SAND2018-7224C

BLIND PREDICTION OF THE RESPONSE OF AN ADDITIVELY MANUFACTURED TENSILE TEST COUPON LOADED TO FAILURE

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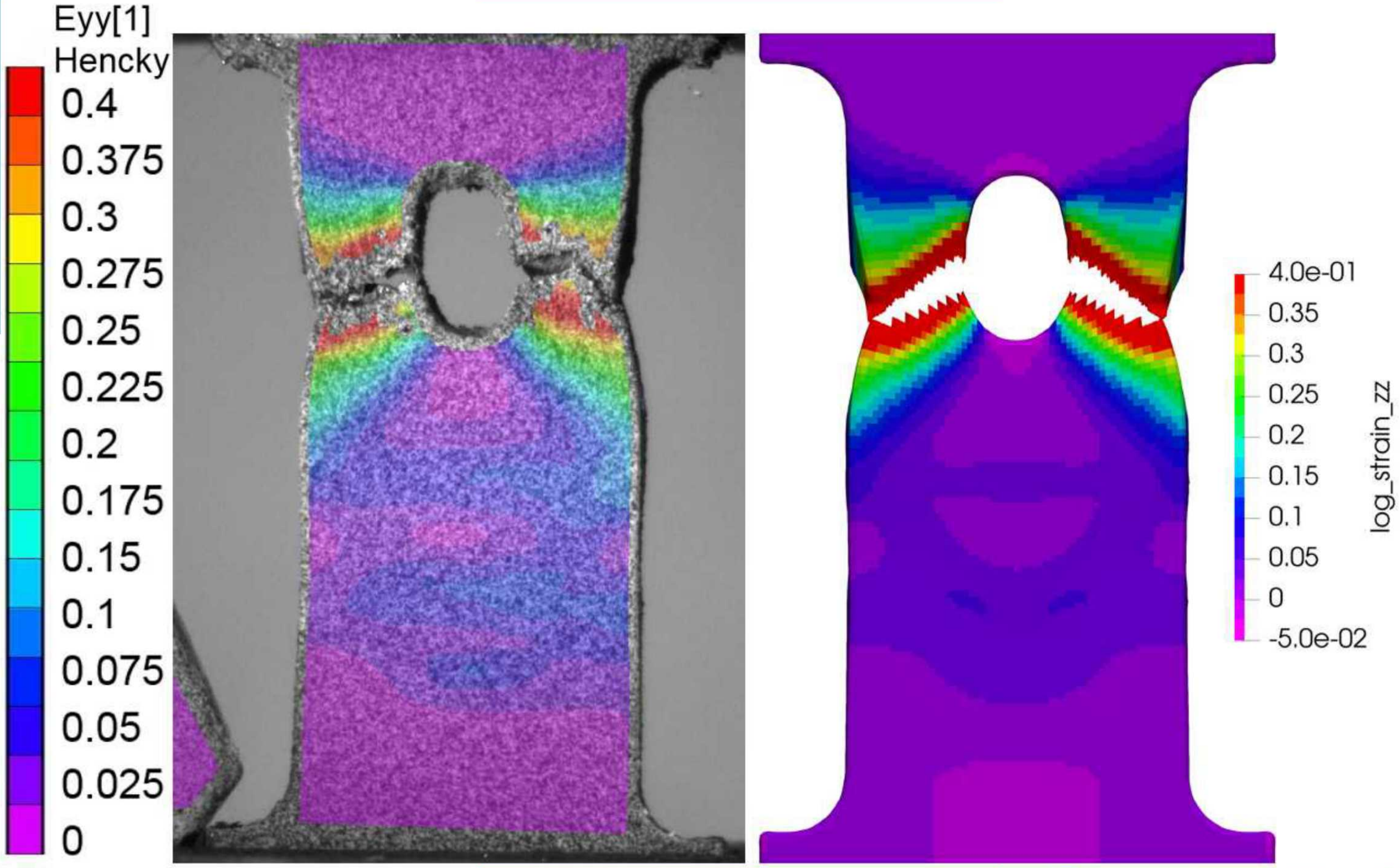

