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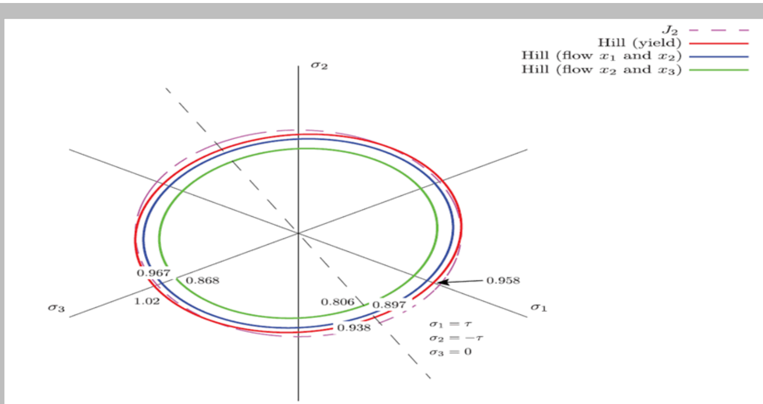

Experimentally Determined Anisotropic Yield Surfaces for Al 7079

Scott Smith - 01554 – Solid Mechanics/Eliot Fang/Edmundo Corona

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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An Introductory Thank You

Many people are directly and indirectly apart of, and invested in, this project. As an intern, I am deeply honored to have been given such substantive work with such little incoming knowledge. Thank you all for your patience, grace, and continual encouragement.

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Jim Redmond & Cassie Miller

01554

Edmundo Corona

Sharlotte Kramer, Bill Scherzinger

Ben Reedlunn, Brian Lester, Judy Brown, Eliot Fang

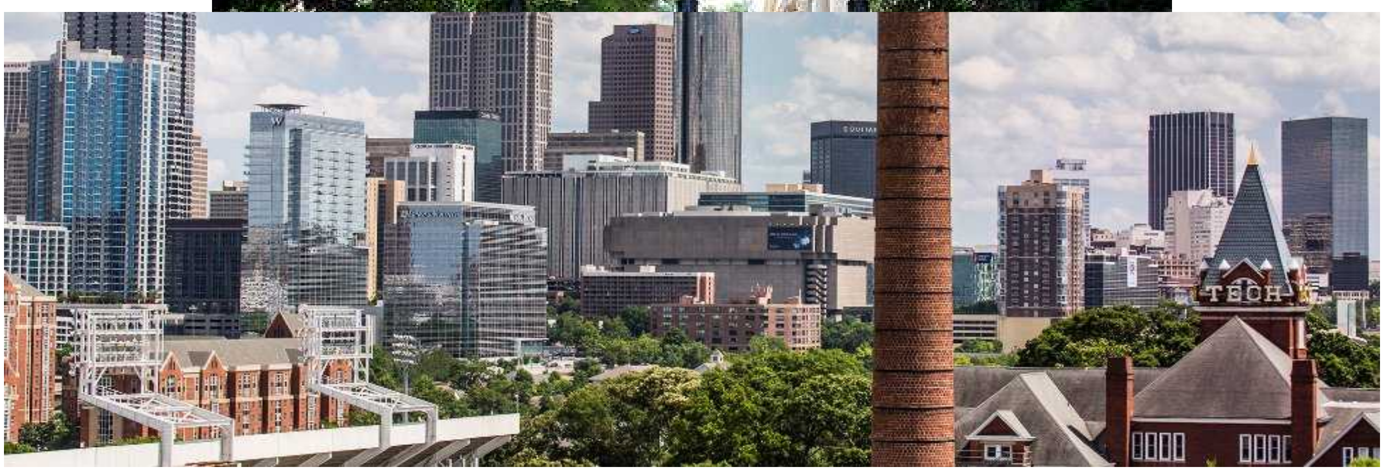
880/B30E

Ashley Saltzman, Sarah Bonk

Joe Lucier, Shivam Barwey, Ian de Vlaming

My Background

- Born and raised in the great peach state
- Matriculated at the University of Georgia
  - B.S. Civil Engineering – Structural Emphasis
  - Thesis: "A cr ... ɪns and energy reduction in
- Attending t ... the Fall
  - Degree In ... Mechanics
  - Advisor: D ... Dean

