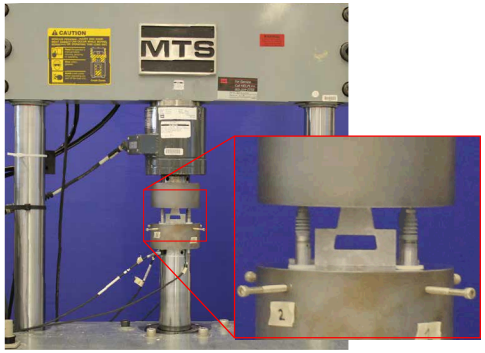
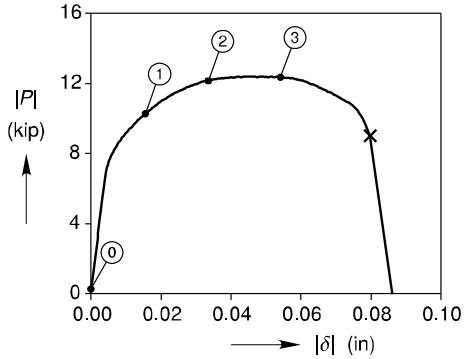
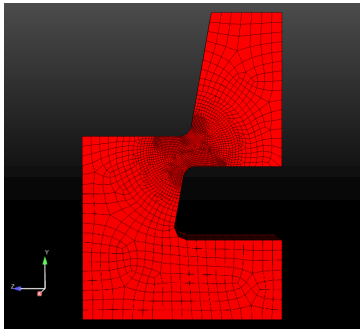
SAND2015-10068C

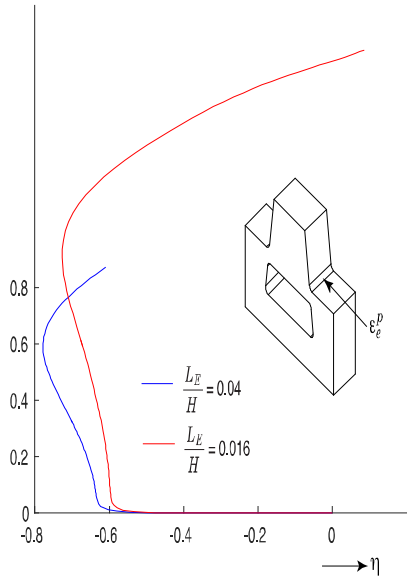
Exceptional service in the national interest

Sandia









A Re-Investigation of Ductile Tearing in the 2013 Sandia Fracture Challenge

E. Corona, B. Reedlunn, L. Deibler, M. Ingraham, S. Williams and W. Scherzinger

(Thanks to Jake Koester and Jim Cox)

U.S. DEPARTMENT OF ENERGY
National Nuclear Security Administration

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THE 2013 SANDIA FRACTURE CHALLENGE

Experimental Setup

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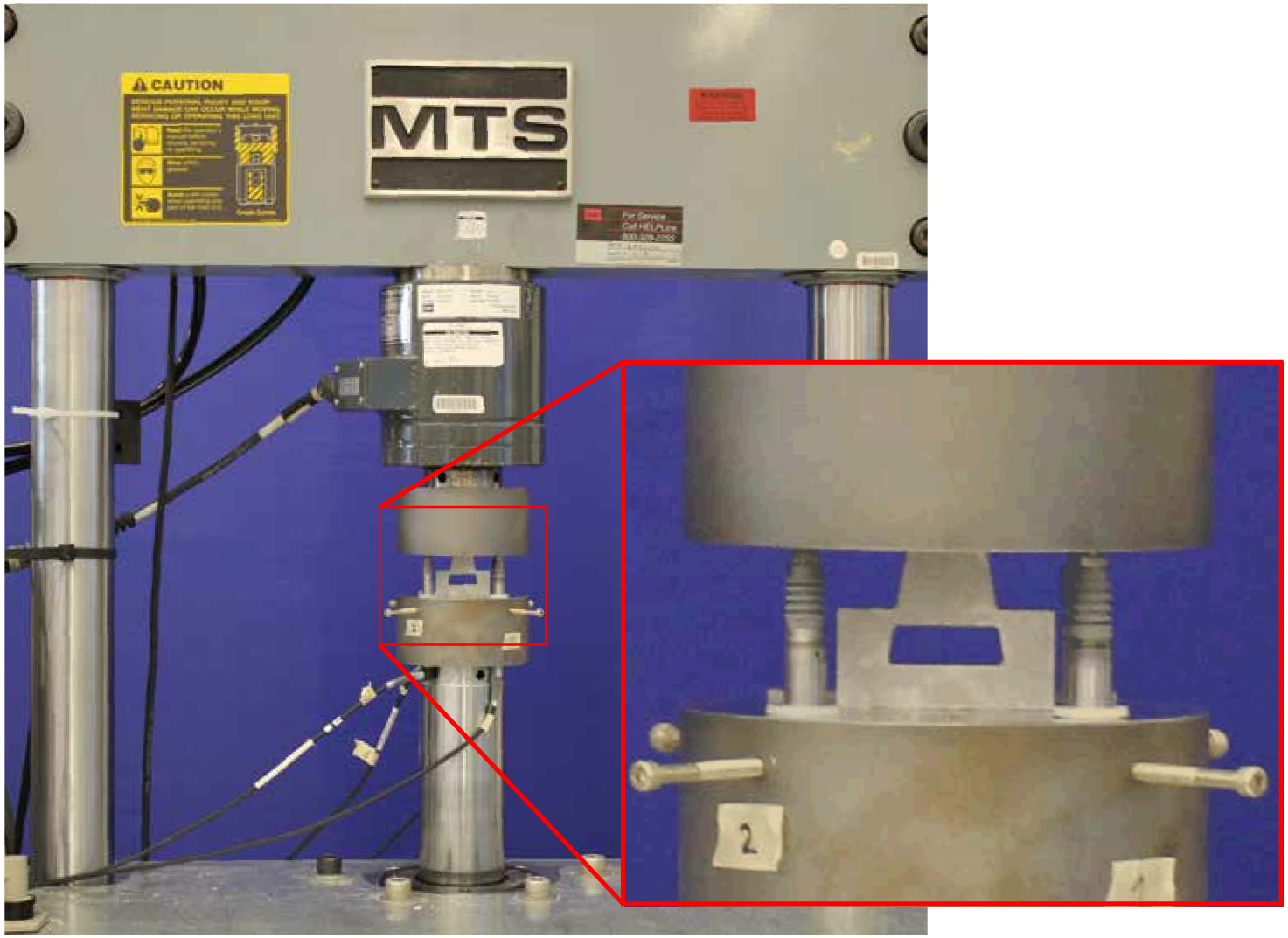
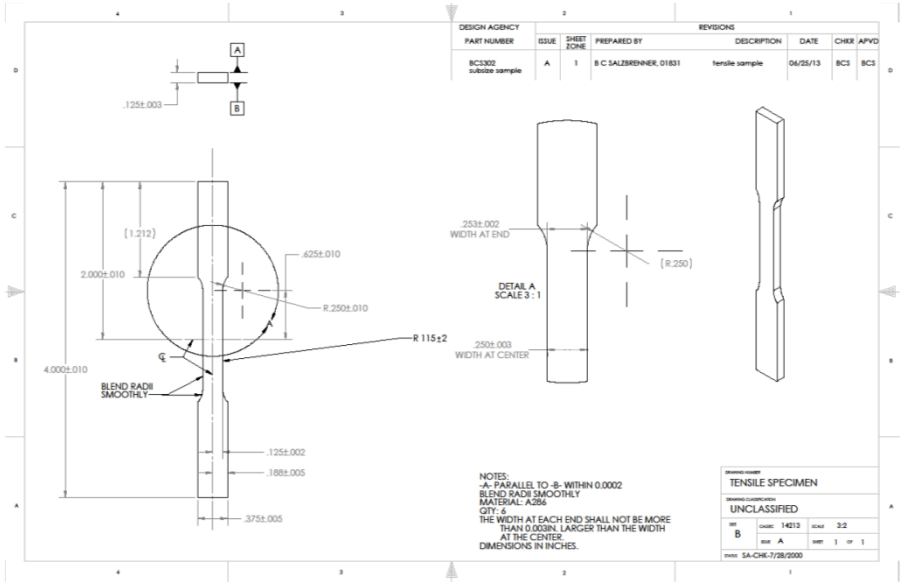
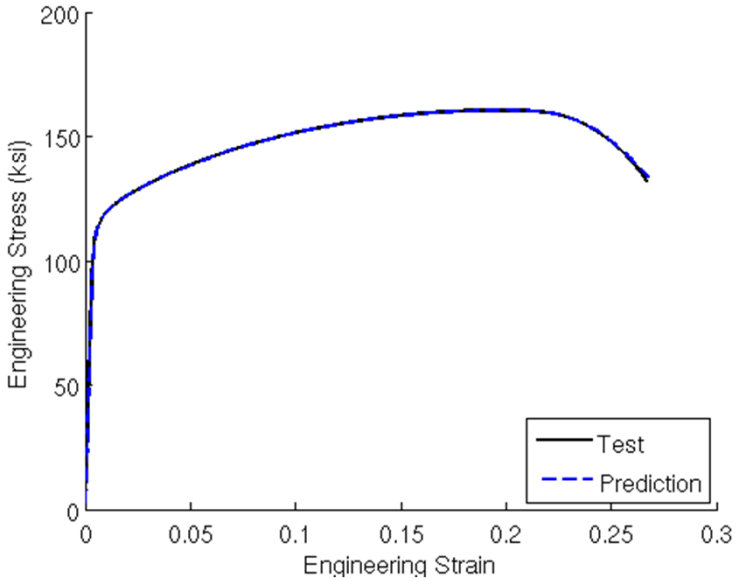
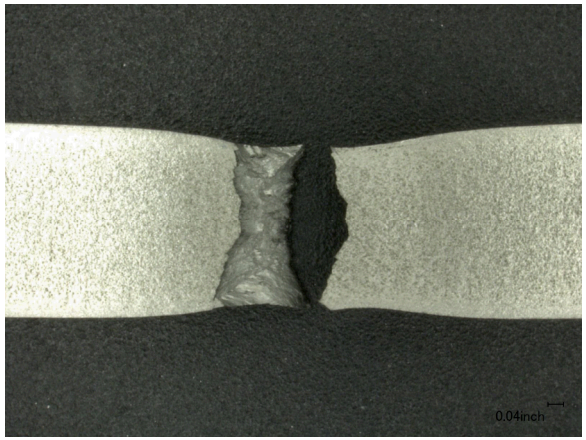
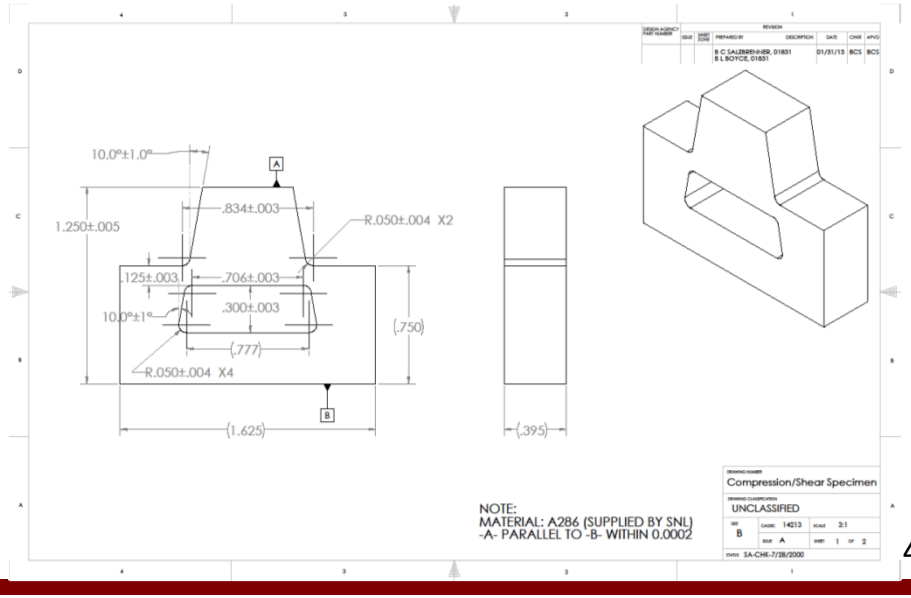