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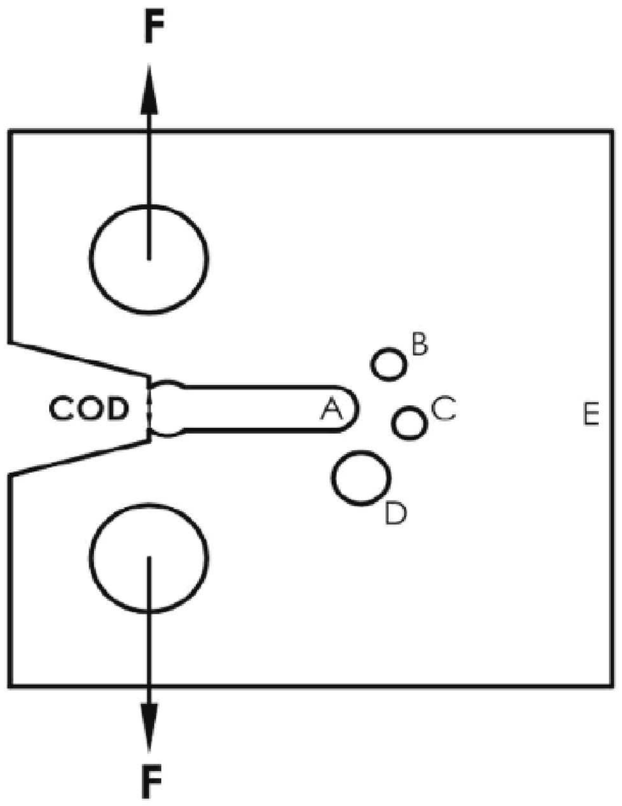
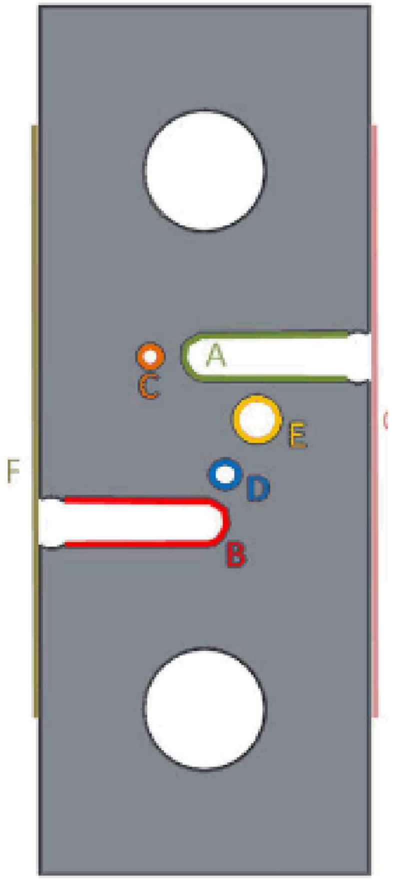
Gauging the state-of-the-art of fracture modeling: Blind prediction through the Sandia Fracture Challenge (SFC)