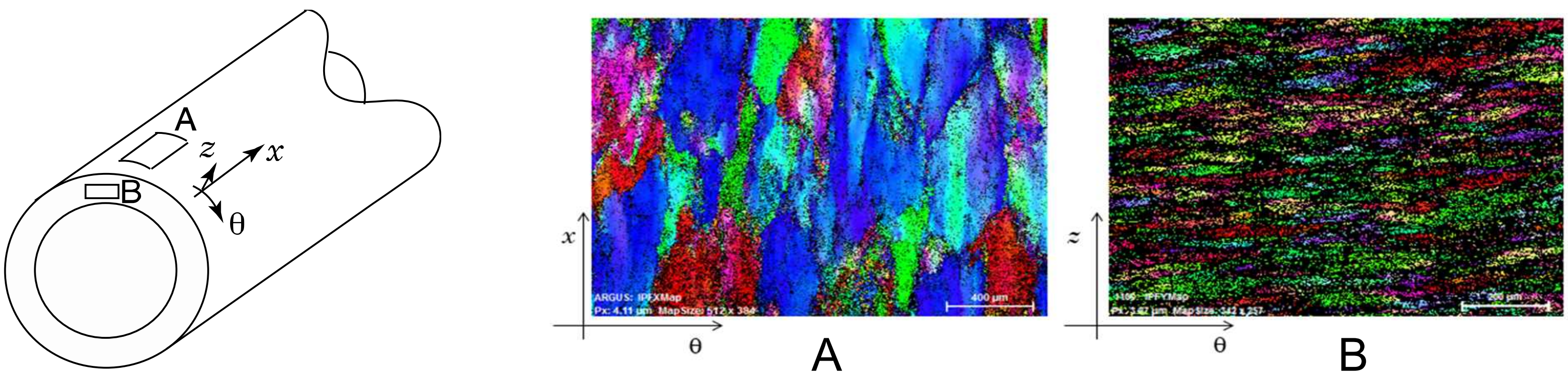


Presentation Outline

- Project Background, Challenges, and High-Level Goal(s)
- Specimen Design and Orientations
- Experimental Set-Up
- Analysis Methods Comparison
- Analysis Findings
- Fitting von Mises and Hill Yield Surfaces
- Solving for the Hill Parameters
- Iso- and Aniso-tropic Yield Surface Fits
- Need for the Barlat Model
- Conclusions and Future Work

Project Background and Challenges

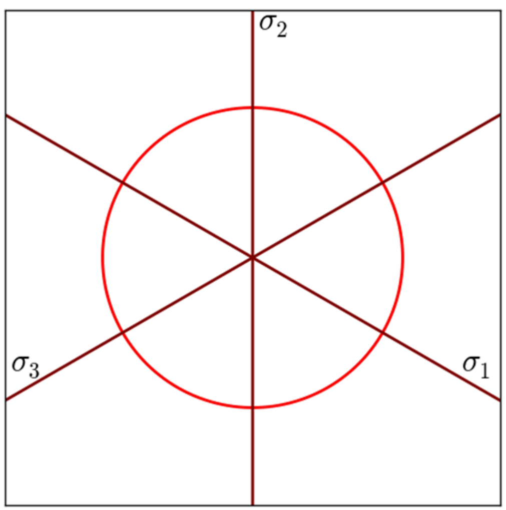
- Manufacturing practices of common metals can influence the microstructure of the material and its continuum level performance.
  - When Al 7079 is cylindrically extruded, it’s texture will likely yield anisotropic properties.



- This warrants the need to profoundly understand the metal’s mechanical properties in order to provide high levels of surety in design.

High-Level Goal(s)

- The Goal:
  - Experimentally establish a yield surface that captures the anisotropic properties of Al 7079.
    - This will aid in more accurate findings from solid mechanics simulations.
- What is a yield surface?
  - A hypersurface in stress space that encloses the elastic regime of a material.



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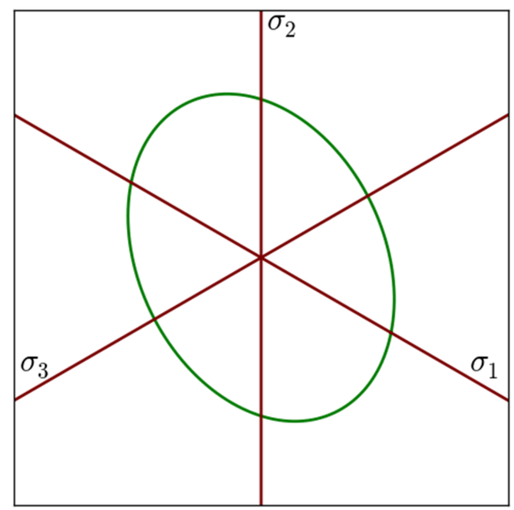

