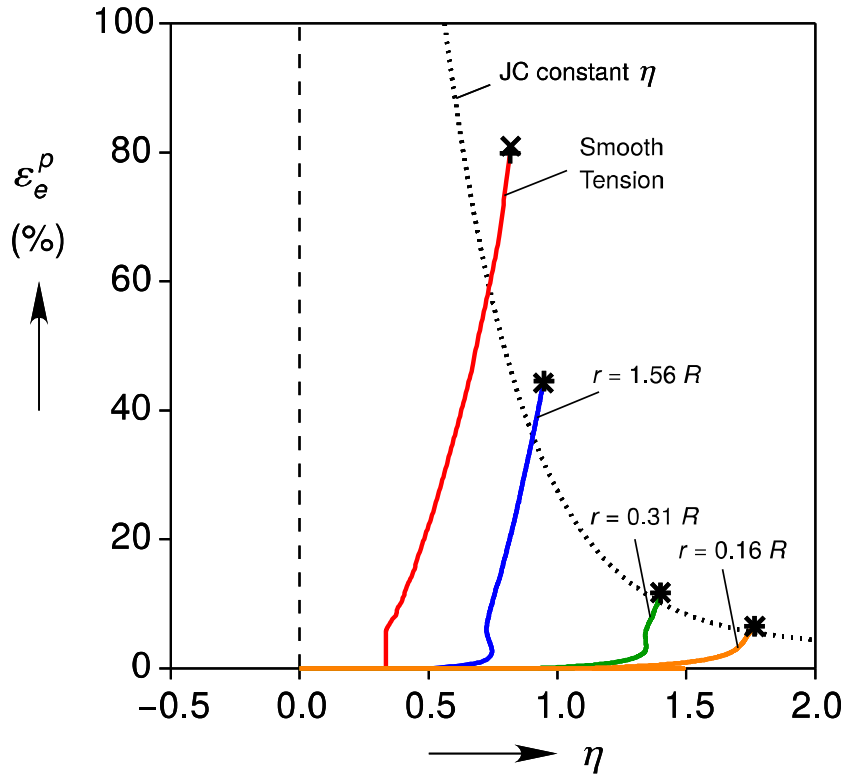
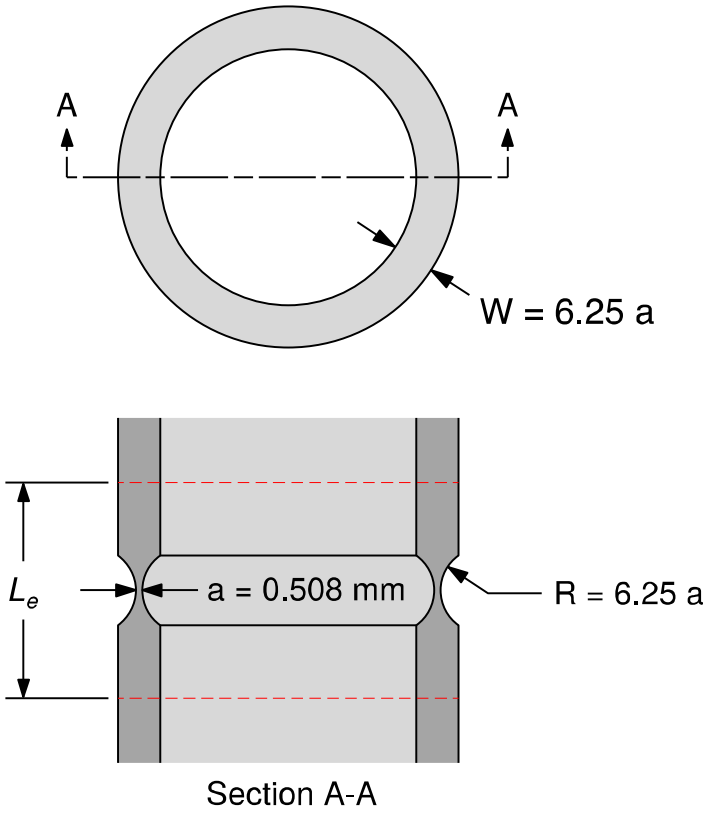