Materials Provided

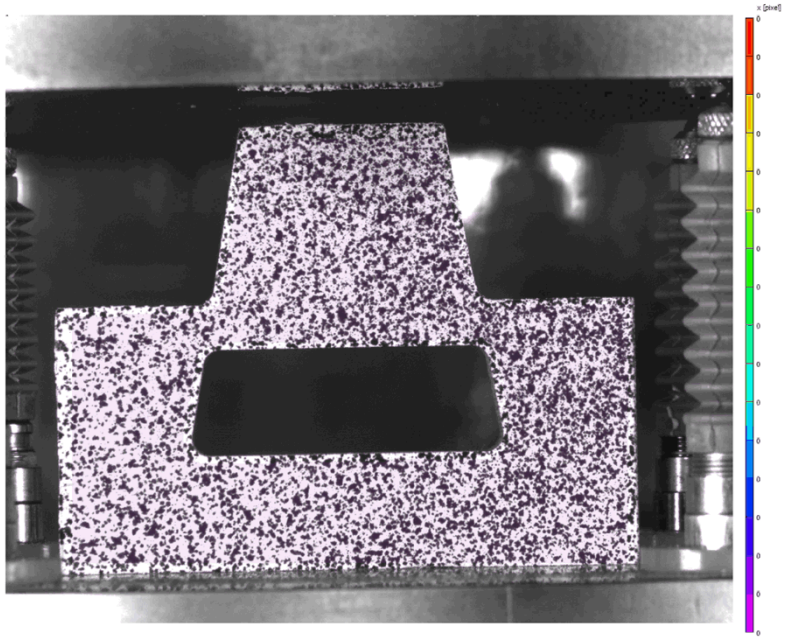


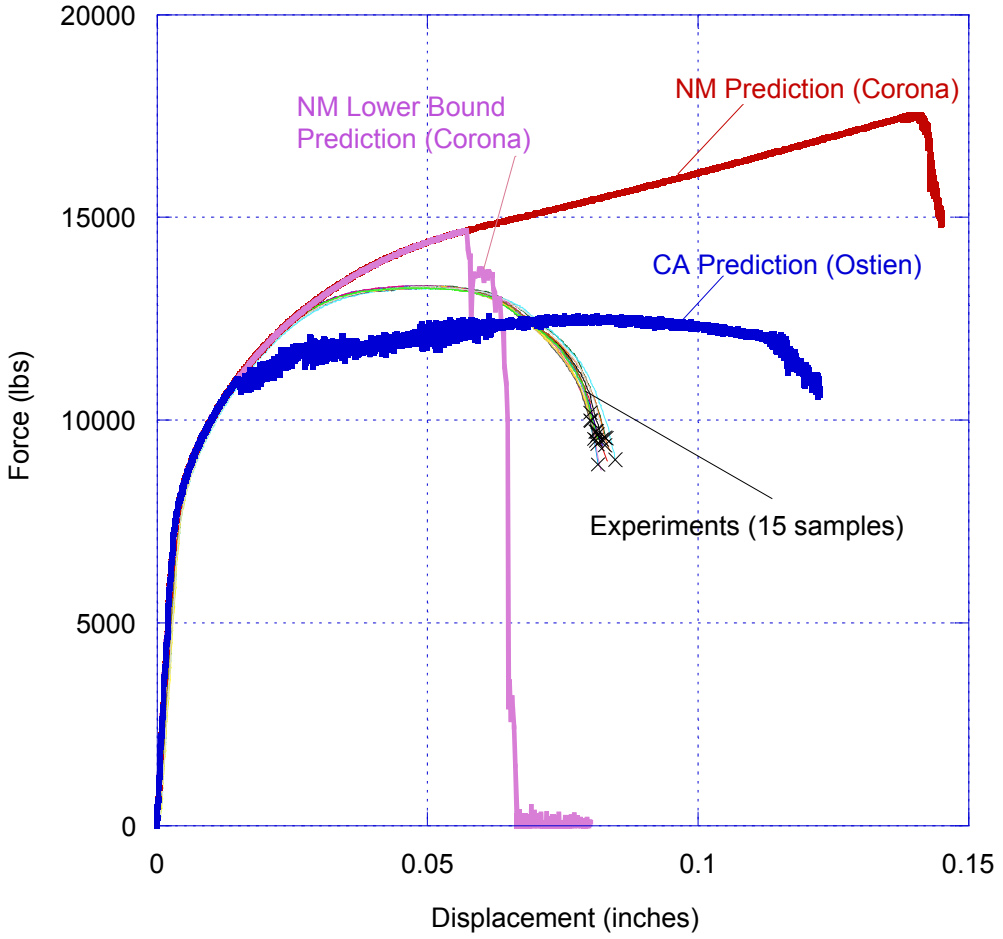






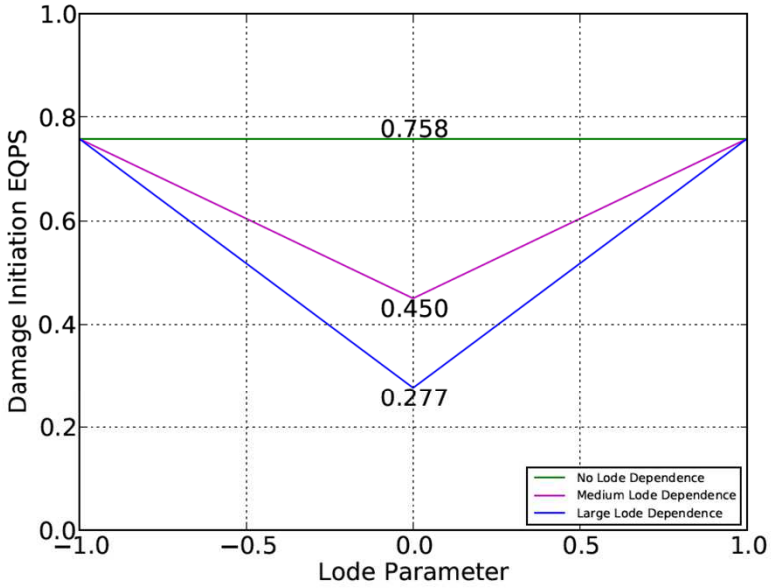
Challenge Results

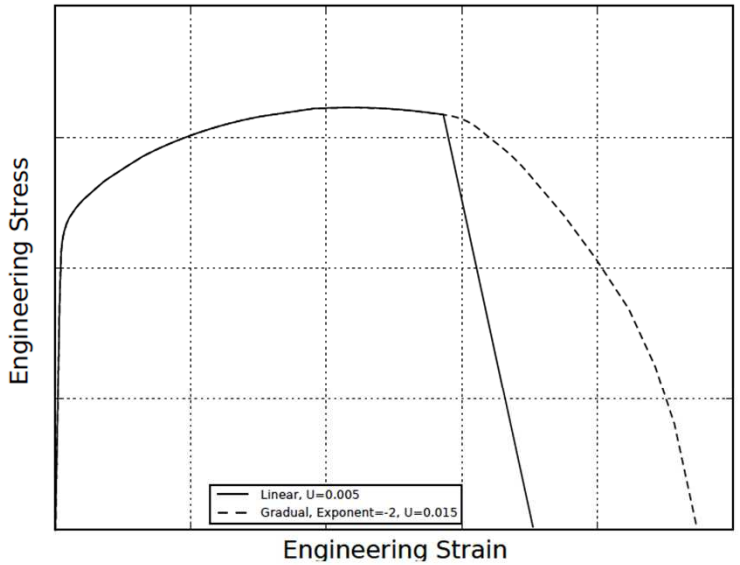


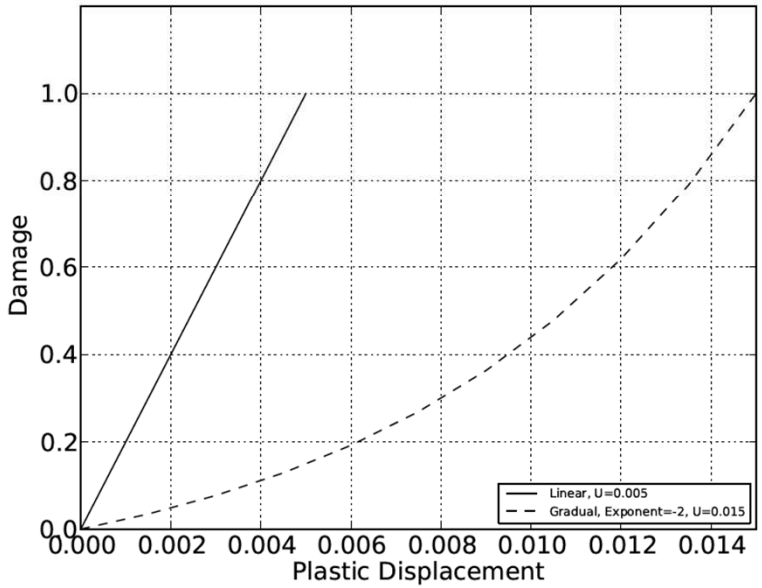


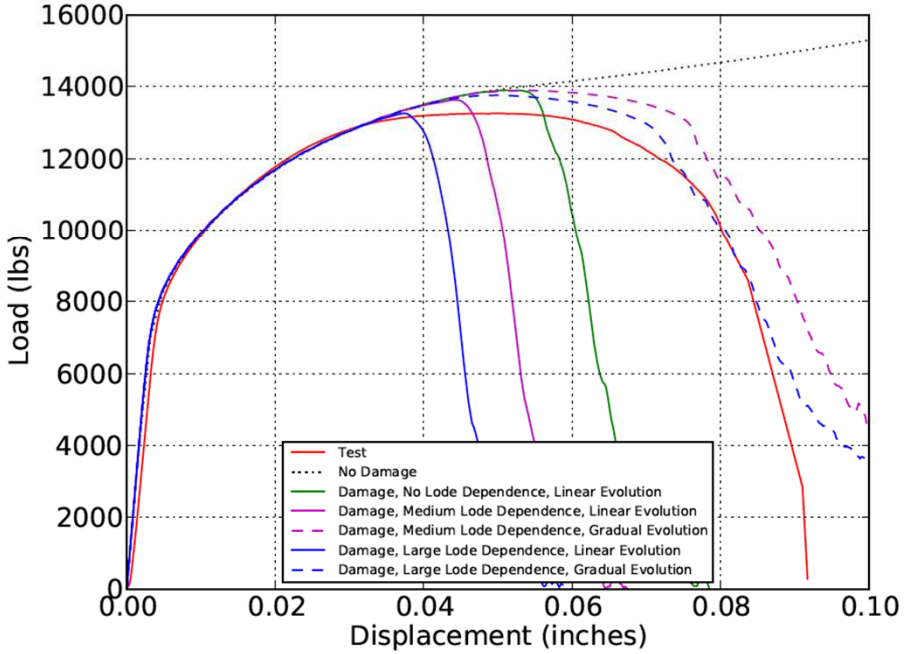
2013 SANDIA FRACTURE CHALLENGE
Initial Re-Investigation

Koester/Corona Re-Investigation (2013)









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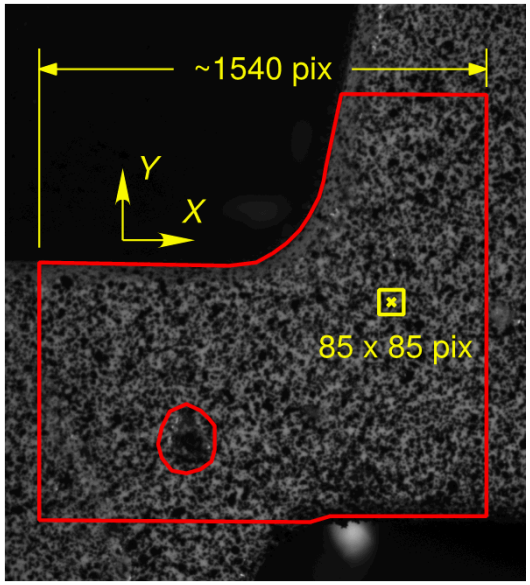
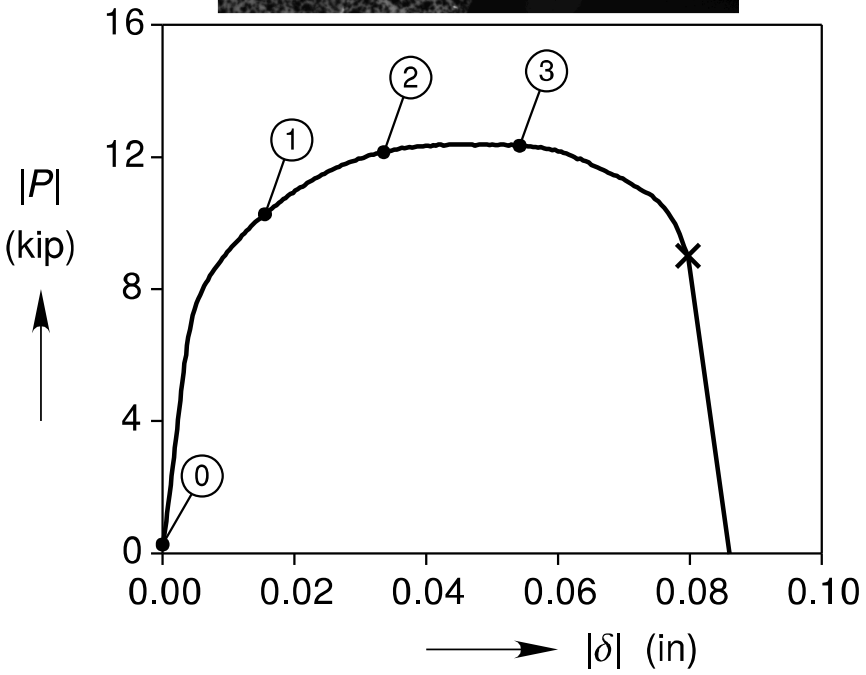
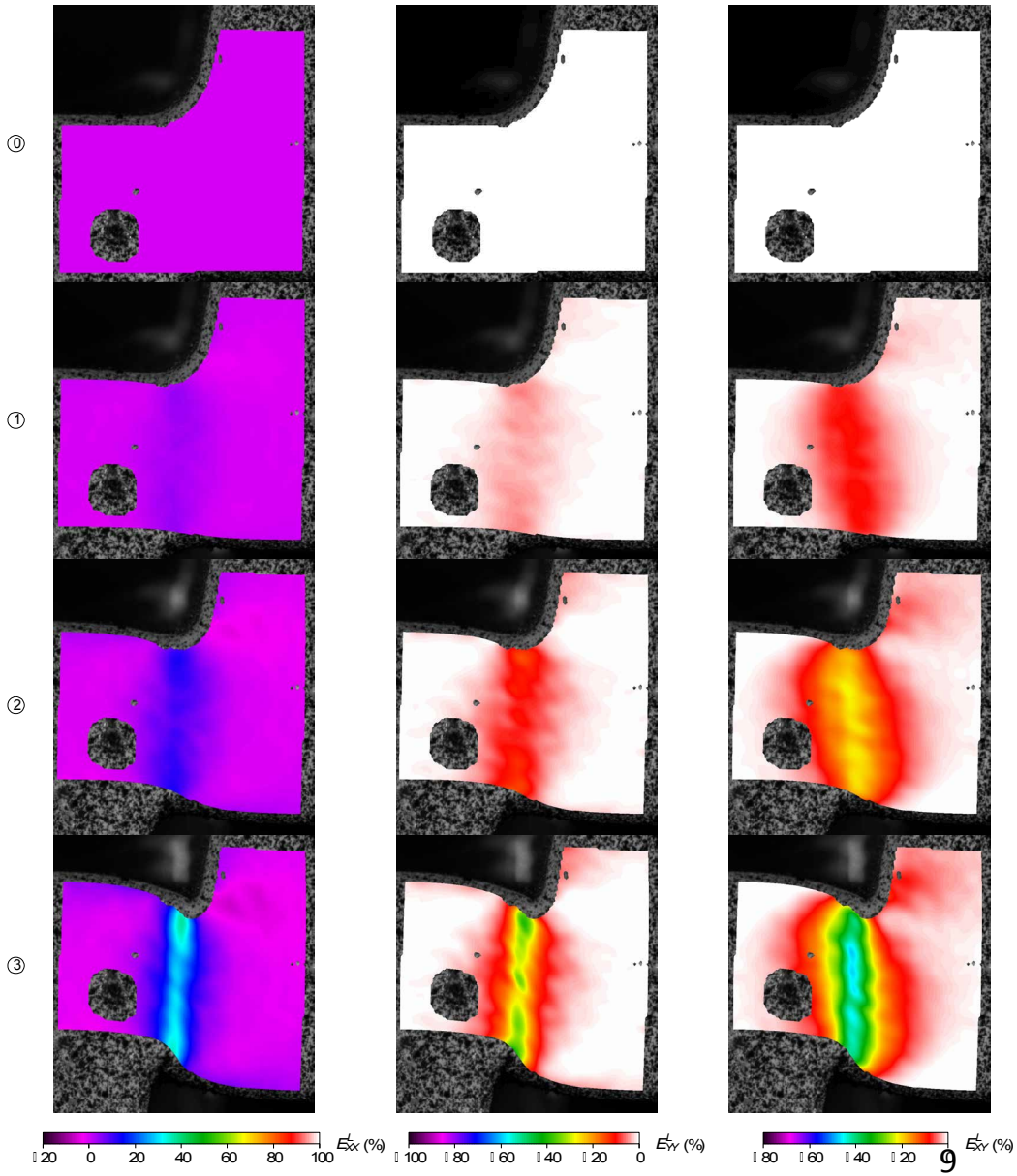
THE 2013 SANDIA FRACTURE CHALLENGE
2014 Experimental Re-Investigation

Corona, E, Deibler, L.A., Redlunn, B., Ingraham, M.D. and Williams, S., 2015. "An Experimental Study of Shear-Dominated Failure in the 2013 Sandia Fracture Challenge Specimen, Sandia Report SAND2015-2850.