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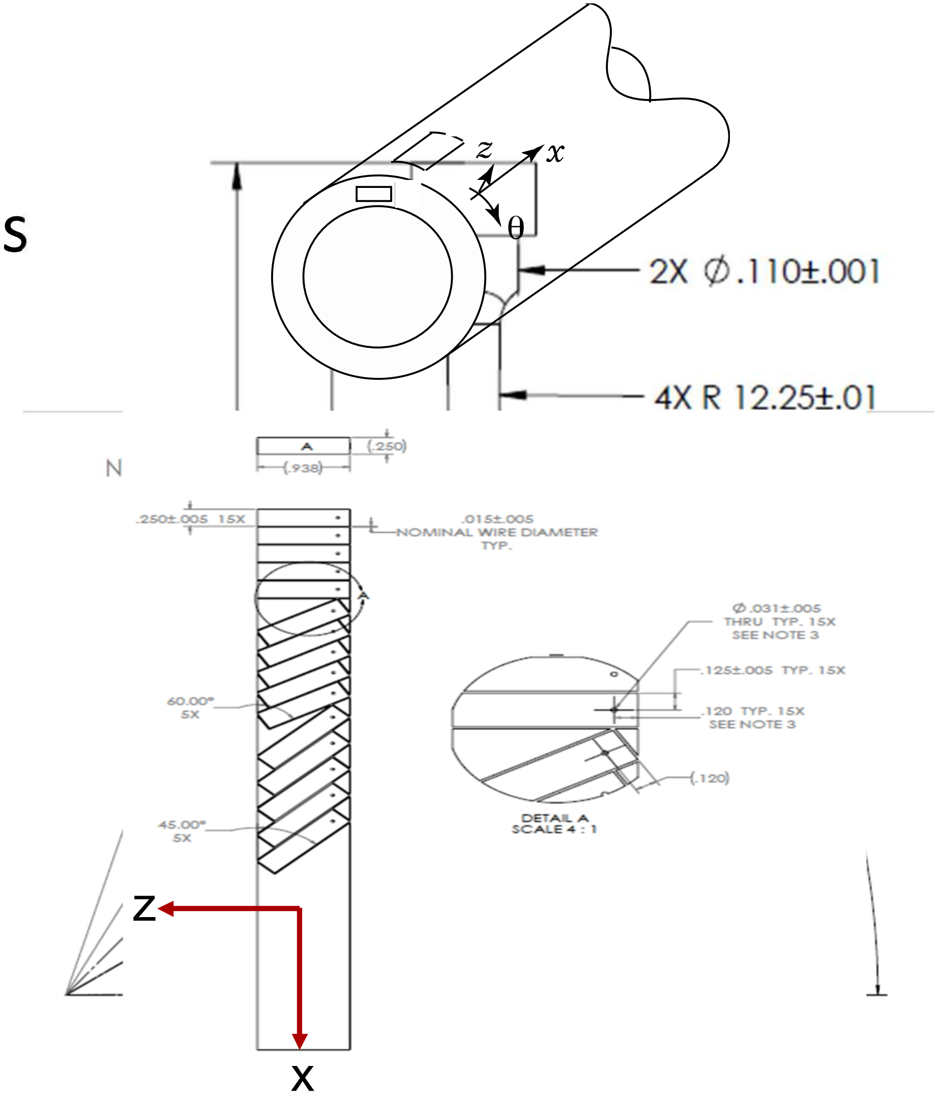
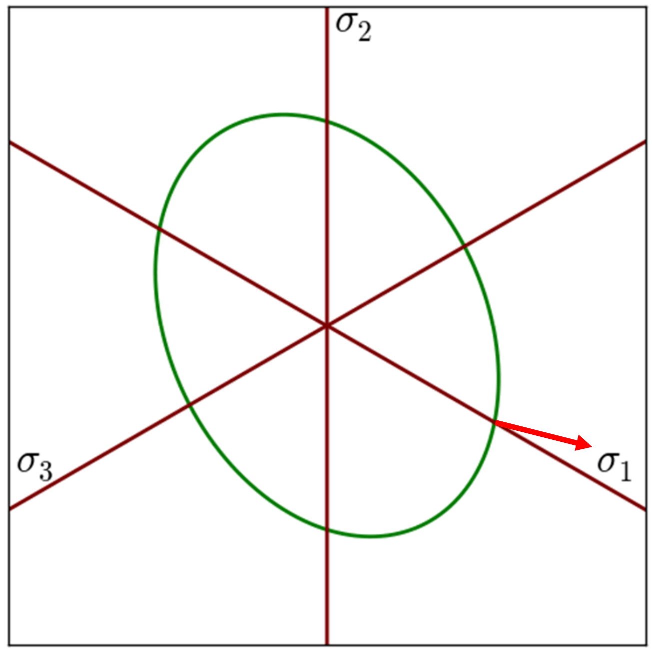
Specimen Design and Orientations