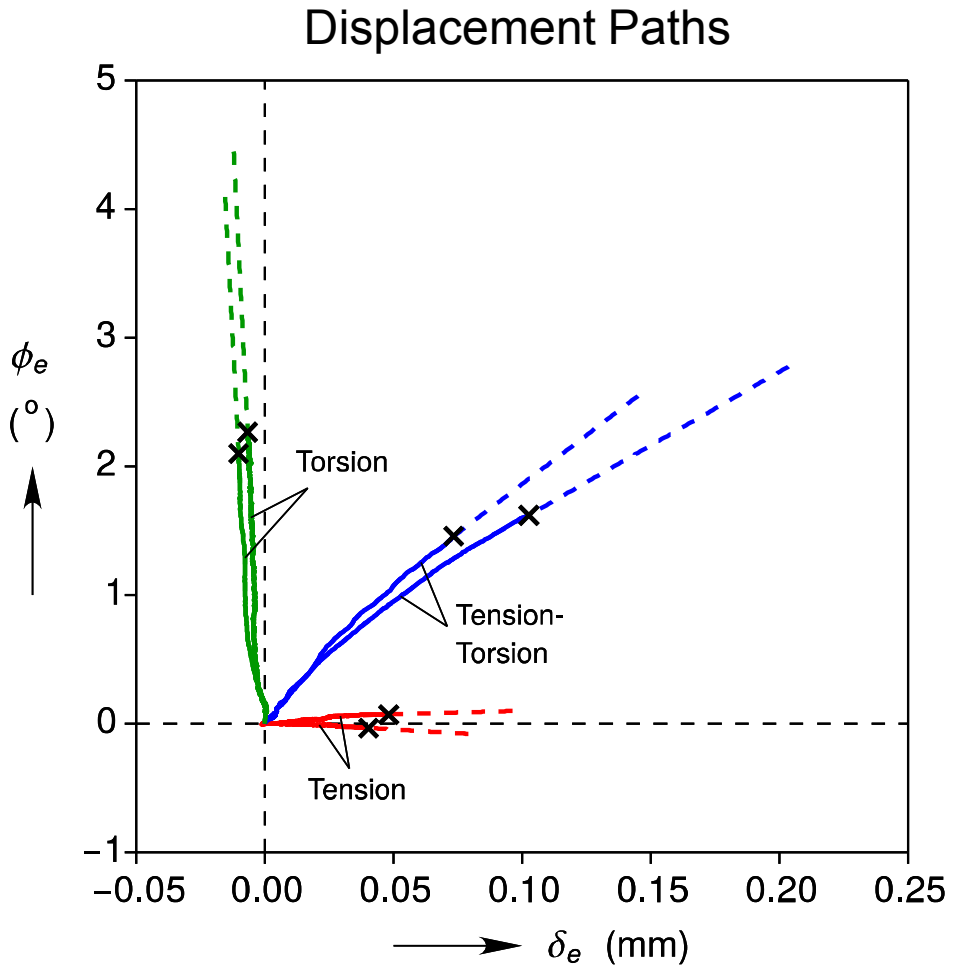
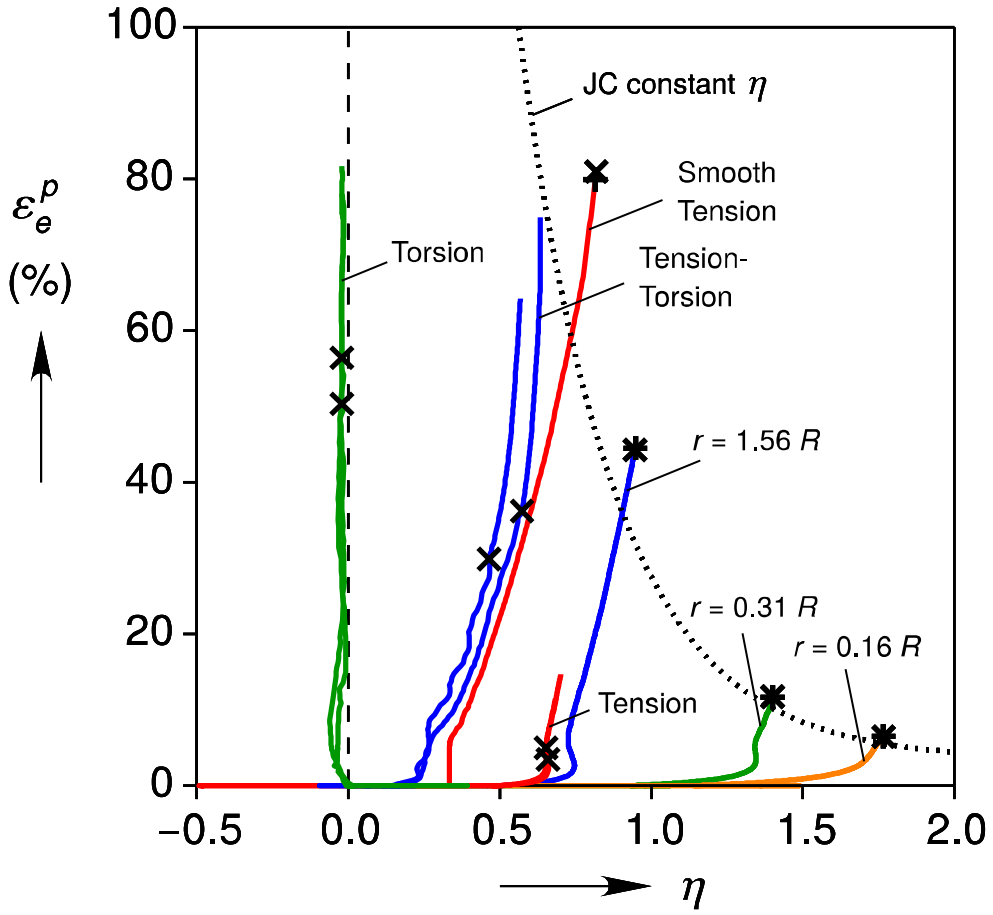