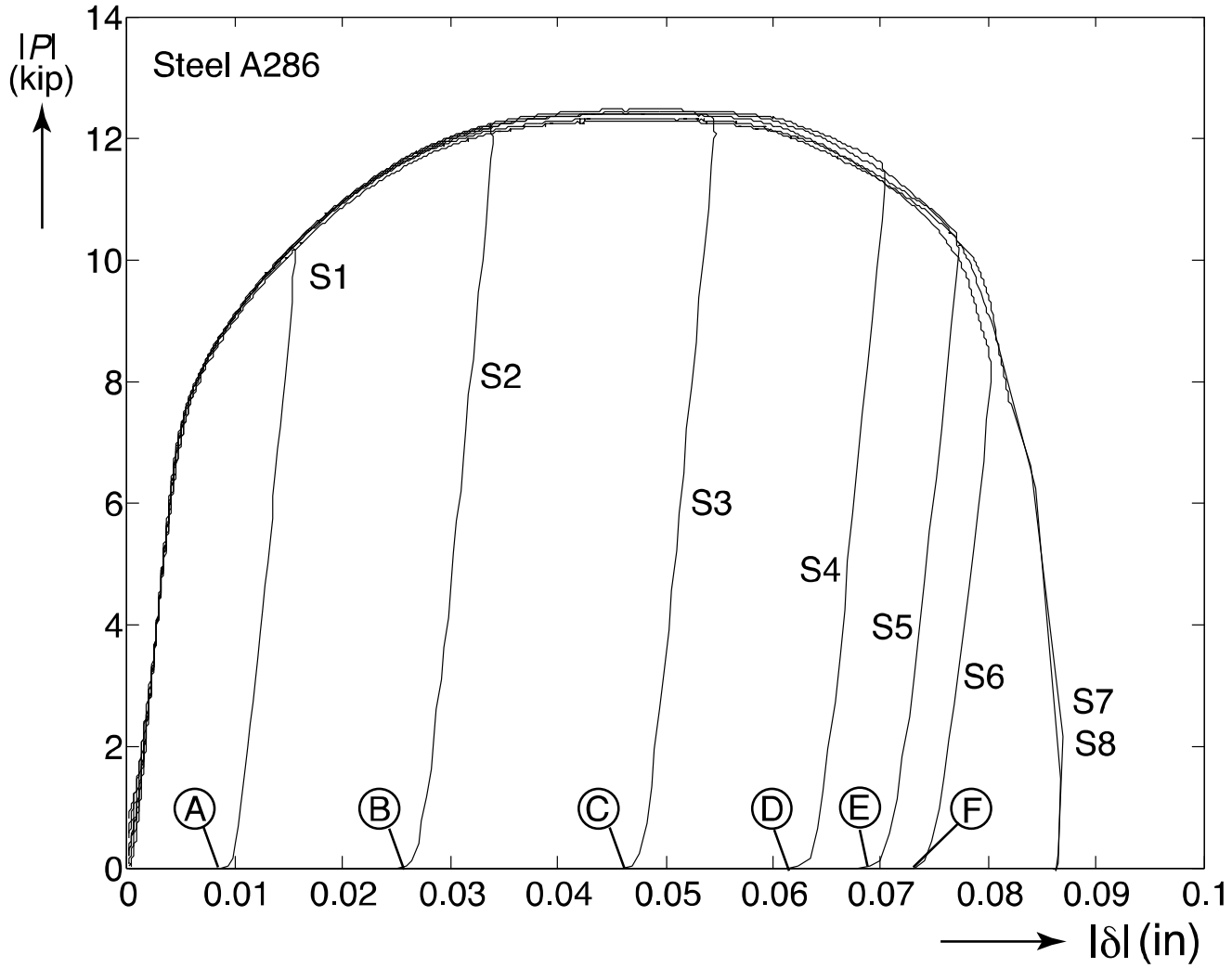
Strain Measurement by DIC – Steel A286



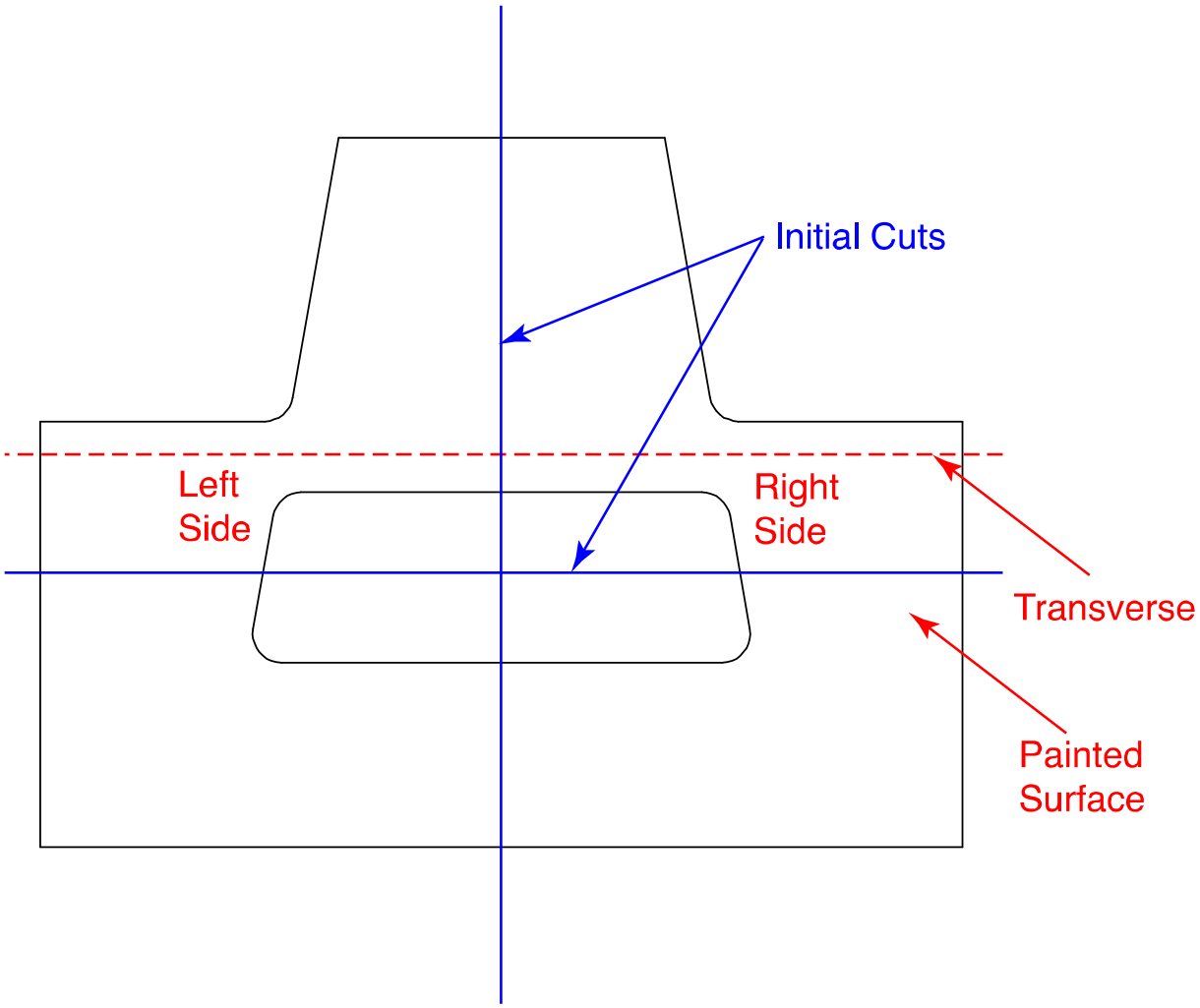


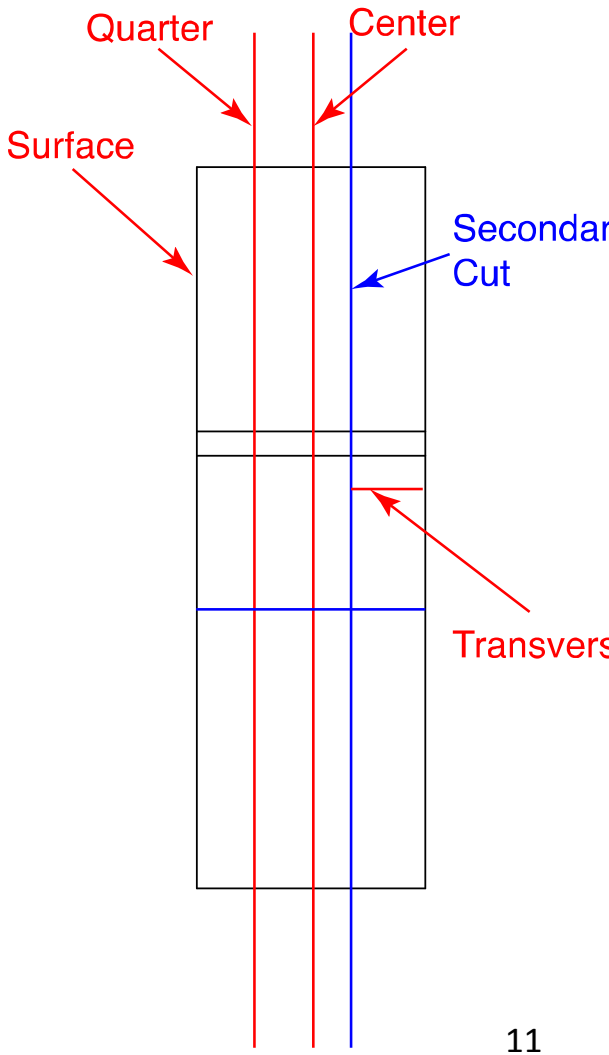


Load-Deflection Responses for All Steel A286 Specimens

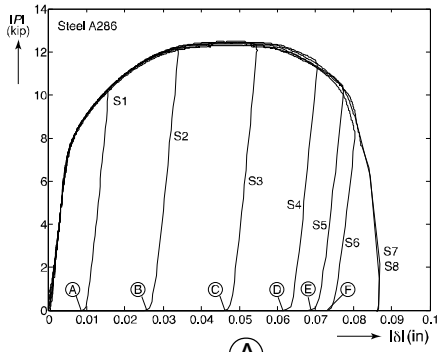


Specimen Sectioning



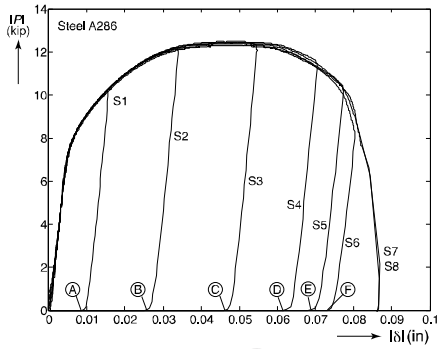


Micrographs for Steel A286 Specimens (Right Side)



	A	B	C	D	E	F
Center						
Quarter						
Surface						

Micrographs for Steel A286 Specimens (Left Side)



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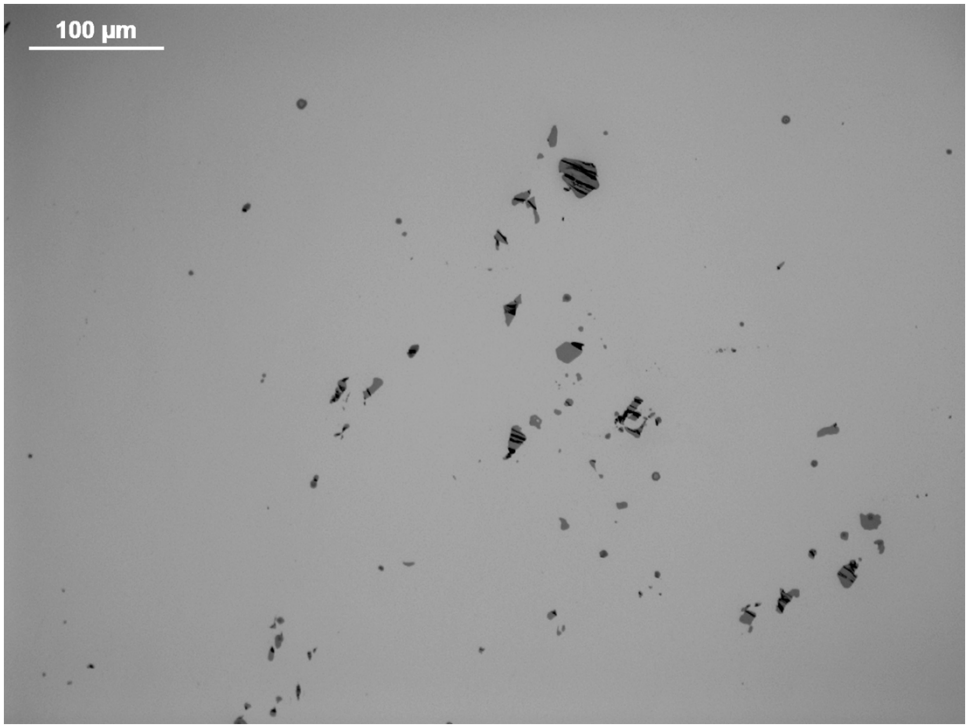
Center