- Specimen Design
  - Dog Bone
- Specimen Orientations
  - A
    - A-0, -30, -45
  - B
  - C
  - P (Large Specimen)
    - P-0, -45, -90

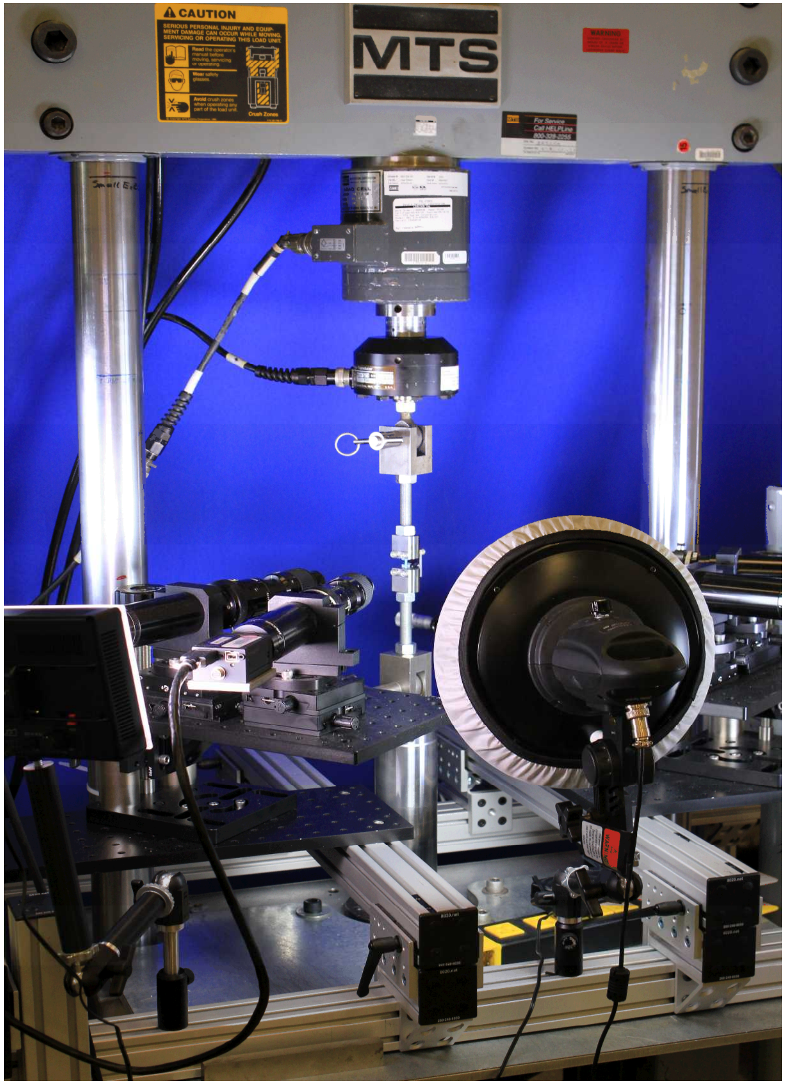


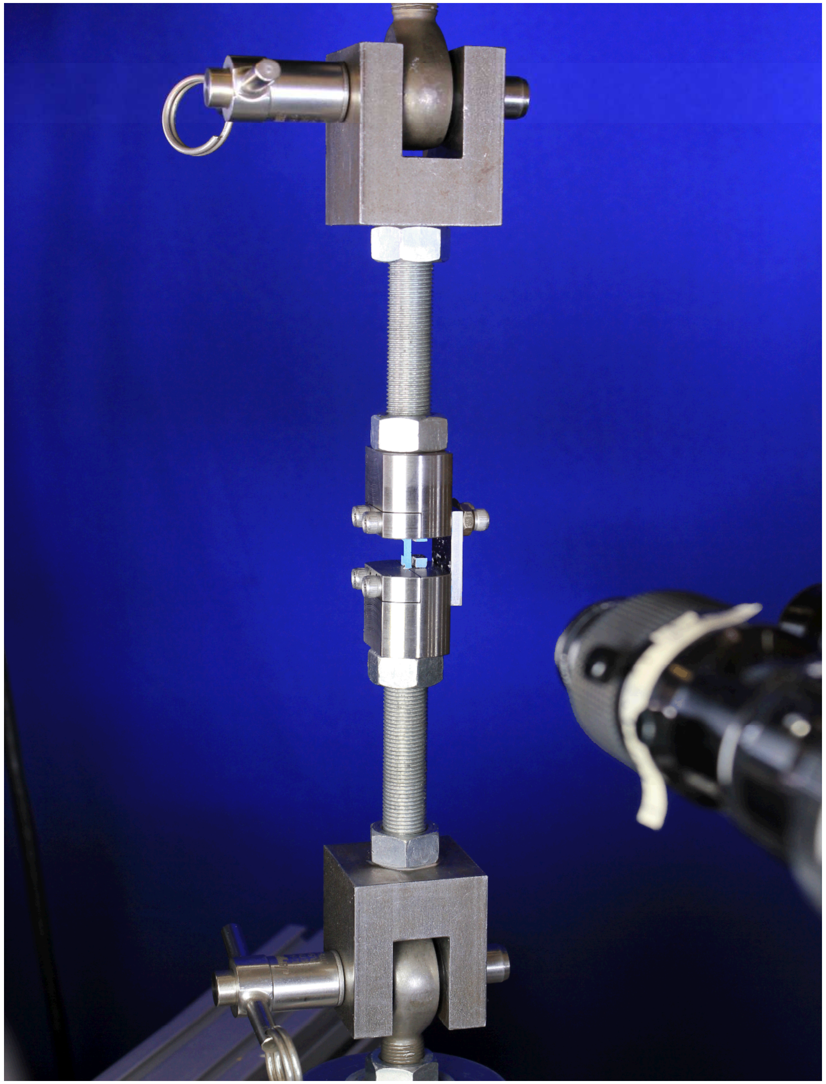
Experimental Set-Up

- Two essential values: Yield stresses and Lankford Ratios.
- P specin … xial tension with ort…
- A, B, an… nder tension, but utili… rrelation (DIC) ste…
  - What … technique.
  - Why I… ditional strain gauge…
  - Show…