Axial Torsion Validation

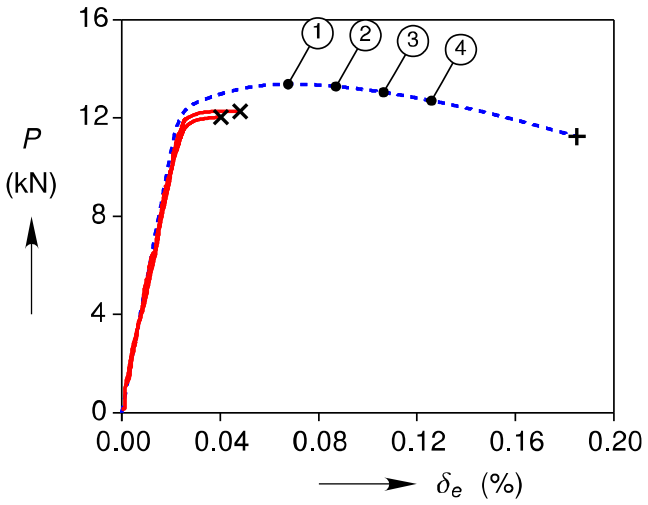




Axial Torsion Failure Validation



Mesh Sensitivity



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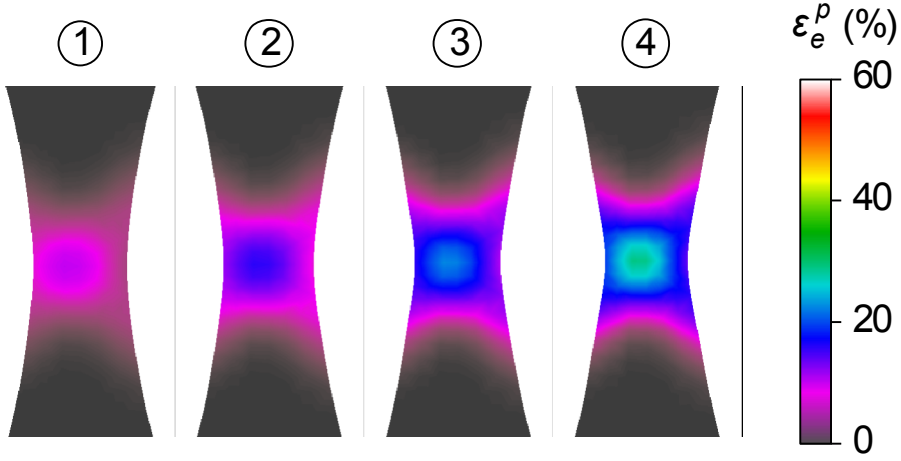