Quarter

Surface

State of Specimen S3



Examples of Higher Magnification Images

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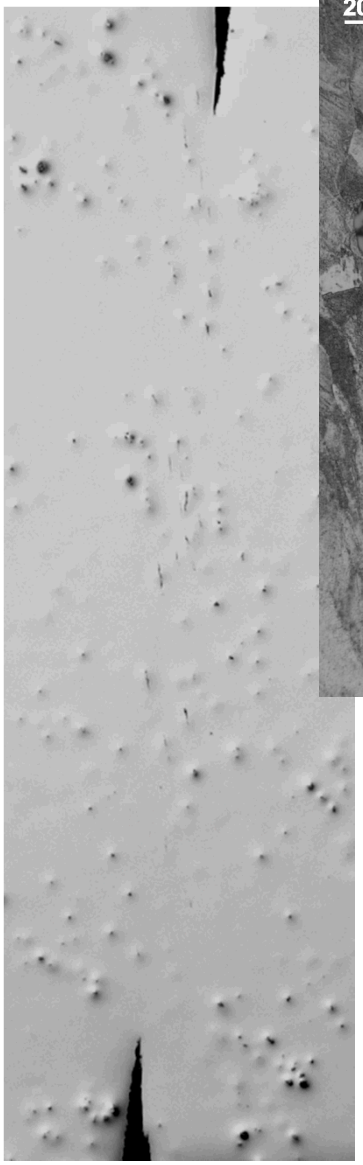
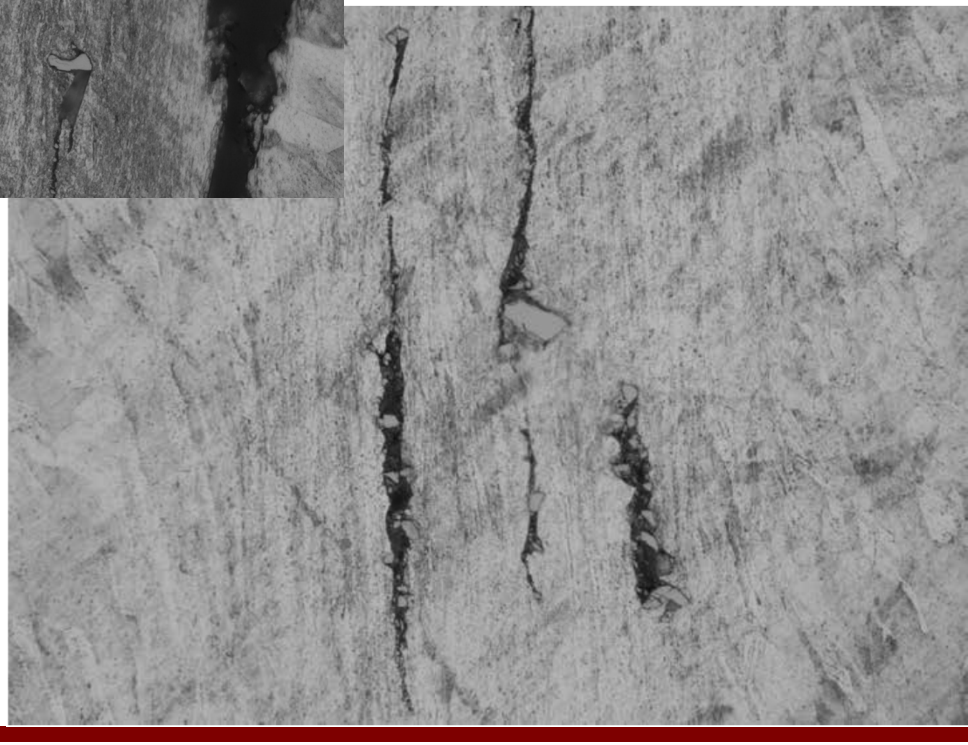
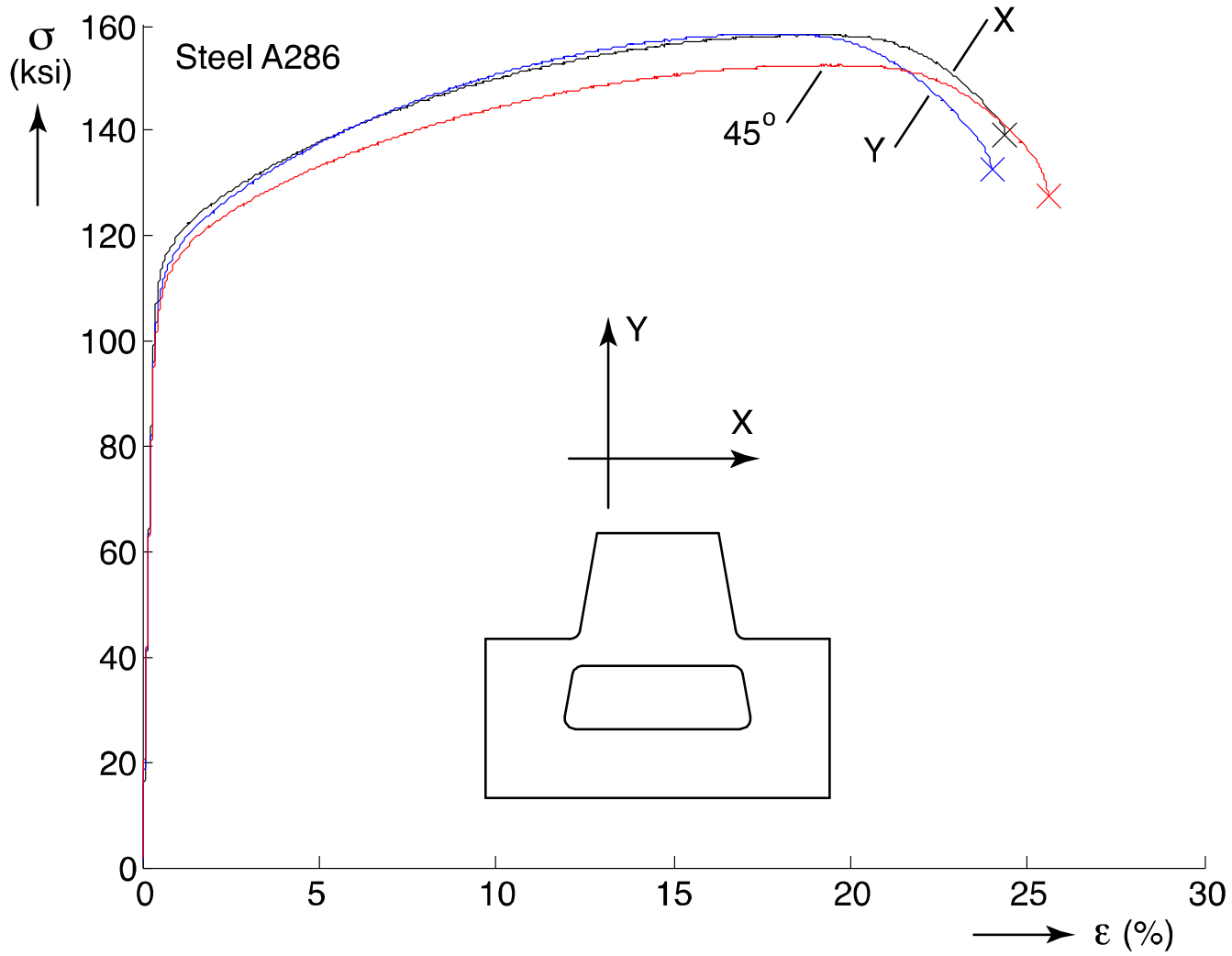


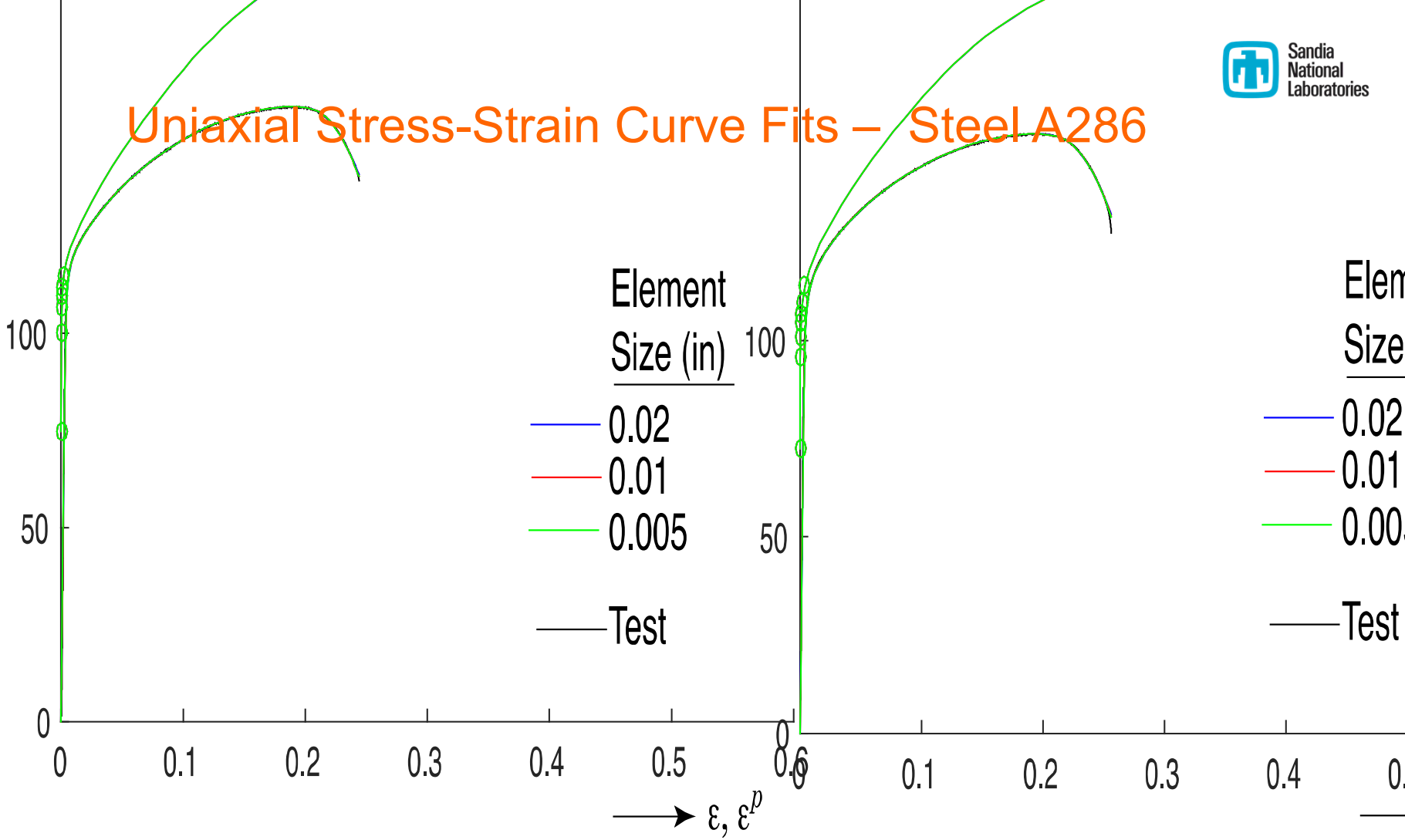


THE 2013 SANDIA FRACTURE CHALLENGE
2014 Material Characterization: Second Round

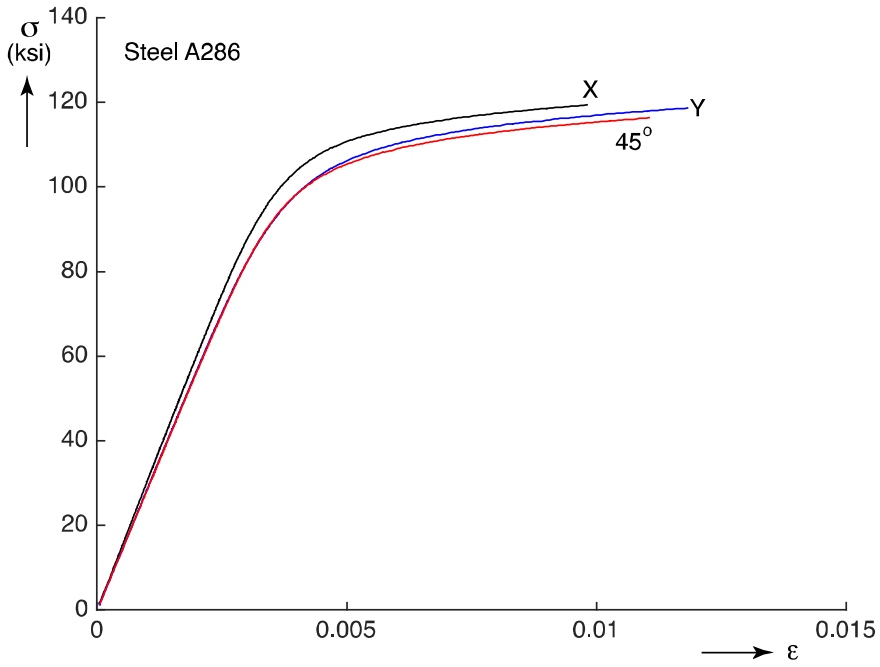
Uniaxial Stress-Strain Curves – Steel A286