Experimental Set-Up

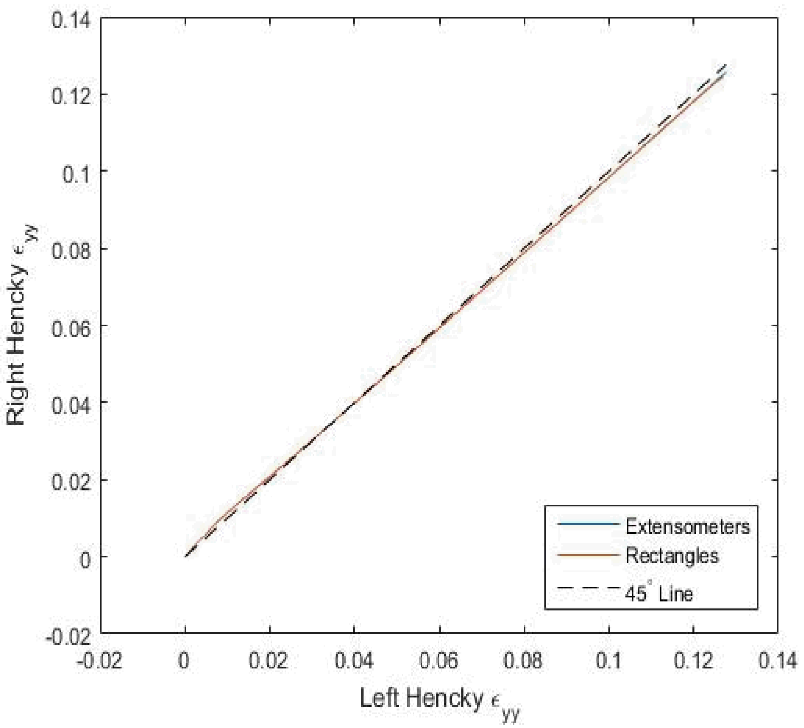


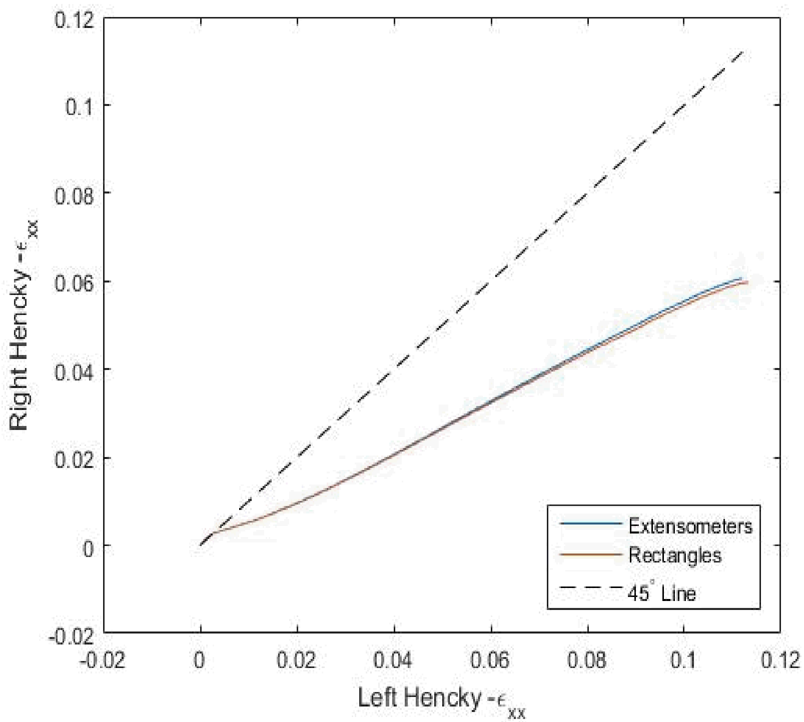


Analysis Methods Comparison

Two different analysis methods (Rectangles and Extensometers) were compared for precision by strain plots.