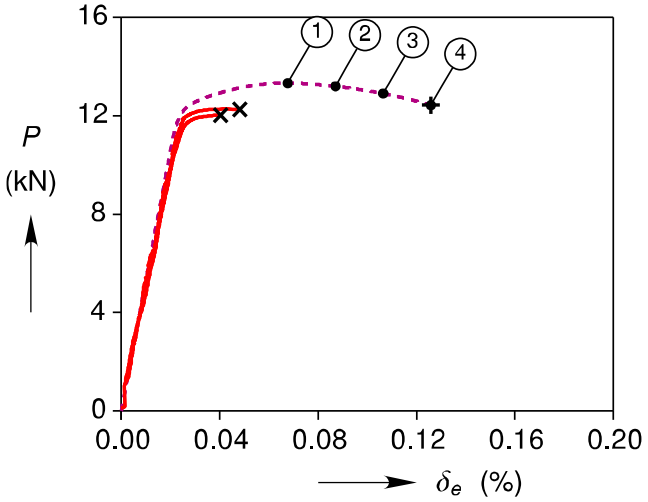

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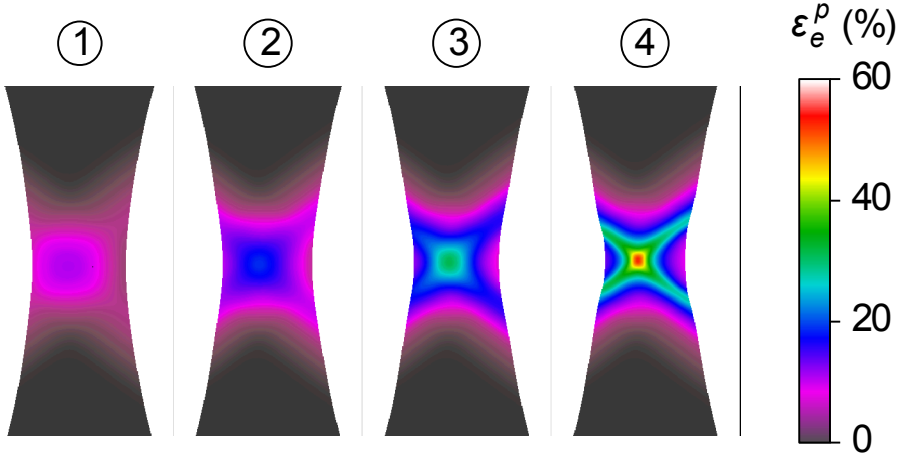
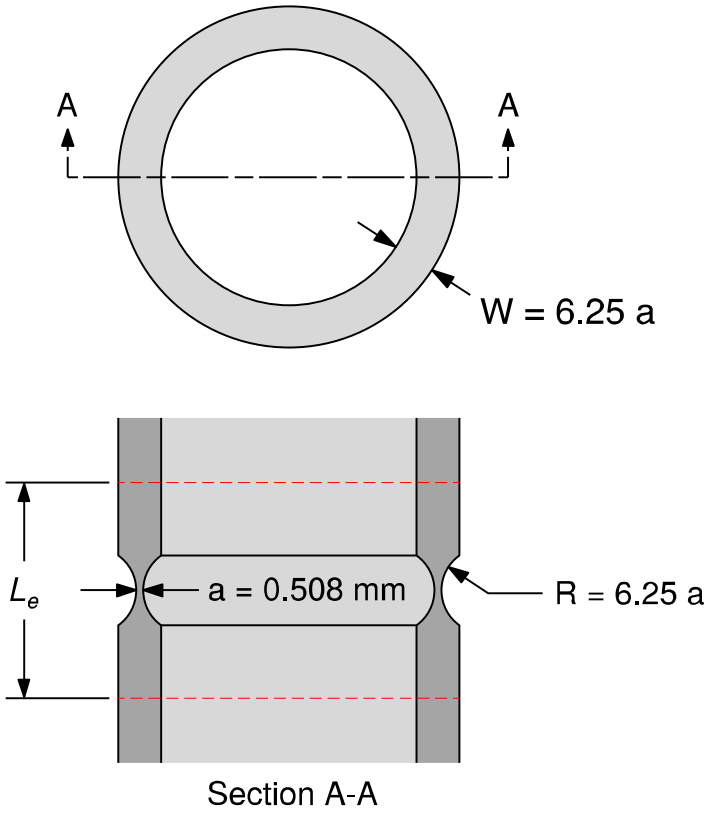
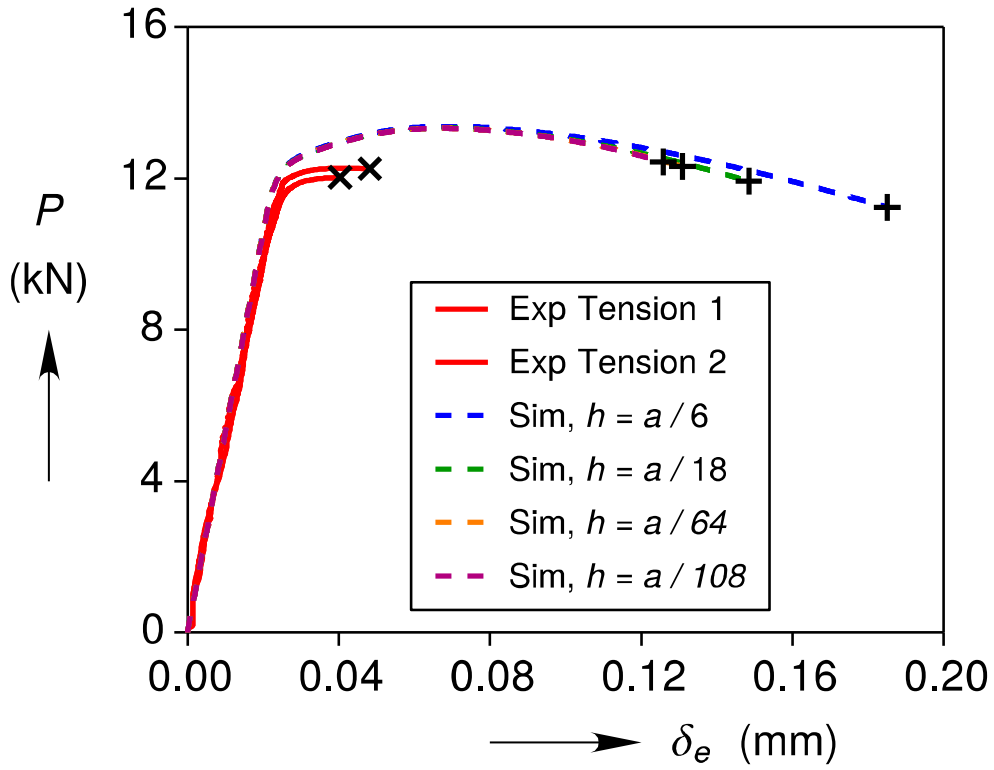
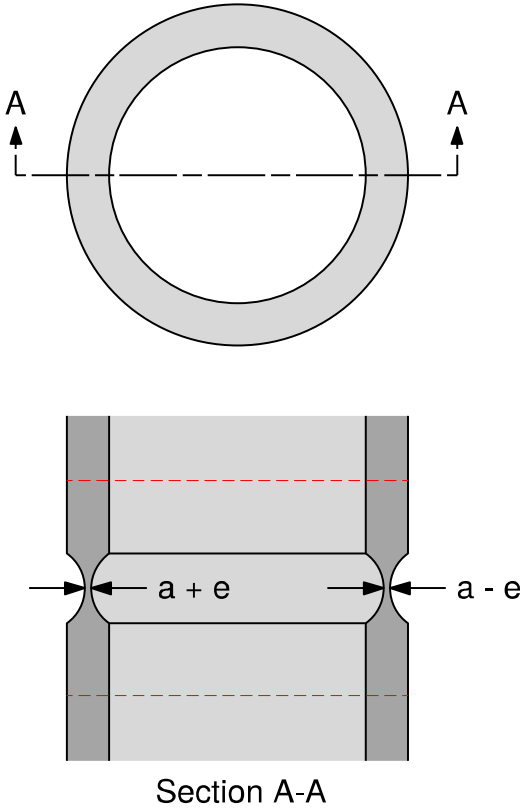