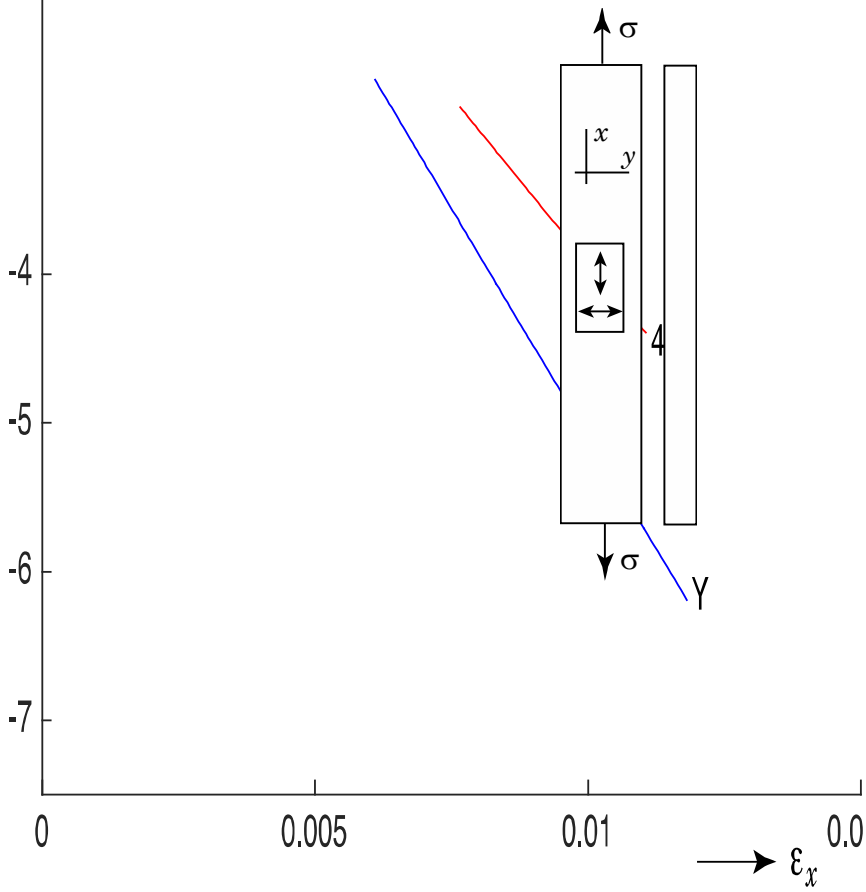


Uniaxial Stress-Strain Curve Fits – Steel A286

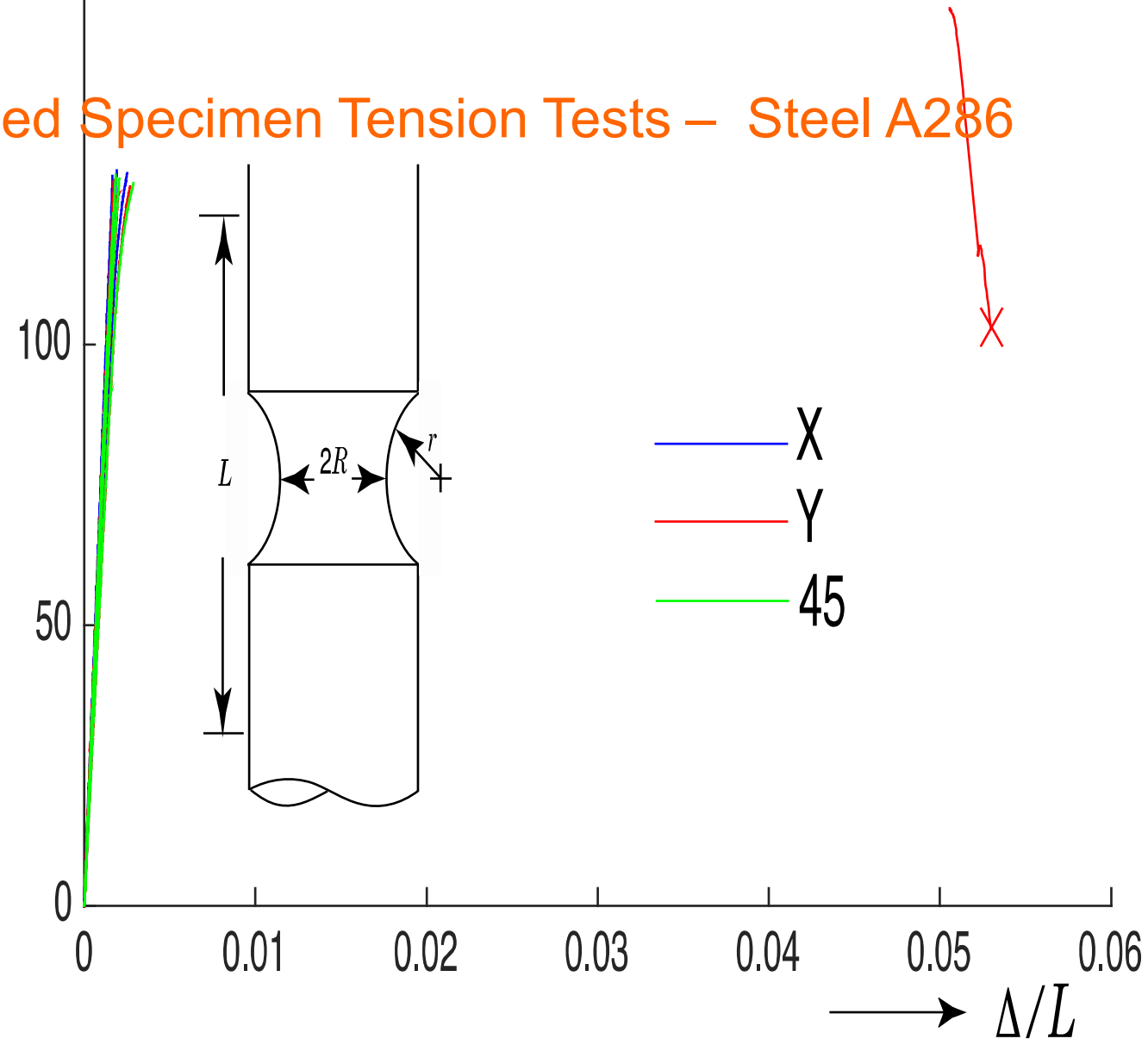


Strain Gage Measurement in Tension Tests – Steel A286



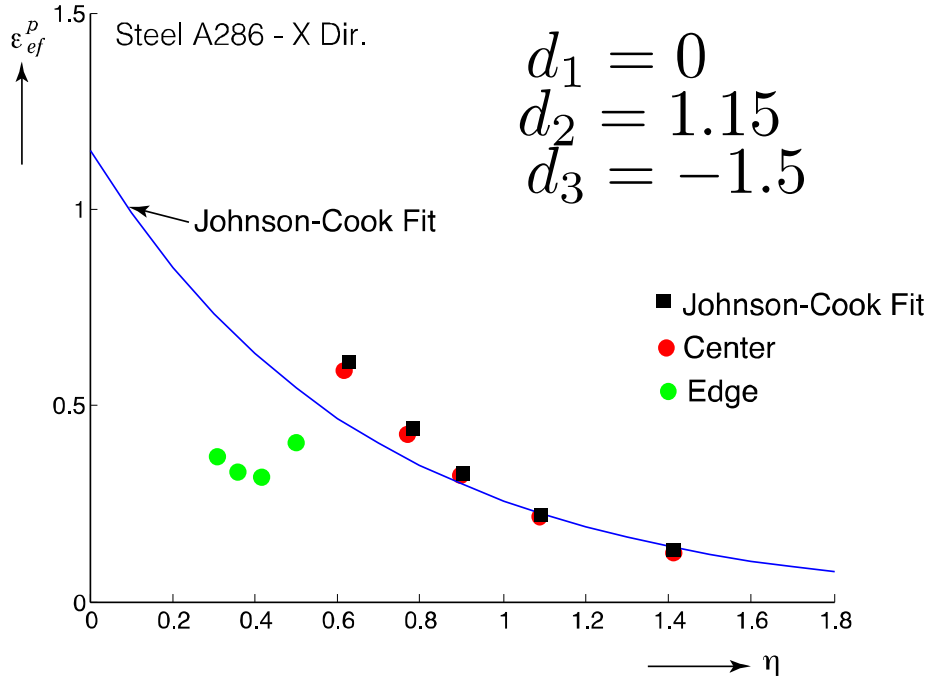


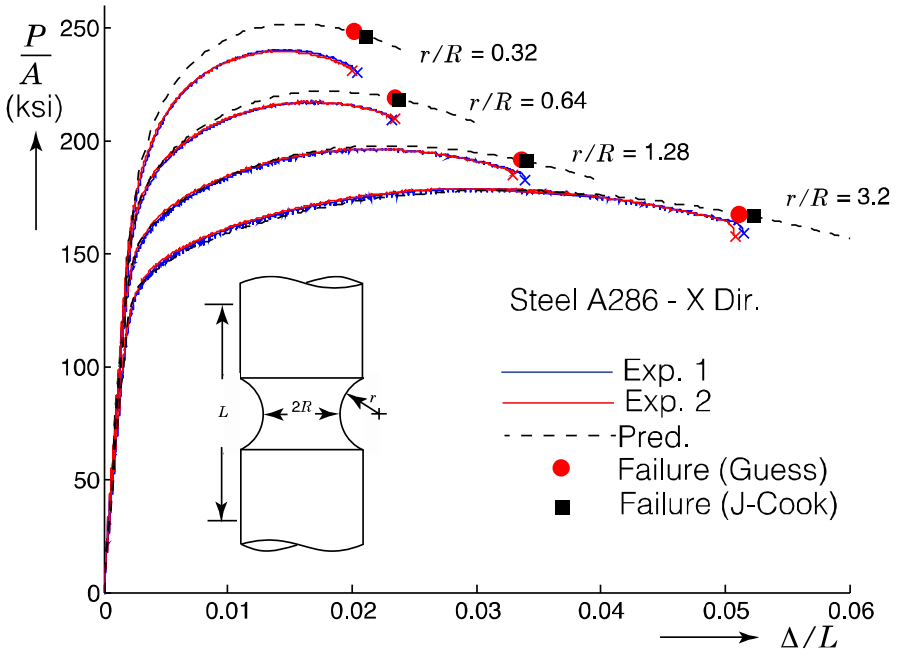
Notched Specimen Tension Tests – Steel A286



Johnson-Cook Failure Calibration

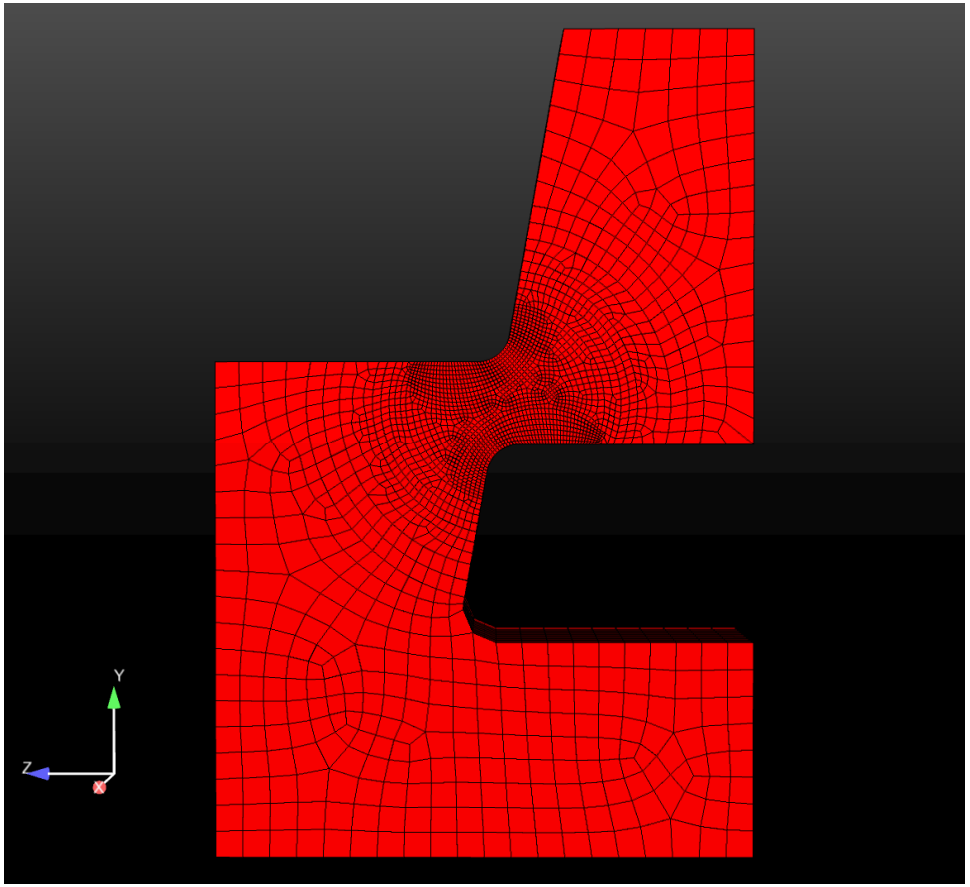
$$\varepsilon^p_{ef} = d_1 + d_2 e^{d_3 \eta}$$





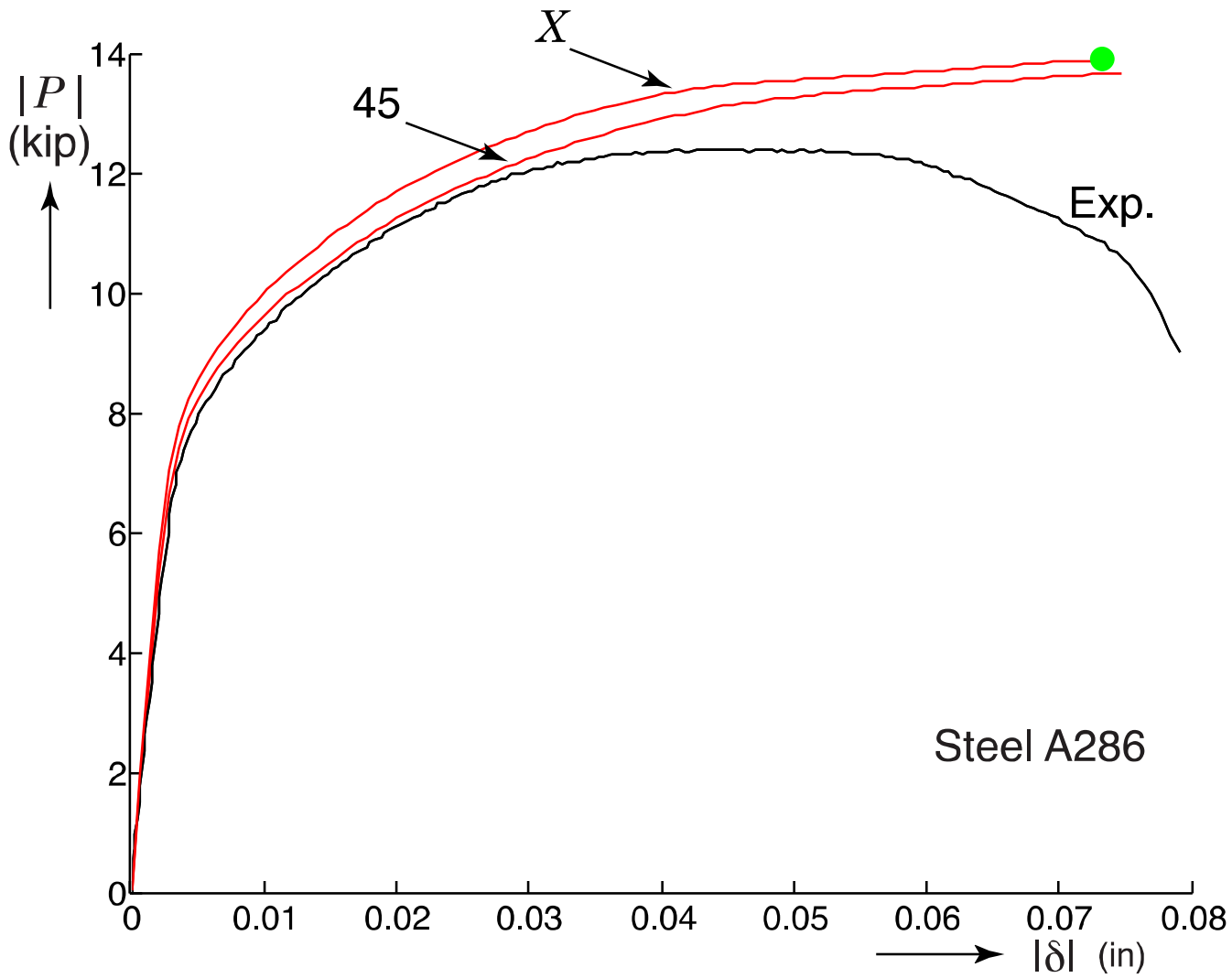
THE 2013 SANDIA FRACTURE CHALLENGE
Numerical Simulations

Finite Element Model



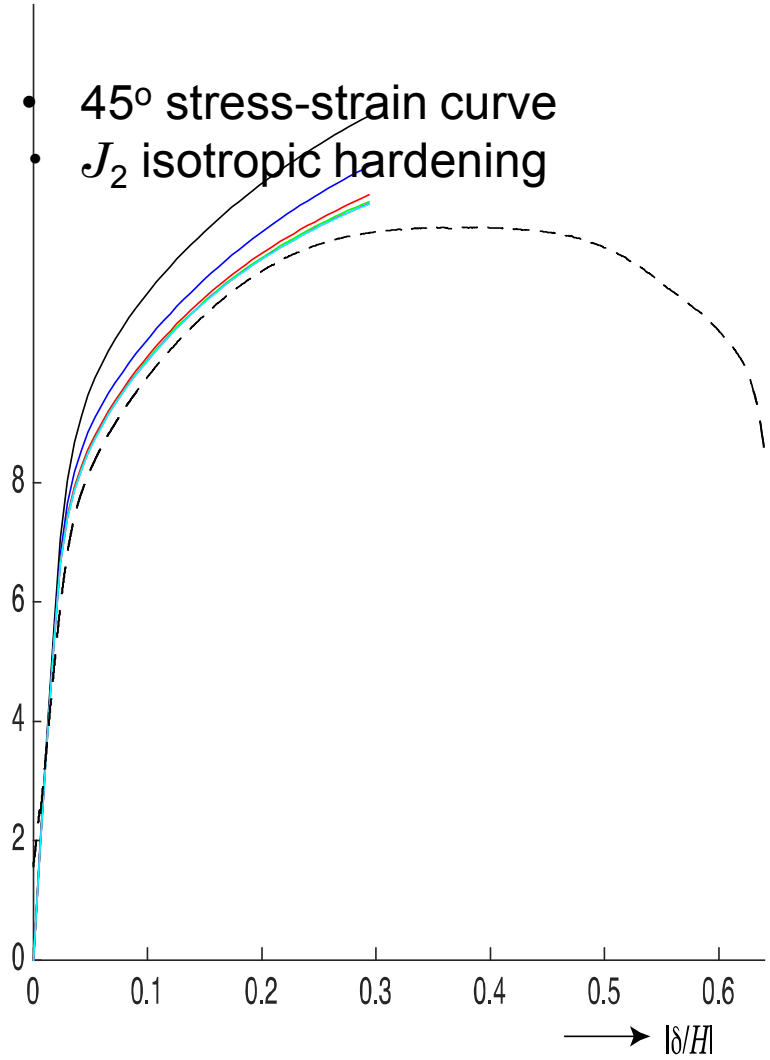
Double symmetry (1/4)
Prescribed displacements top/bottom
Rate-independent plasticity
J_2 or Hill anisotropic
Johnson-Cook damage