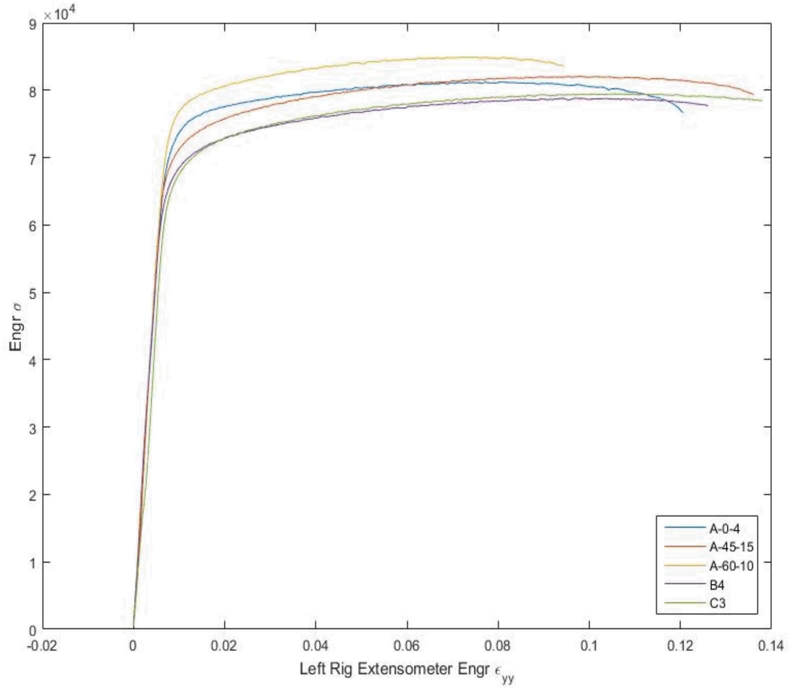
Specimen: A-45-15

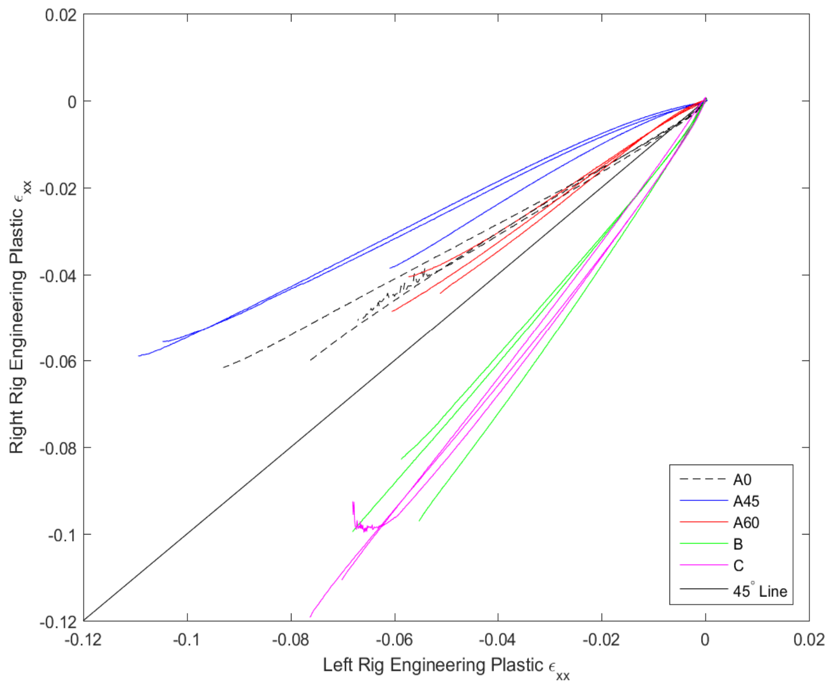




Analysis Method Findings

Determination of Stress-Strain curves and Lankford Ratios.





Fitting the von Mises and Hill Yield Equations

- von Mises (J_2)
  - Experimental Needs: 1 uniaxial test

$$\sigma_0^2 = \frac{1}{2}[(\sigma_{11} - \sigma_{22})^2 + (\sigma_{22} - \sigma_{33})^2 + (\sigma_{33} - \sigma_{11})^2 + 6(\sigma_{12}^2 + \sigma_{23}^2 + \sigma_{31}^2)] = 3J_2$$

- Hill Equations
  - Experimental Needs: 6 uniaxial tests
    - 3 tests along the material coordinate directions
    - 3 tests at 45^0 between each coordinate direction
  - Hill introduces (F,G,H,L,M,N) parameters to capture anisotropy.

$$\varphi = \sigma_0 - \sigma_y$$

$$\varphi(\boldsymbol{\sigma})^2 = F(\hat{\sigma}_{22} - \hat{\sigma}_{33})^2 + \mathrm{G}(\hat{\sigma}_{33} - \hat{\sigma}_{11})^2 + \mathrm{H}(\hat{\sigma}_{11} - \hat{\sigma}_{22})^2 + 2L\hat{\sigma}_{23}^2 + 2M\hat{\sigma}_{31}^2 + 2N\hat{\sigma}_{12}^2$$

Solving for the Hill Parameters

$$\varphi(\boldsymbol{\sigma})^2 = F(\hat{\sigma}_{22} - \hat{\sigma}_{33})^2 + G(\hat{\sigma}_{33} - \hat{\sigma}_{11})^2 + H(\hat{\sigma}_{11} - \hat{\sigma}_{22})^2 + 2L\hat{\sigma}_{23}^2 + 2M\hat{\sigma}_{31}^2 + 2N\hat{\sigma}_{12}^2$$