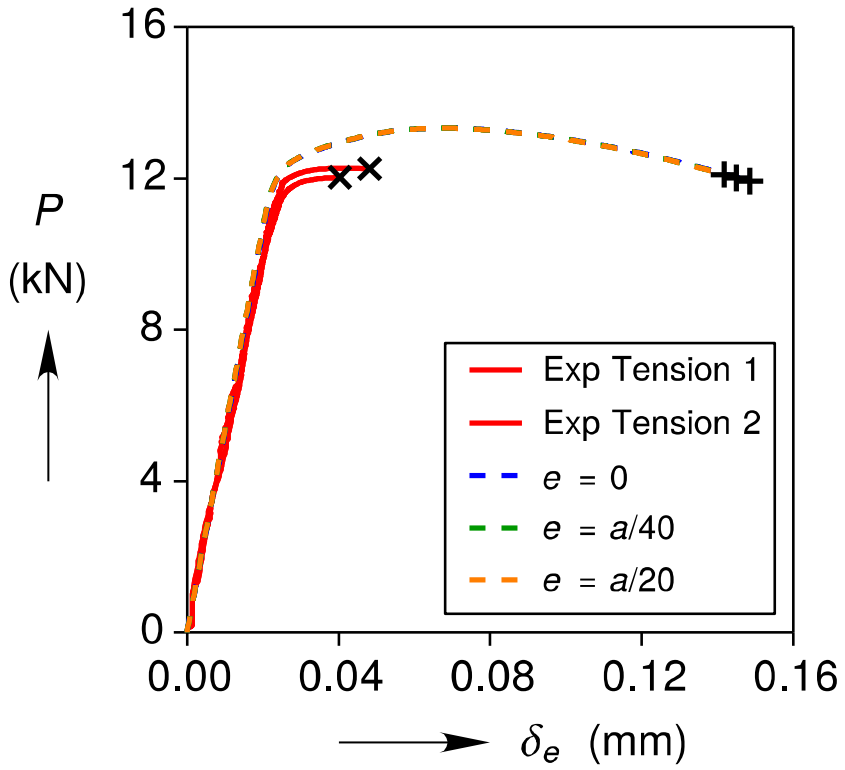
Mesh Sensitivity





Defect Sensitivity: Eccentric ID Notch

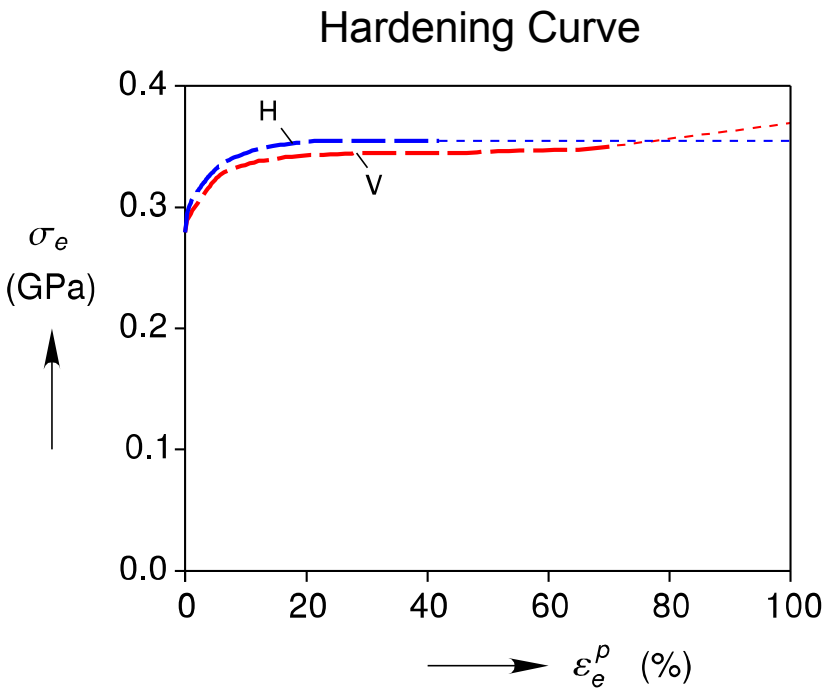


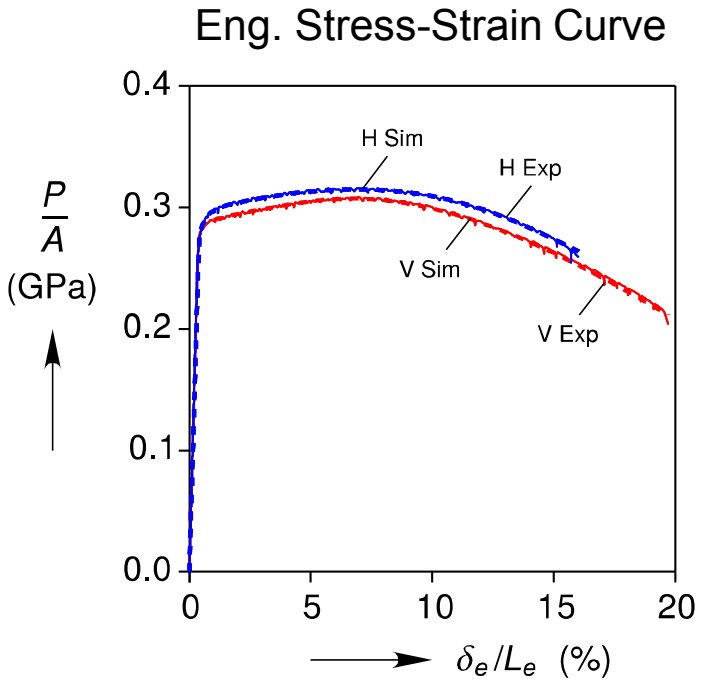


Summary

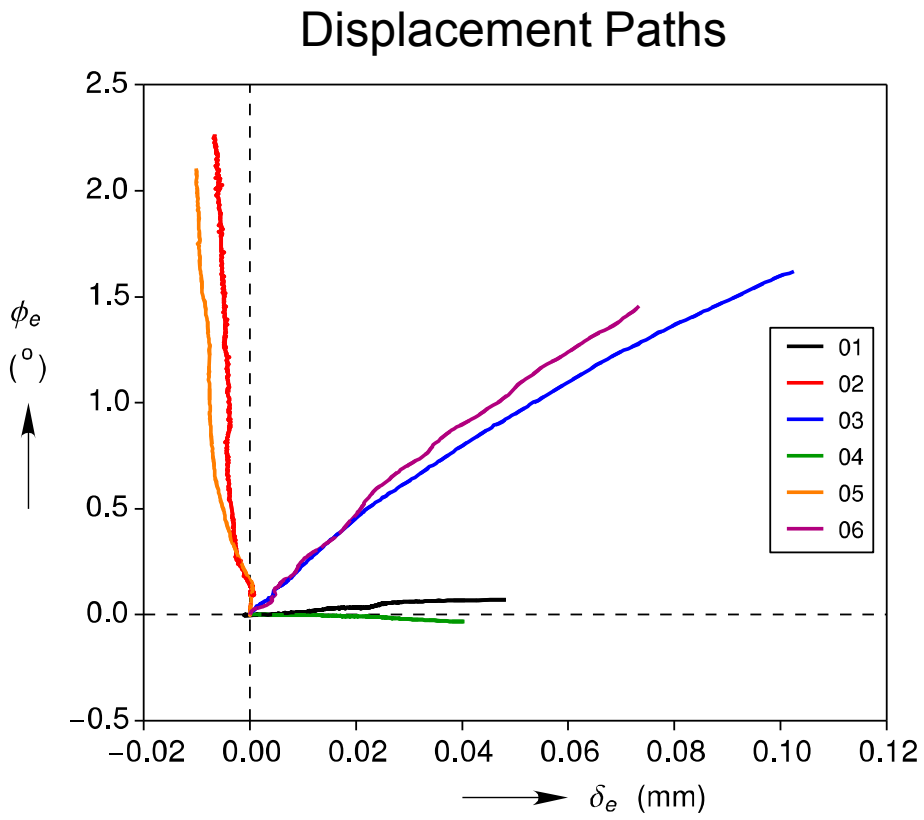
- Conclusions
  - The Johnson-Cook failure model may be unable capture the experimental observations
- Future Work
  - Investigate the poor failure predictions for the thin walled tube experiments
    - Continue to examine highly localized necking
    - Consider failure models with Lode angle dependence and/or anisotropic failure
  - Calibrate the modified Gurson model and, if possible, compare it to validation experiments.