SFC - 2012



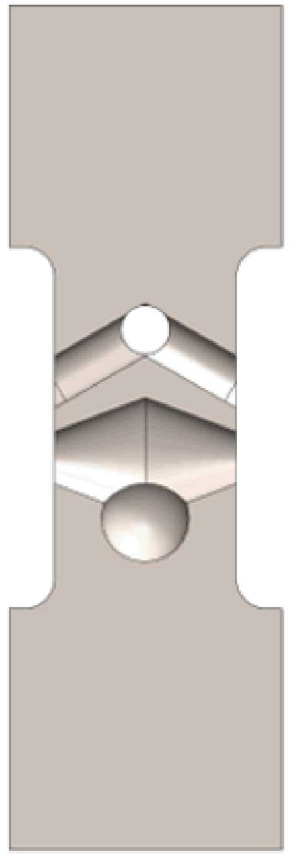
Quasi-static loading
Stainless steel

SFC2 - 2015



Quasi-static and dynamic loading
Higher Loading Rates

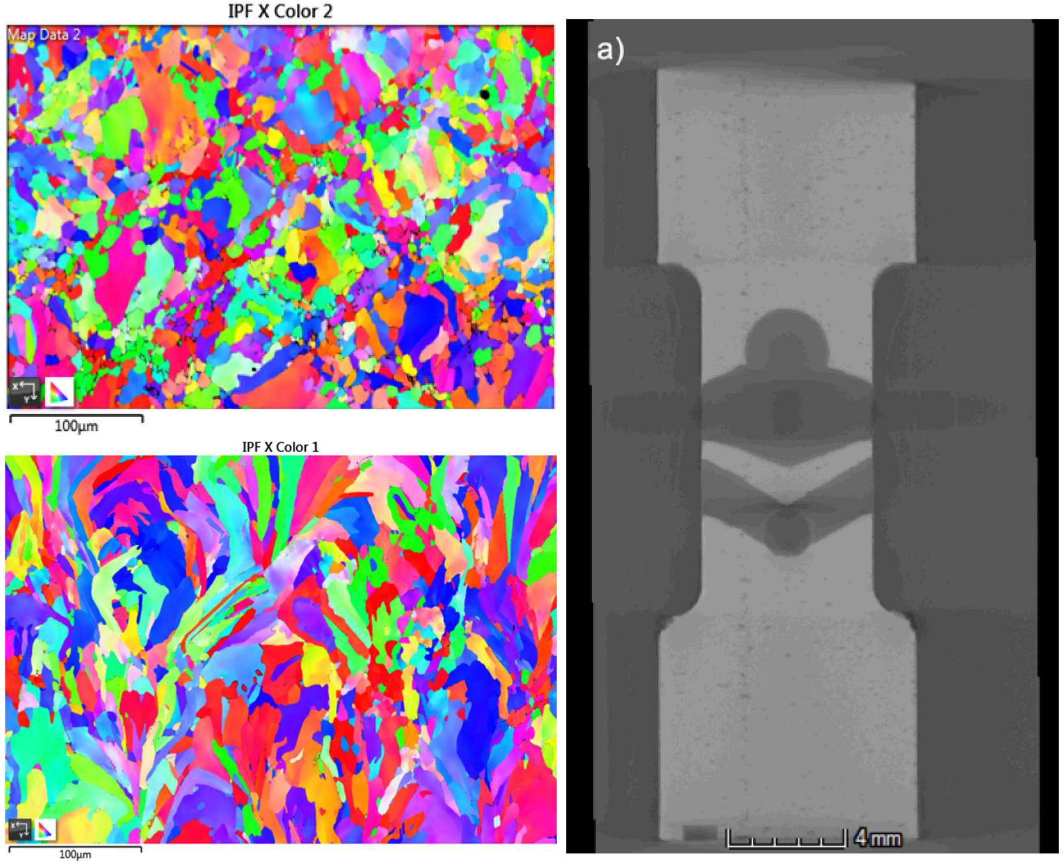
SFC3 - 2017



Complex inner geometry
AM component

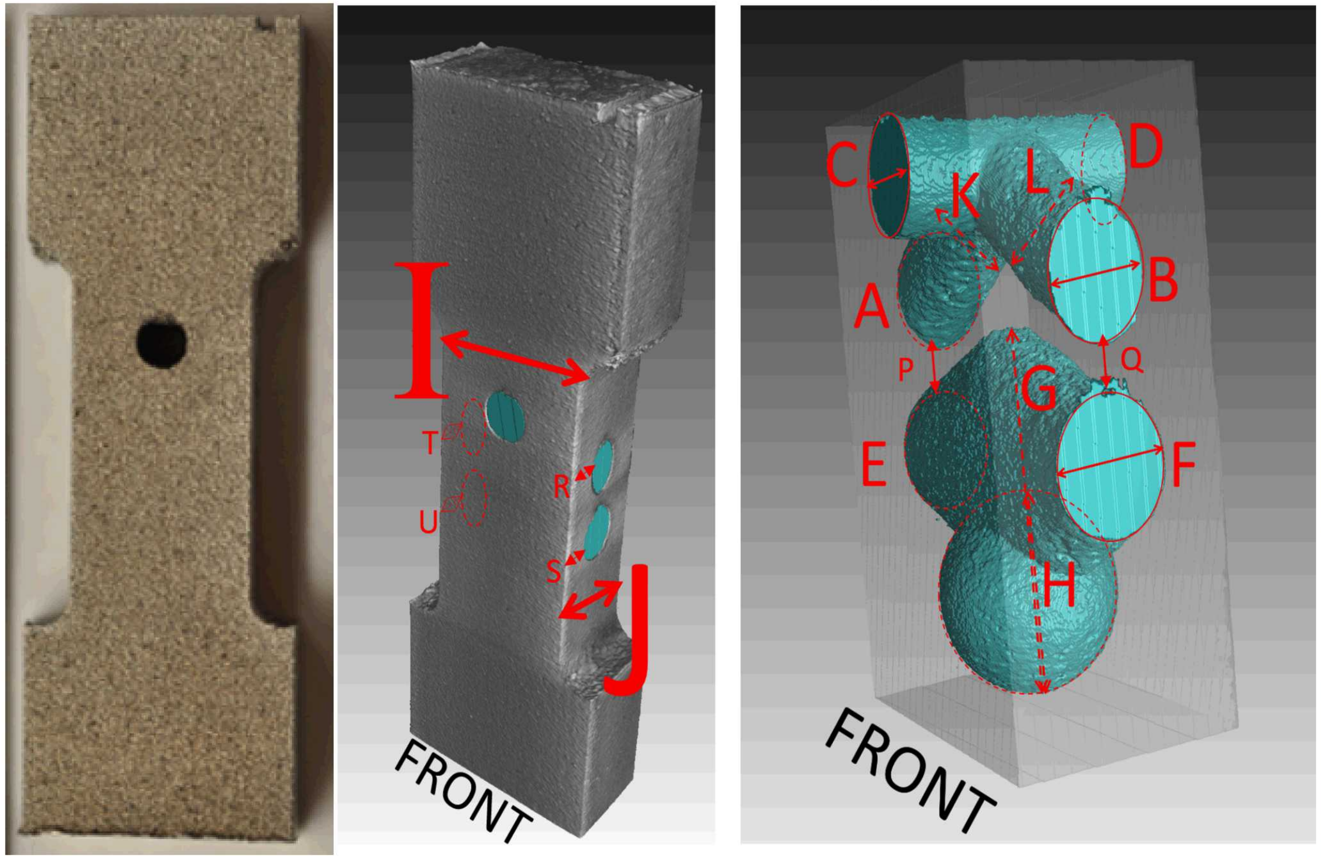
Modeling fracture for AM components is challenging