- Yield Stresses
  - Solved directly using the 6 load orientations.
- Lankford Ratios $\left({\dot{\varepsilon}_{33}^{p}}/{\dot{\varepsilon}_{22}^{p}}\right)$
  - Two approaches:
    - Assume uniaxial tension and the Lankford Ratio in the same direction .
      - $1 = \sigma_{0x}^2(G + H)$
    - Assume uniaxial tension and the two Lankford Ratios in the opposite coordinate directions.

- Final Equations:

$$F = \frac{1}{2}\left[\sigma_{0y}^{-2} + \sigma_{0z}^{-2} - \sigma_{0x}^{-2}\right]$$

$$\frac{\dot{\varepsilon}_{22}^{p}}{\dot{\varepsilon}_{33}^{p}} = \frac{H}{G}$$

$$G = \frac{1}{2}\left[\sigma_{0z}^{-2} + \sigma_{0x}^{-2} - \sigma_{0y}^{-2}\right]$$

$$\frac{\dot{\varepsilon}_{33}^{p}}{\dot{\varepsilon}_{11}^{p}} = \frac{F}{H}$$

$$H = \frac{1}{2}\left[\sigma_{0x}^{-2} + \sigma_{0y}^{-2} - \sigma_{0z}^{-2}\right]$$

$$\frac{\dot{\varepsilon}_{11}^{p}}{\dot{\varepsilon}_{22}^{p}} = \frac{G}{F}$$

$$L = \frac{1}{2}\left[4\sigma_{0yz}^{-2} - \sigma_{0x}^{-2}\right]$$

$$\frac{\dot{\varepsilon}_{45^0 23}^{p}}{\dot{\varepsilon}_{11}^{p}} = \frac{L}{H + G} - \frac{1}{2}$$