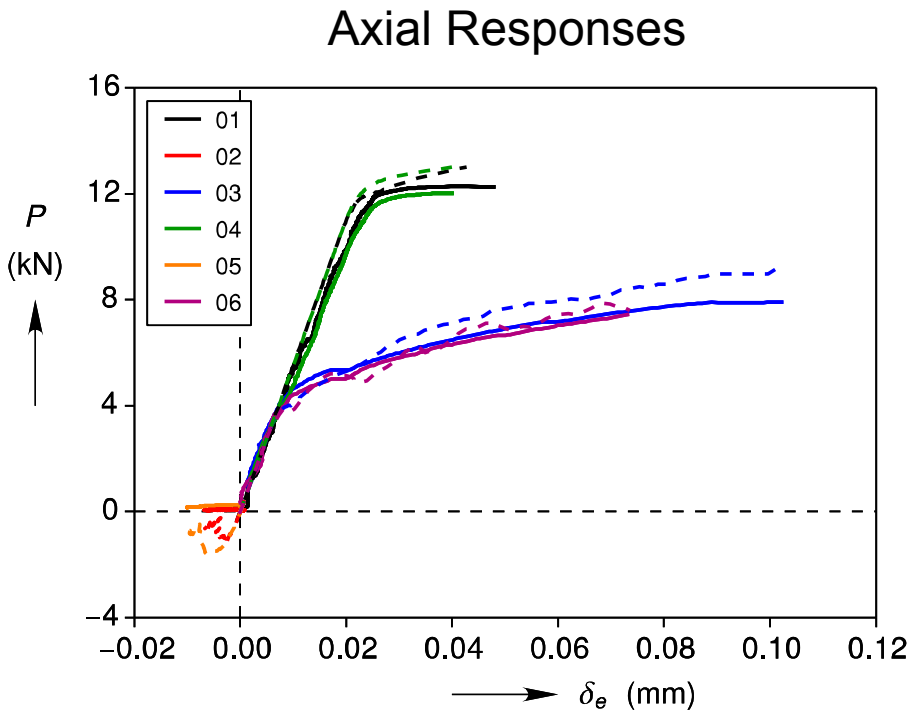
Hardening Curve Calibration





Axial Torsion Plasticity Validation





Axial Torsion Plasticity Validation

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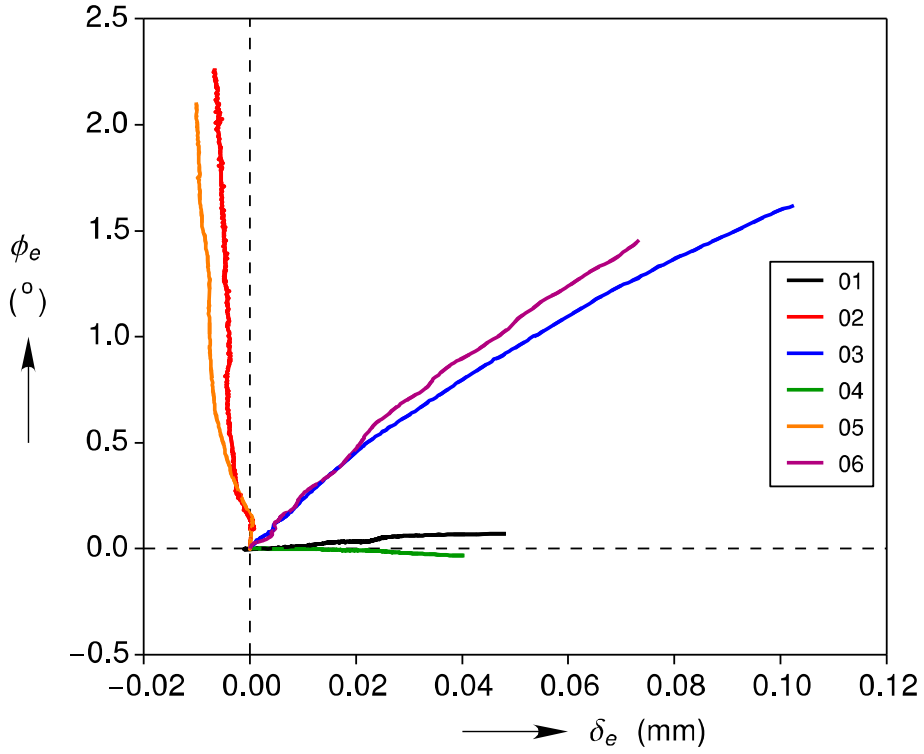
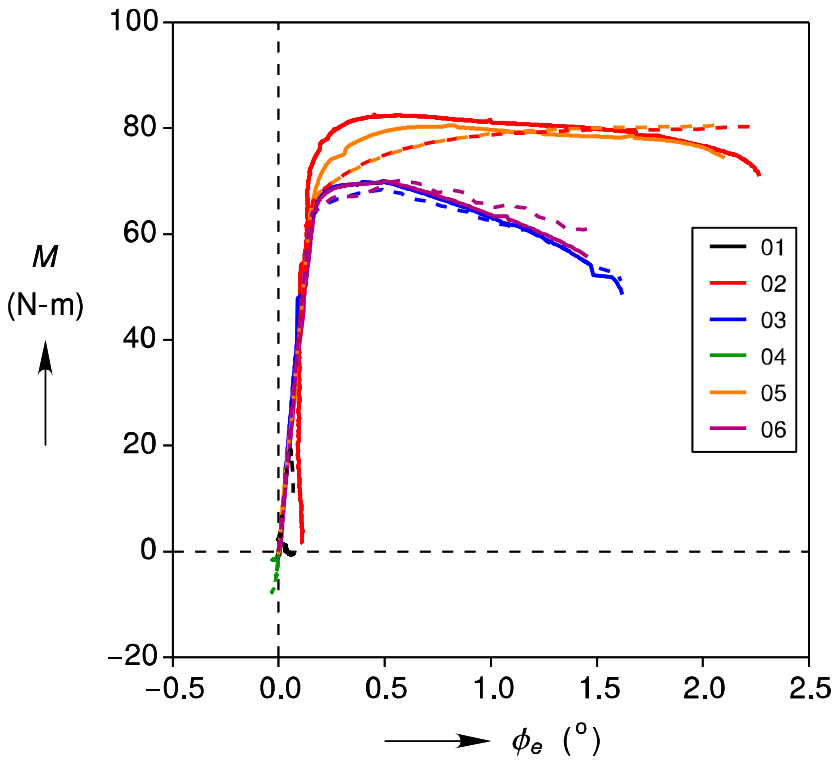
Displacement Paths