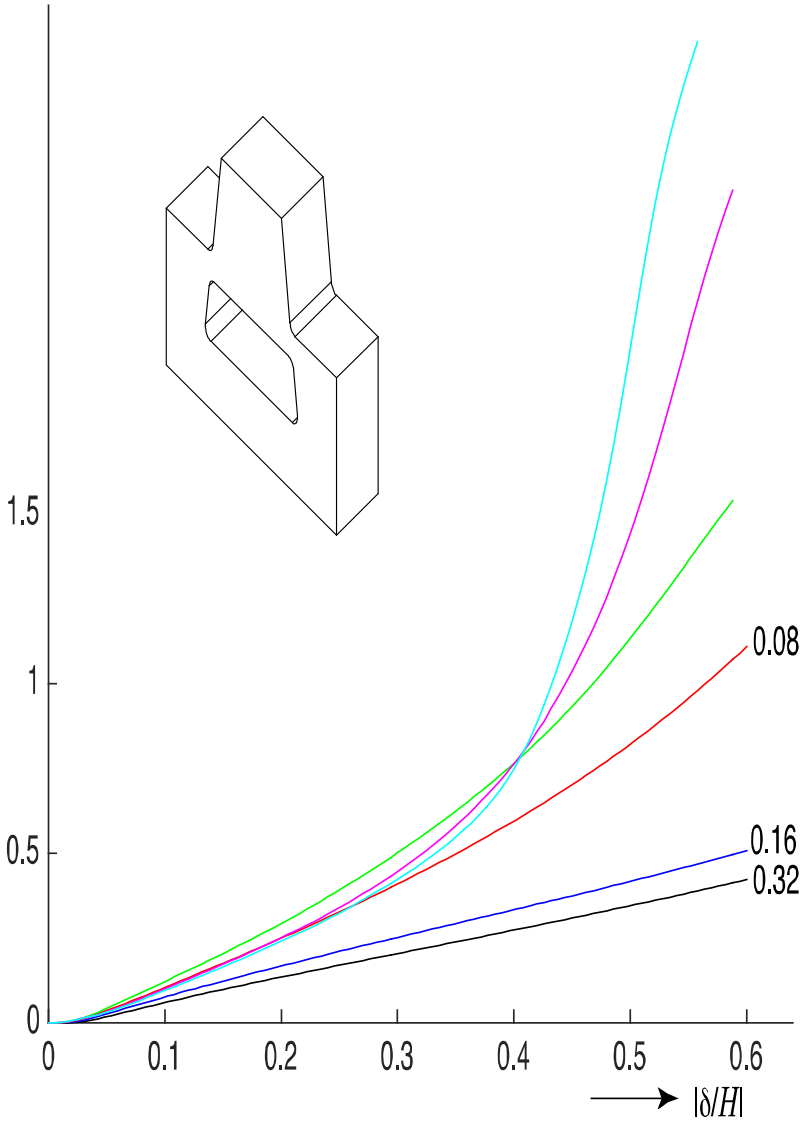
Prediction for Compression Specimen

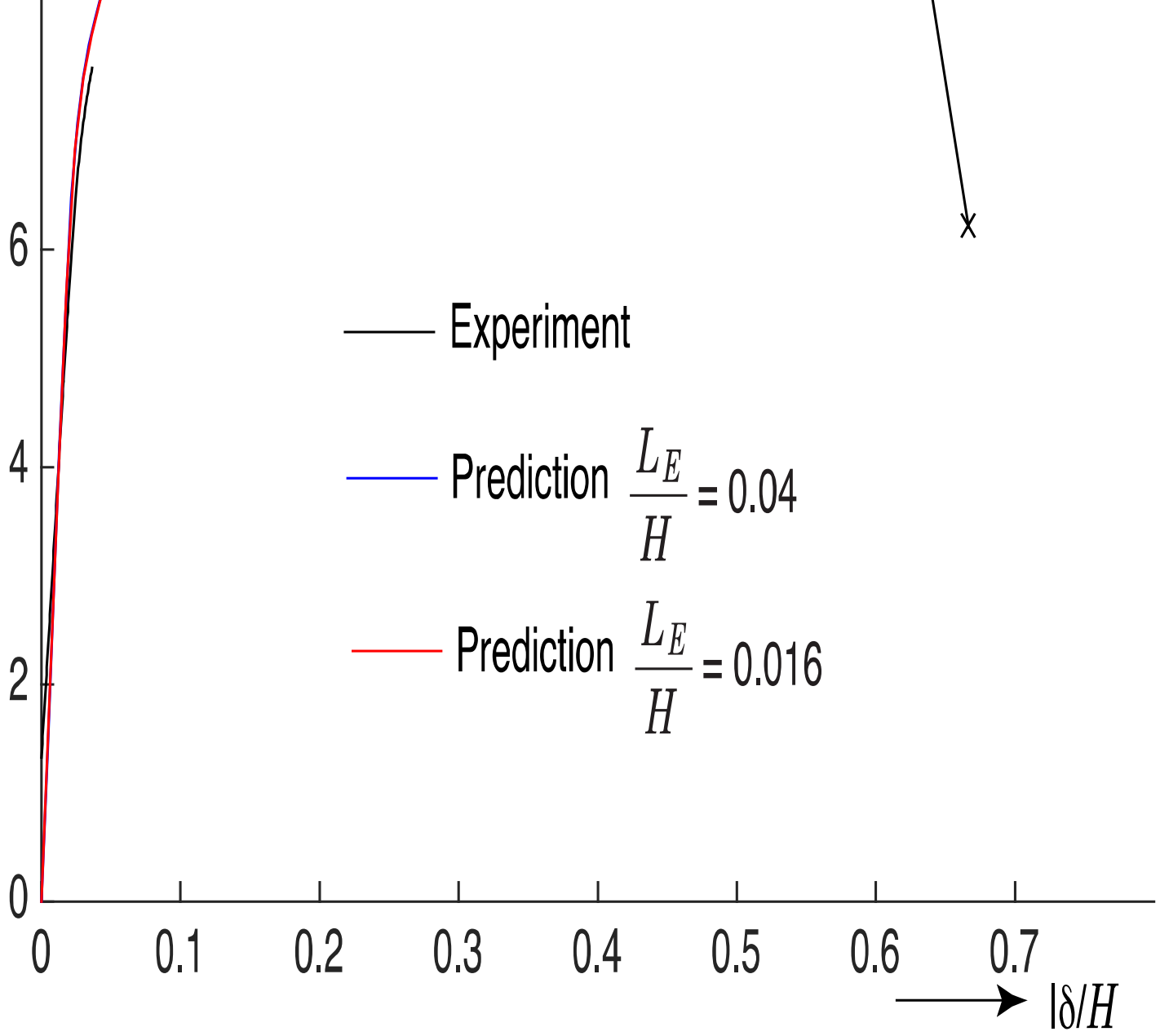


Mesh Convergence Study

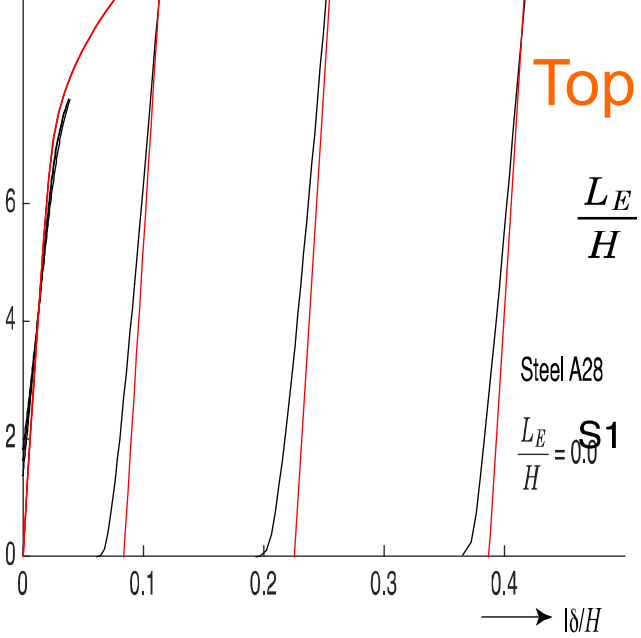
- 45° stress-strain curve
- J_2 isotropic hardening






6
4
2
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Experiment
Prediction $\frac{L_E}{H} = 0.04$
Prediction $\frac{L_E}{H} = 0.016$
$|\delta/H$

Top Profile Comparisons



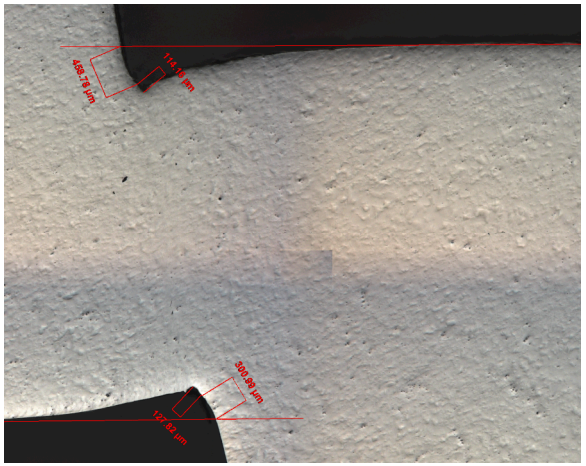
$\frac{L_E}{H} = 0.016$

Center

Surface

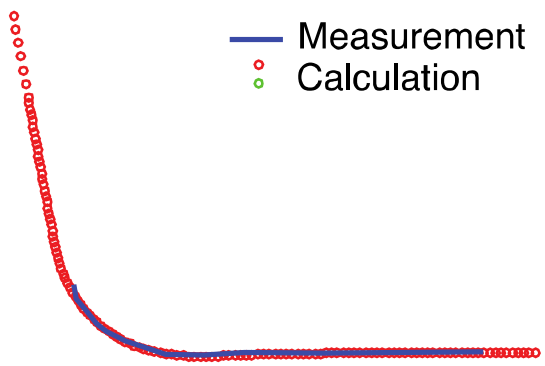
Measurement

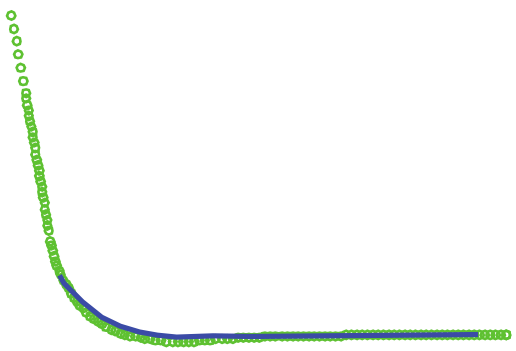
Calculation

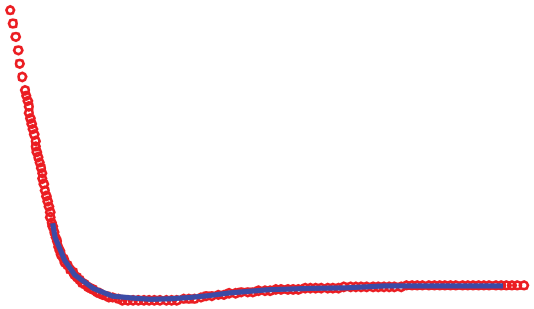


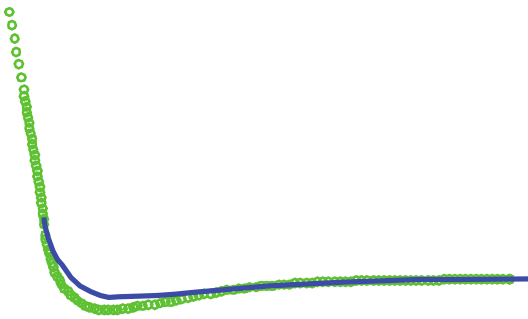
S2

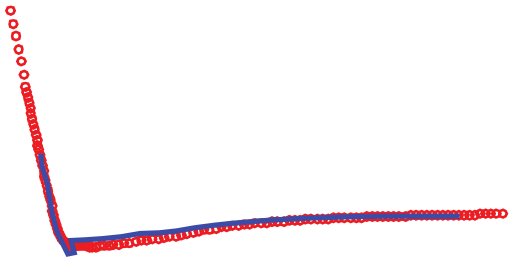
S3

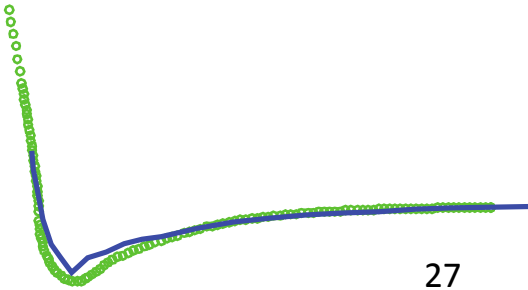












Maps of Johnson-Cook Damage (S3)