$$M = \frac{1}{2}\left[4\sigma_{0xz}^{-2} - \sigma_{0y}^{-2}\right]$$

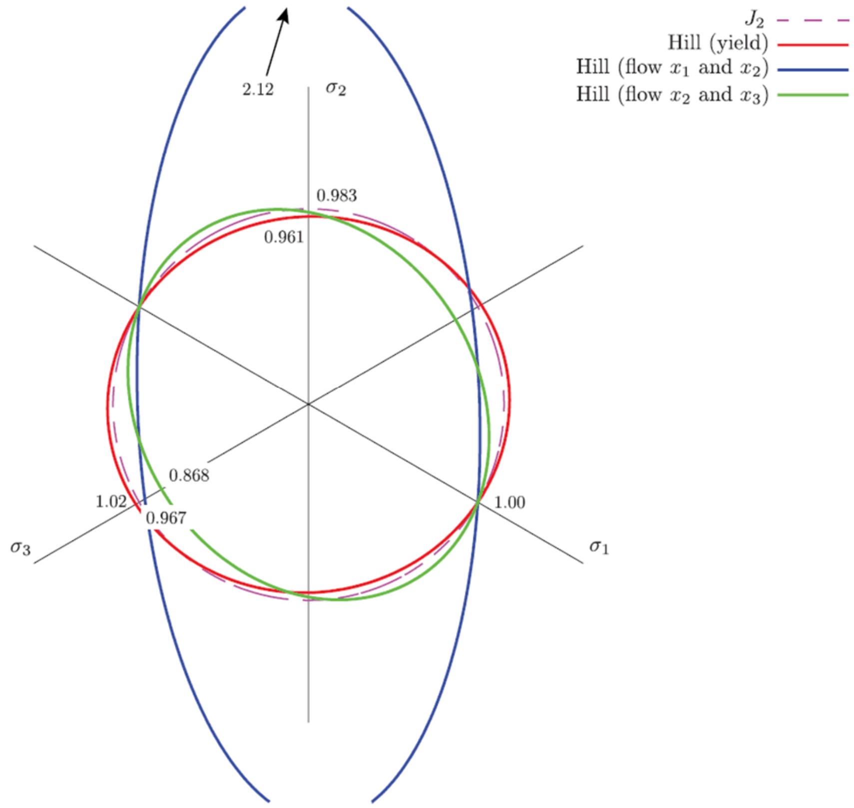
$$\frac{\dot{\varepsilon}_{45^0 13}^{p}}{\dot{\varepsilon}_{22}^{p}} = \frac{M}{F + H} - \frac{1}{2}$$

$$N = \frac{1}{2}\left[4\sigma_{0xy}^{-2} - \sigma_{0z}^{-2}\right]$$

$$\frac{\dot{\varepsilon}_{45^0 12}^{p}}{\dot{\varepsilon}_{33}^{p}} = \frac{N}{G + F} - \frac{1}{2}$$

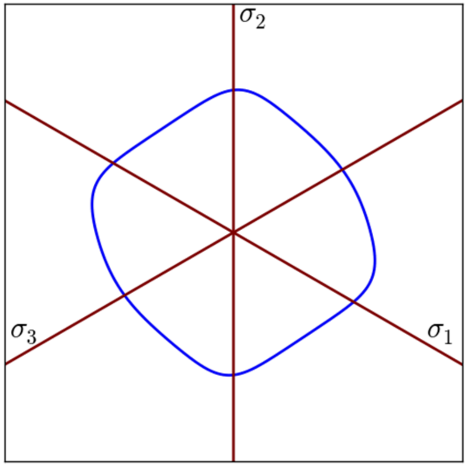
Iso- and Aniso-tropic Yield Surface

- Yield Stresses and Lankford Ratios



Need for the Barlat Model

- The previous plots display that neither von Mises or Hill yield surfaces consistently represent the anisotropic nature of Al 7079.
  - The surfaces are highly dependent upon how the equations are solved.
- The Barlat model, Yld2004-18p, has 20 parameters that has the potential to generate a more appropriate yield surface.
  - This will require some work…



Conclusions and Future Work

- Al 7079 has isotropic and anisotropic forms – the difference is derived from the manufacturing methods.
  - An Al 7079 that is annealed ≠ An Al 7079 that is cylindrically extruded.
- Developing yield surfaces that capture anisotropic behavior is experimentally expensive.
  - Moving from von Mises to Hill requires 6x the number of tests.
- All models and yield surfaces are limited in some way
  - This is why calibration is so essential.
- Future Work
  - The Barlat model has the ability to better capture the anisotropic nature of the extruded Al 7079 due to the higher number of parameters and required error minimization.

Thank you for your time and attention!

Questions?