Torsion Responses



Notched Tube SEM Images

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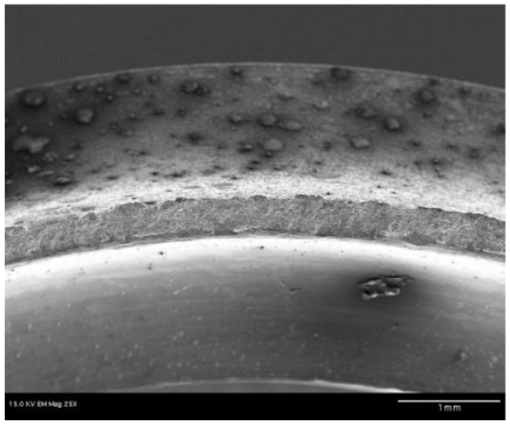
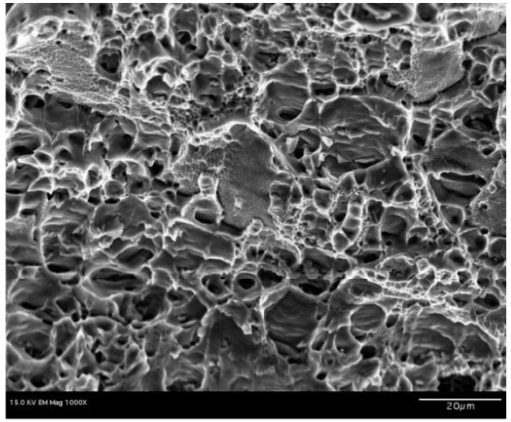
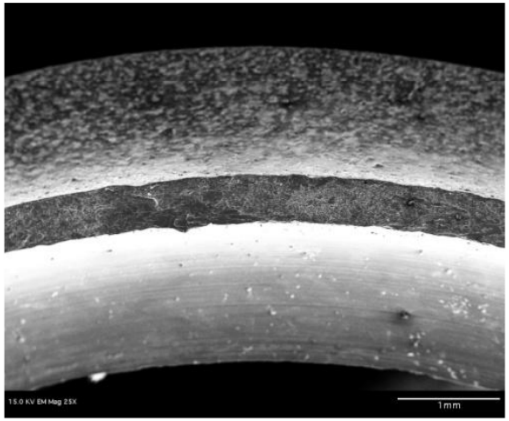
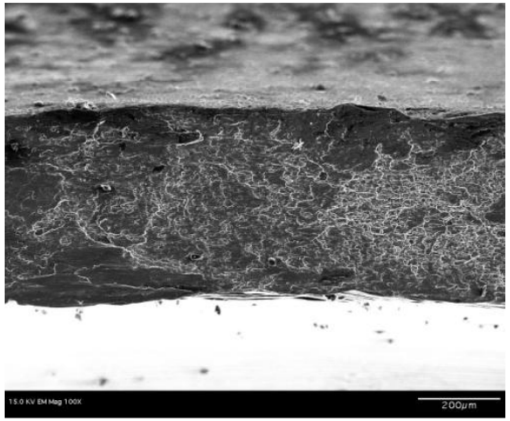
Tension

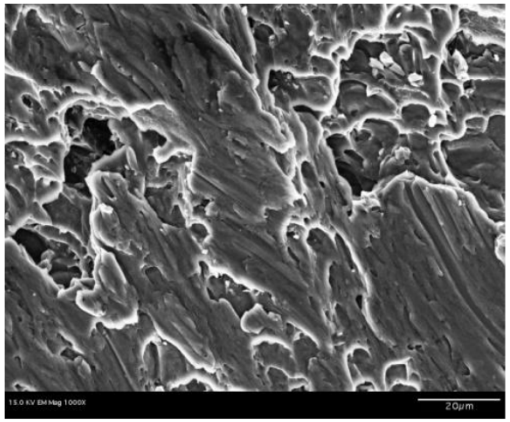




Torsion

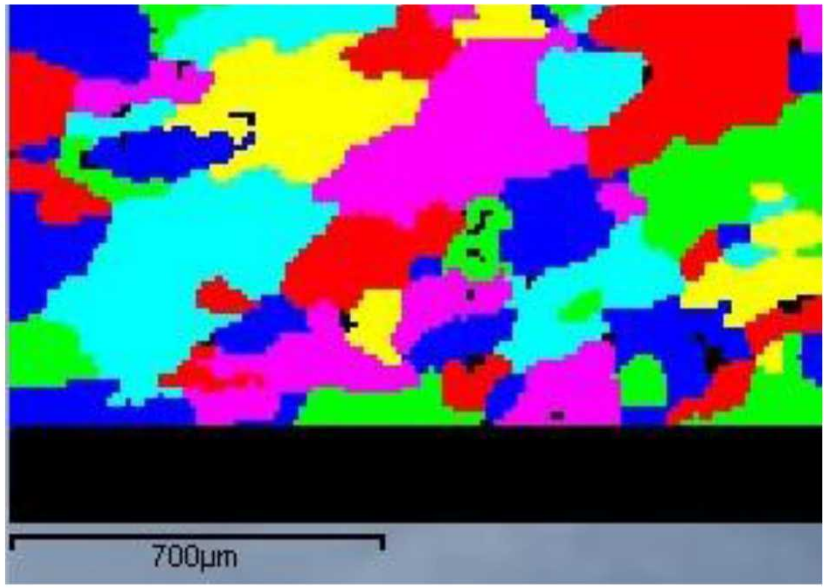






Grain Size

EBSD Results



Tube Wall