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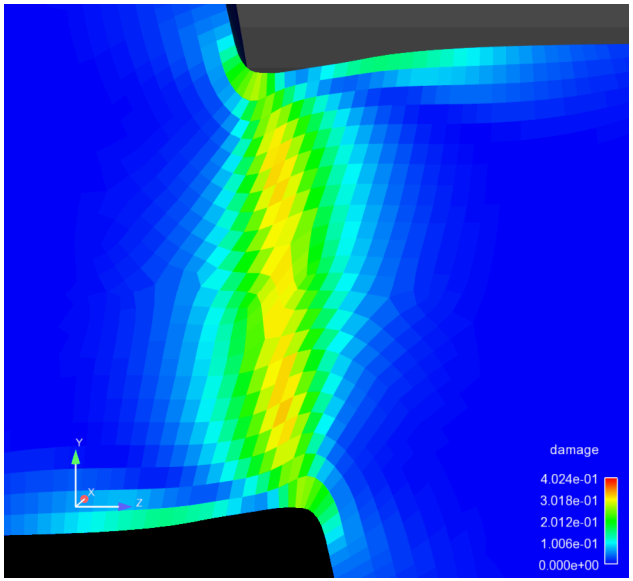
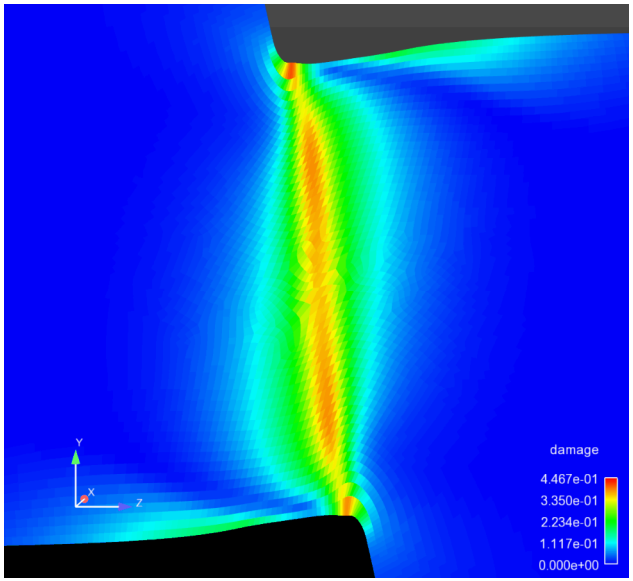
L_E/H=0.04

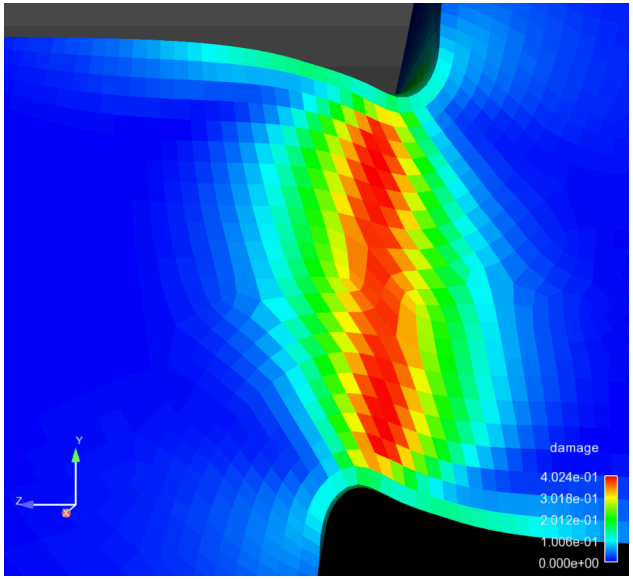
L_E/H=0.016

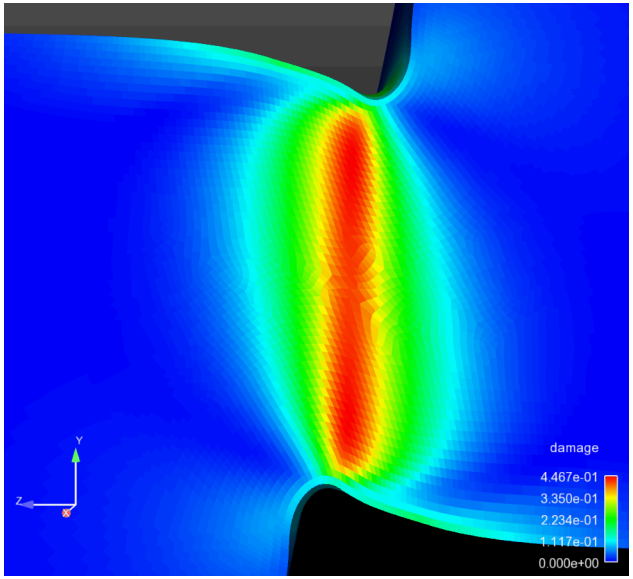
Center



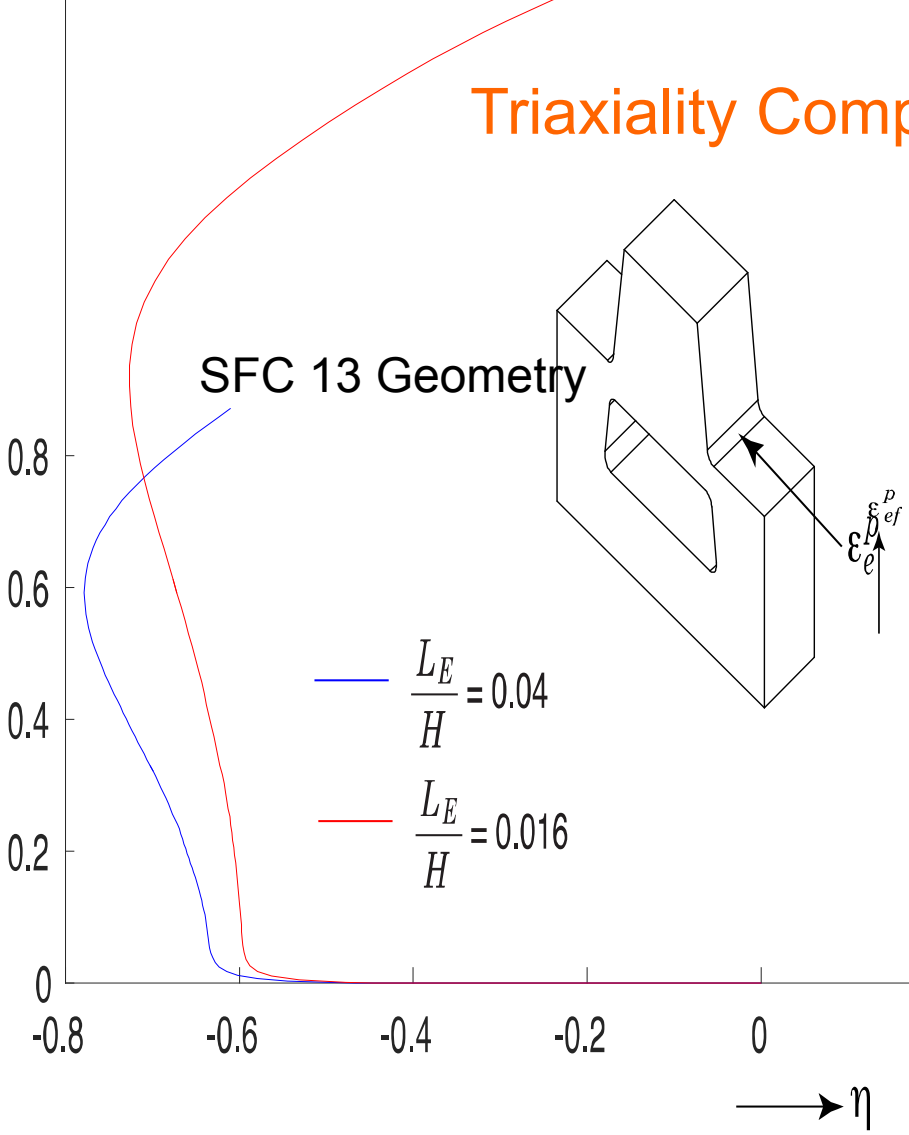


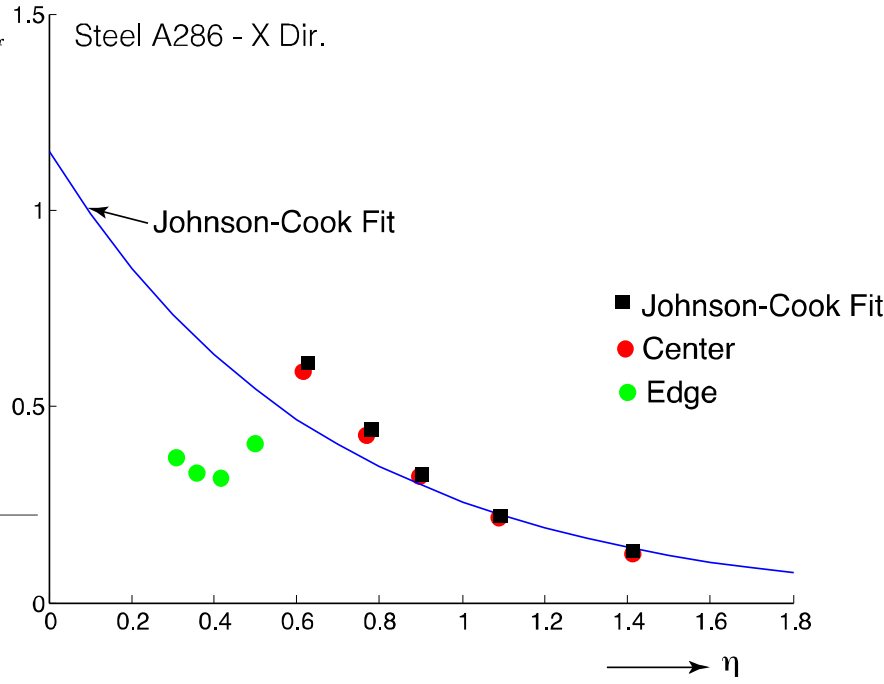
Surface





Triaxiality Comparisons





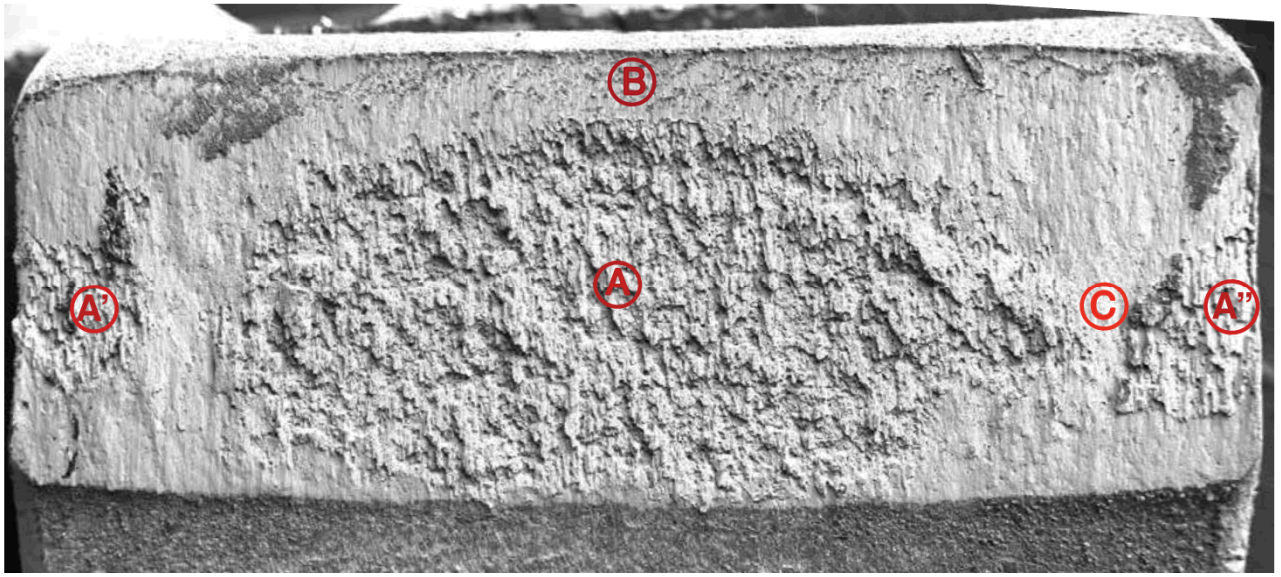
Conclusions

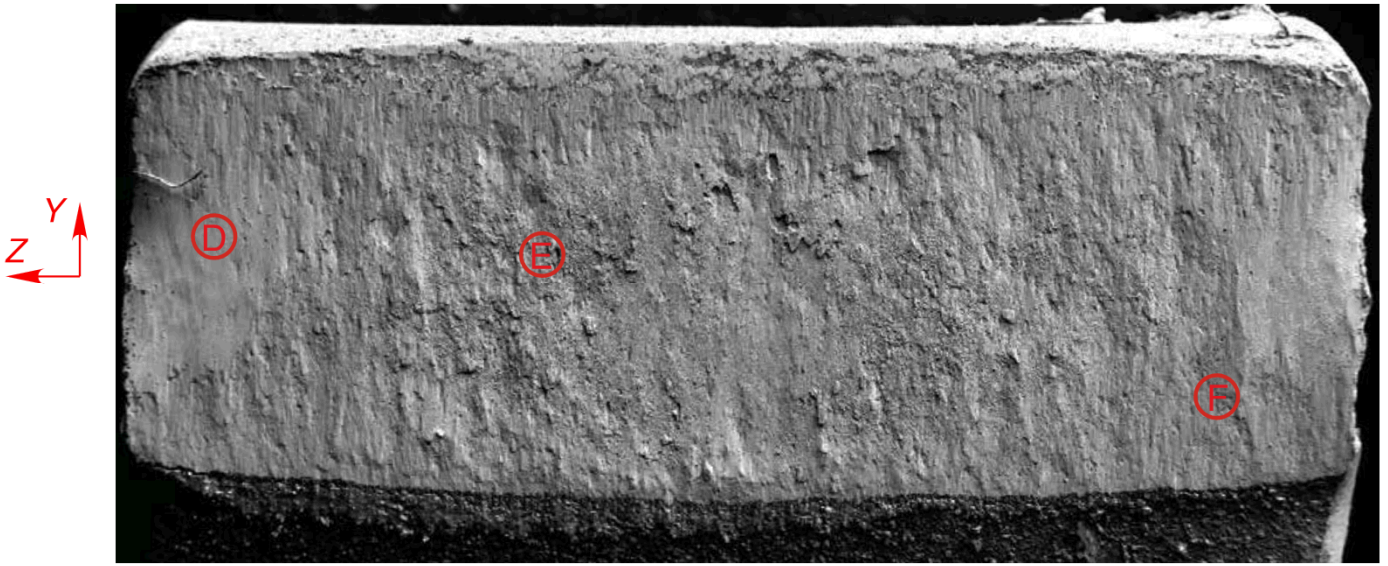
- Initial response (elasticity/yield/early plasticity) captured reasonably well

- The occurrence of the limit load is not captured by the model
  - Damage start not captured by the model
  - Plasticity model may constrain localization
  - Further mesh refinement needed
  - Un-symmetric deformations not captured by symmetric model (not obvious in tests, damage asymmetry seen late).

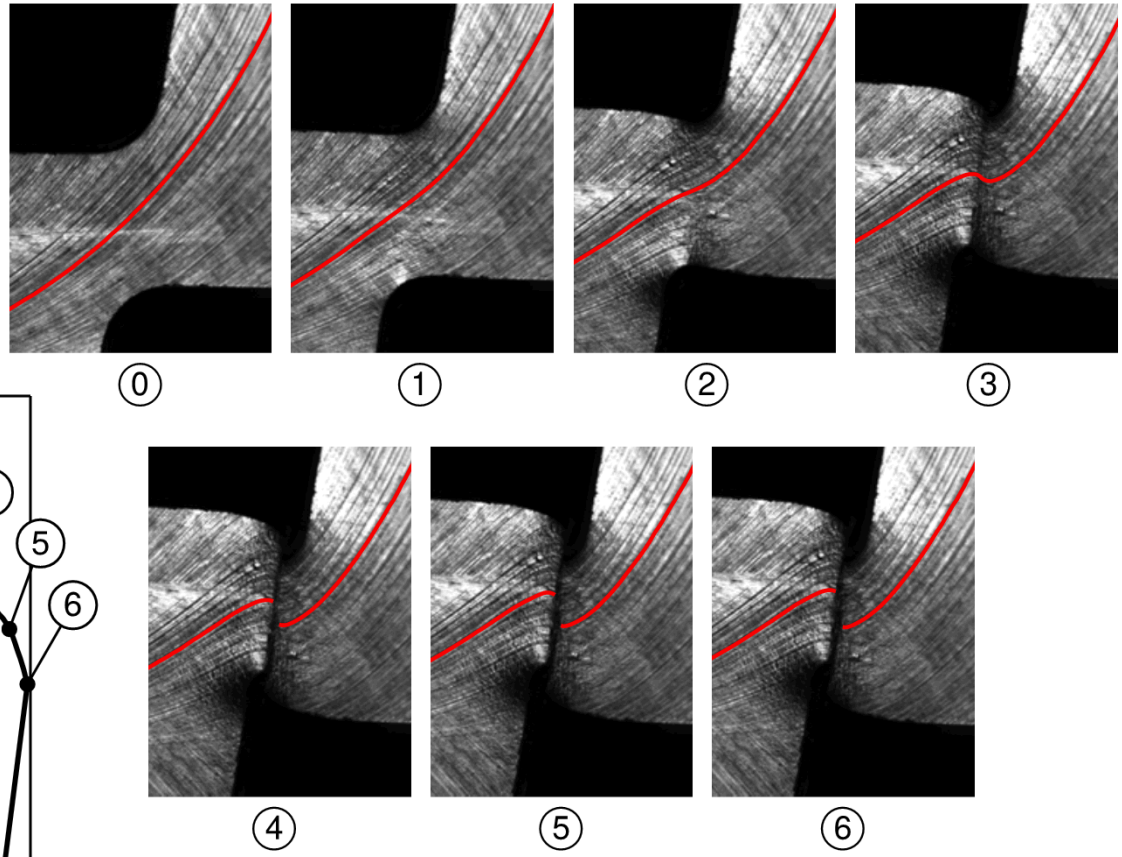
- Evidence seems to point to the influence of damage eroding load-carrying capacity
  - Cracks at regions with high curvature appeared by limit load
  - Fracture of inclusions leads to mini-cracks in high shear zone
    - How can we capture that?
    - Our material testing has not helped us in this front
    - Supplemental shear tests will be conducted.

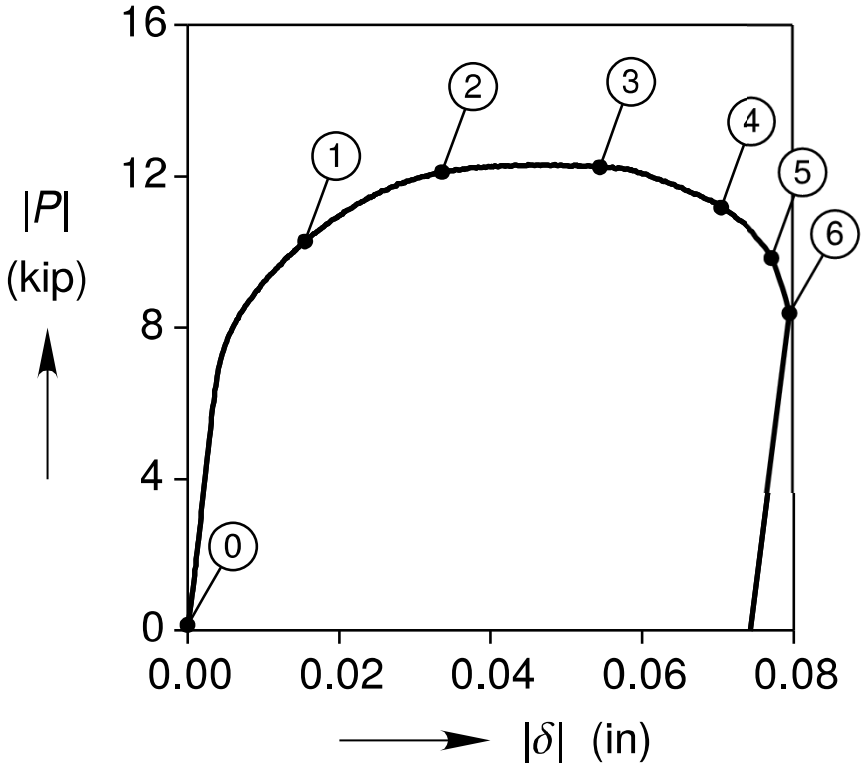
Fracture Surfaces for a Steel A286 Specimen



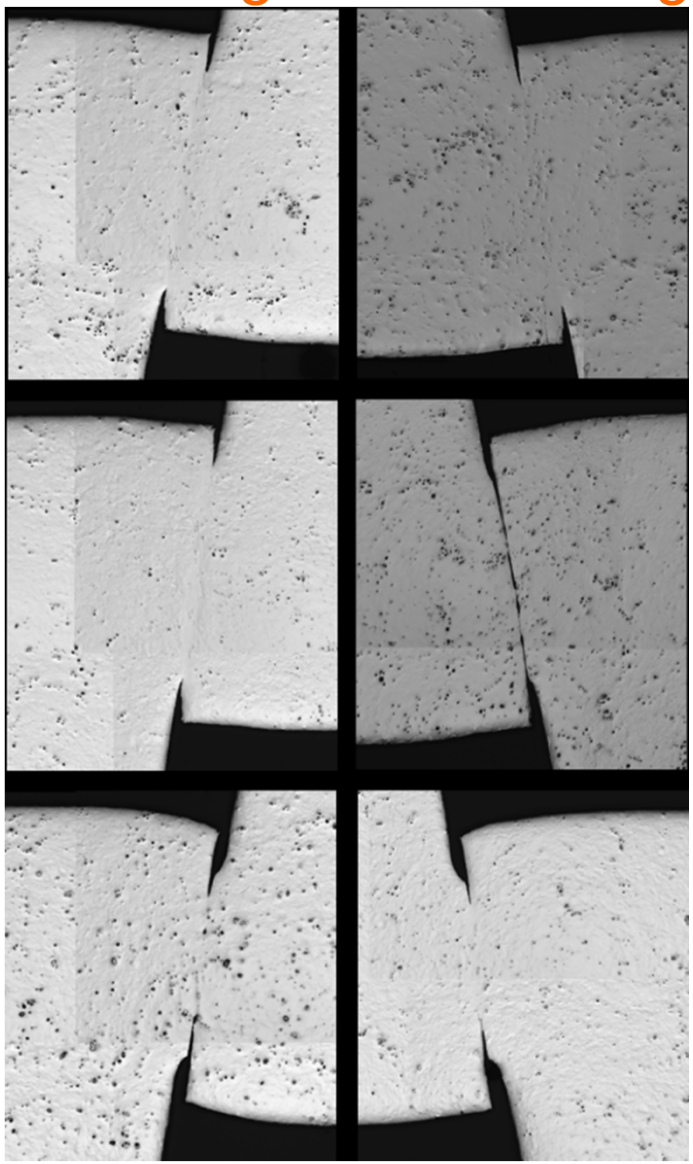


Example of Specimen Deformation for Steel A286 Specimen

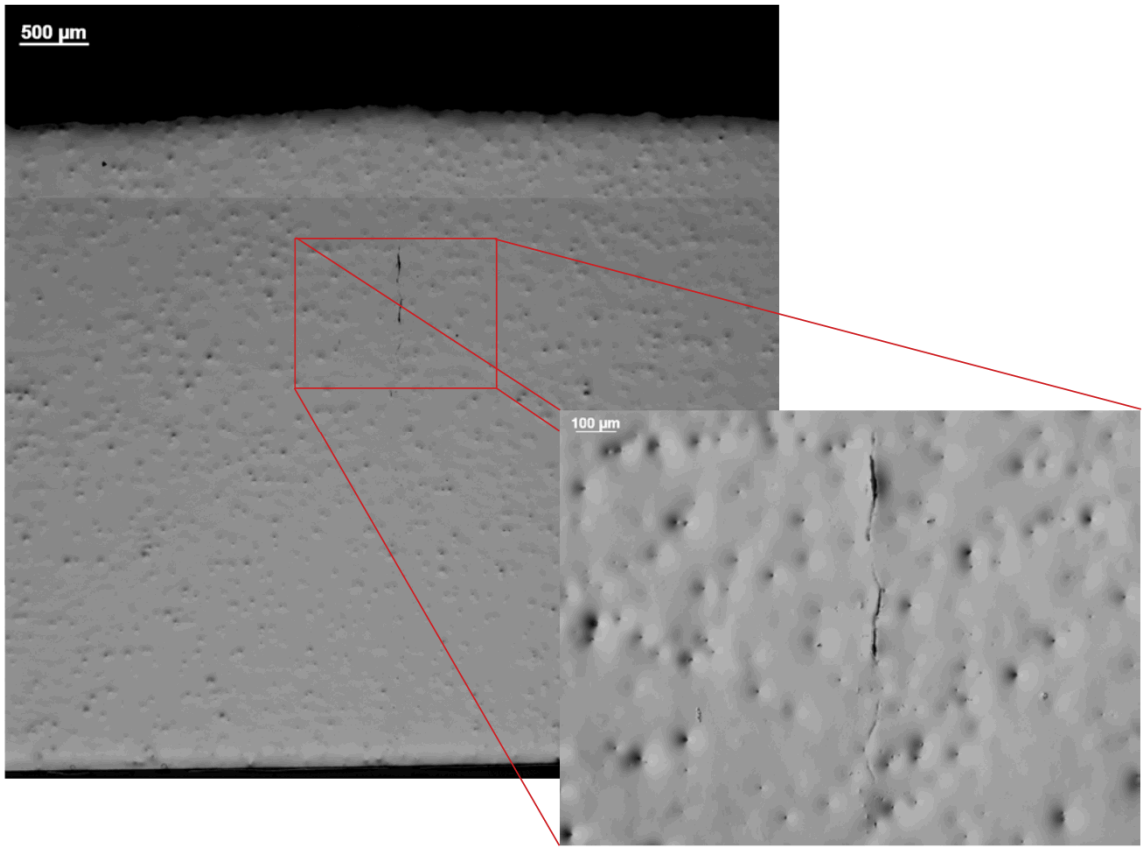


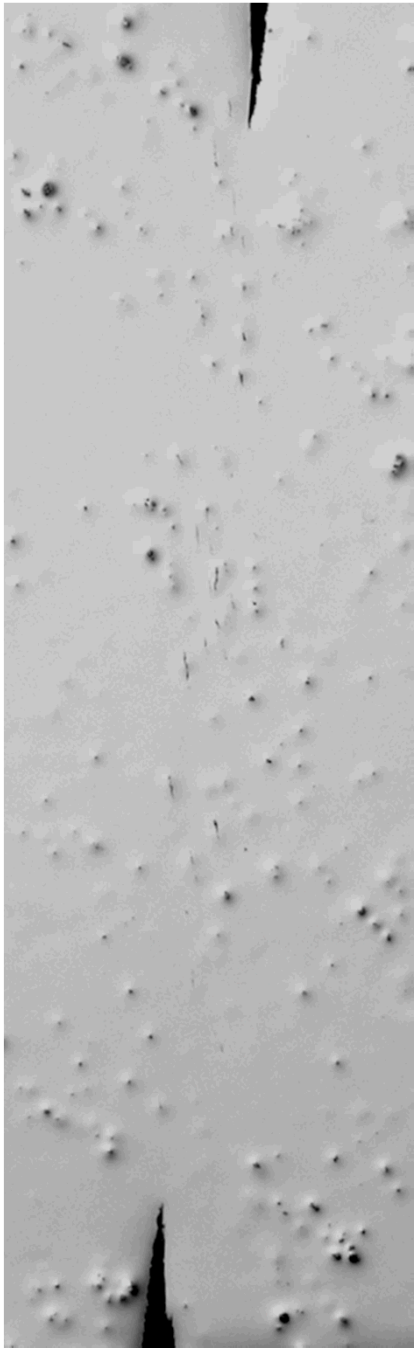


Micrographs for Steel A286 Specimens
Comparison of Left and Right Sides at Highest Displacement



State of Specimen S6





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Maps of Johnson-Cook Damage (δ/H=0.6)

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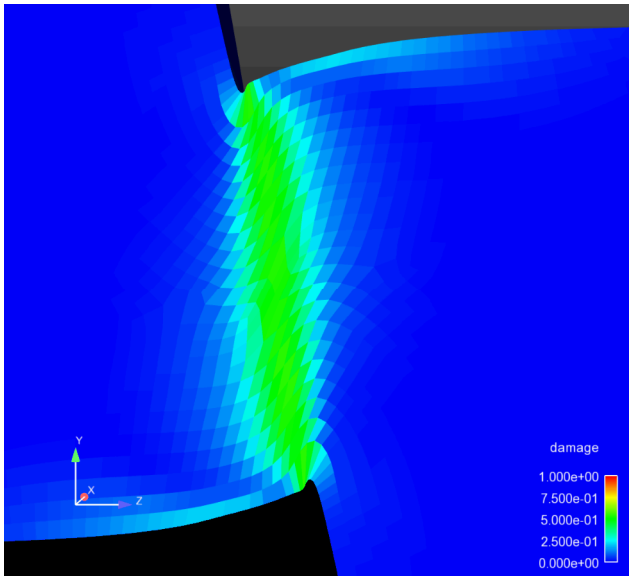
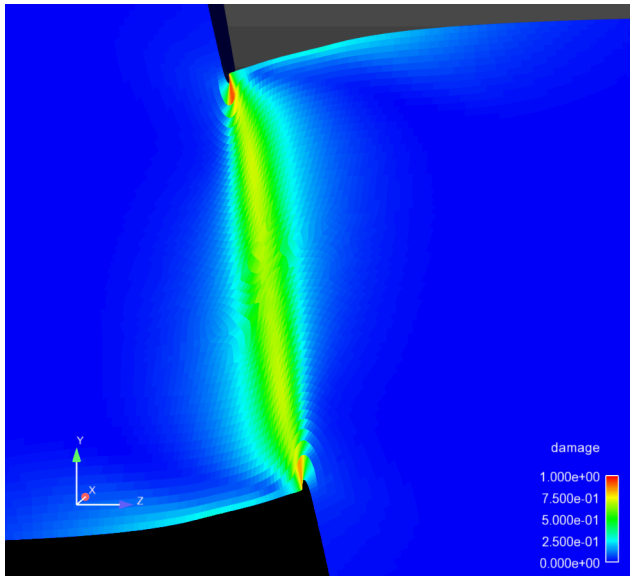
	L_E/H=0.04	L_E/H=0.016
Center		
Surface