AM Material Variability



- Property variability
- Residual stresses
- Inhomogeneous
- Porosity and defect inclusion

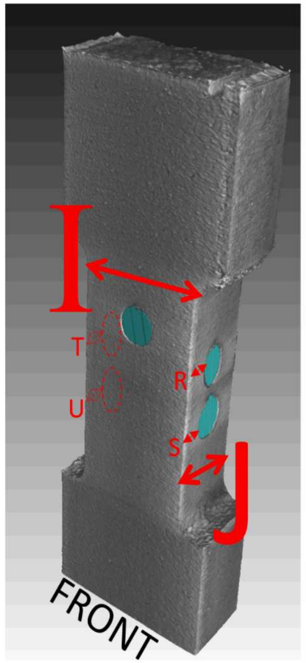
AM Component Geometry

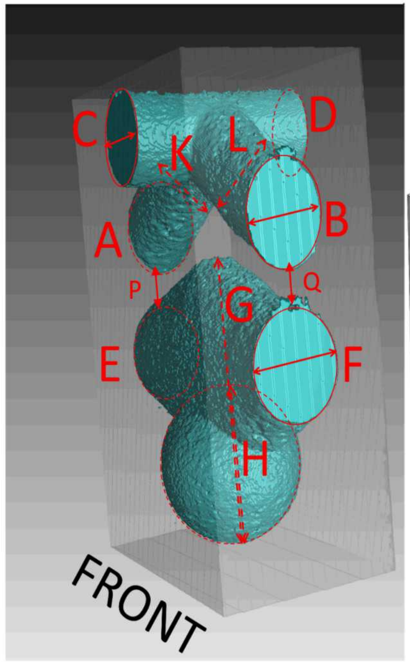


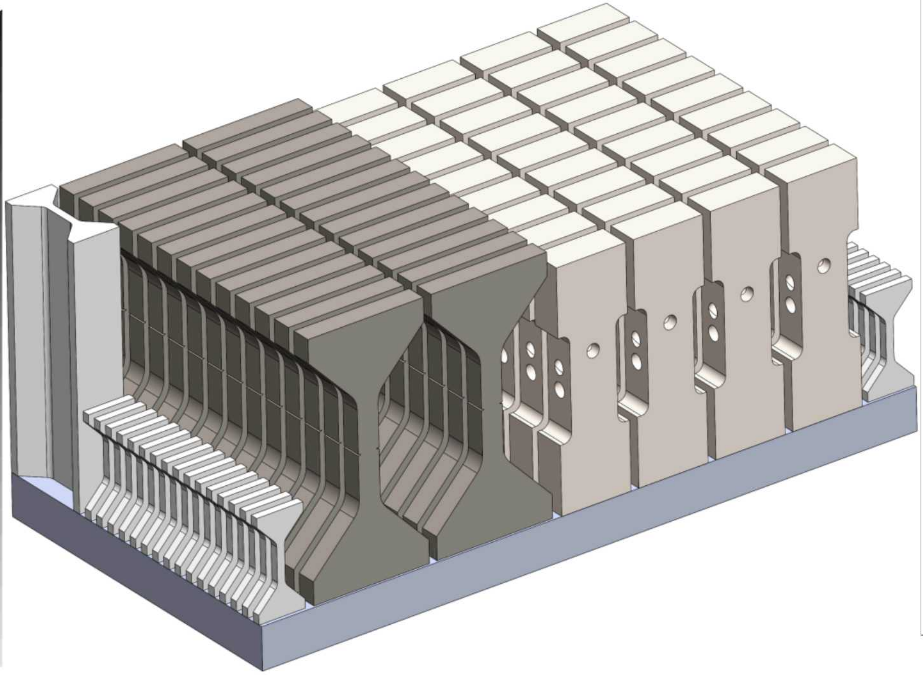
- Complex Geometry
- Non machinable
- Geometric variability
- Surface finish

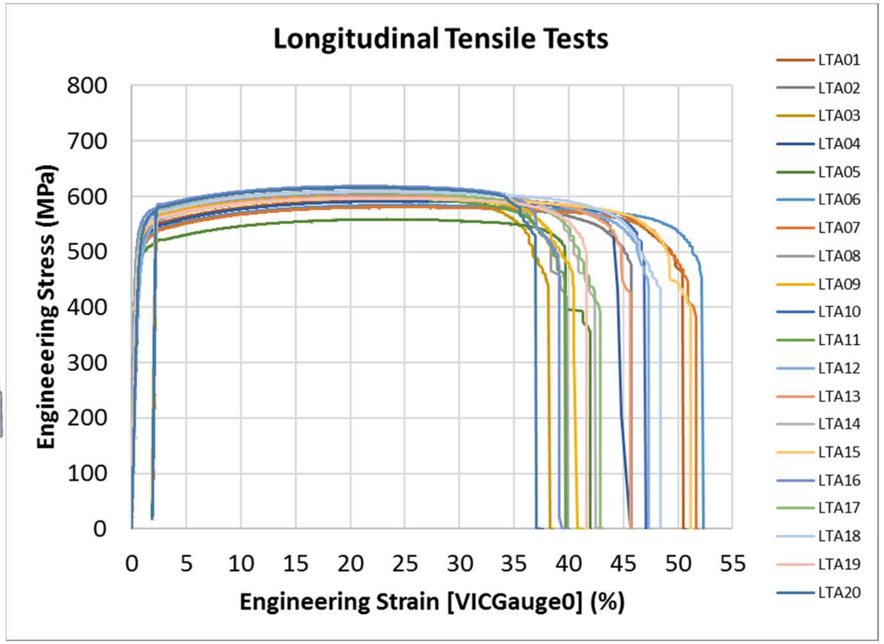
What was provided for the fracture challenge

- Detailed **geometric data** on specimen dimensions
- CT scan images for longitudinal, notched, and challenge coupons.
- **Porosity** distribution.
- Post-test fracture shape images for longitudinal, transverse, and notched coupons.
- Post-test SEM images of **fracture surface** for longitudinal and notched coupons.
- **Force vs gage displacement for longitudinal**, transverse, and notched coupons.



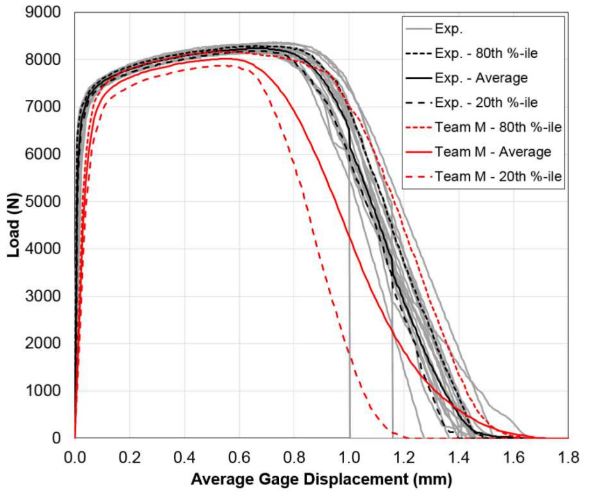




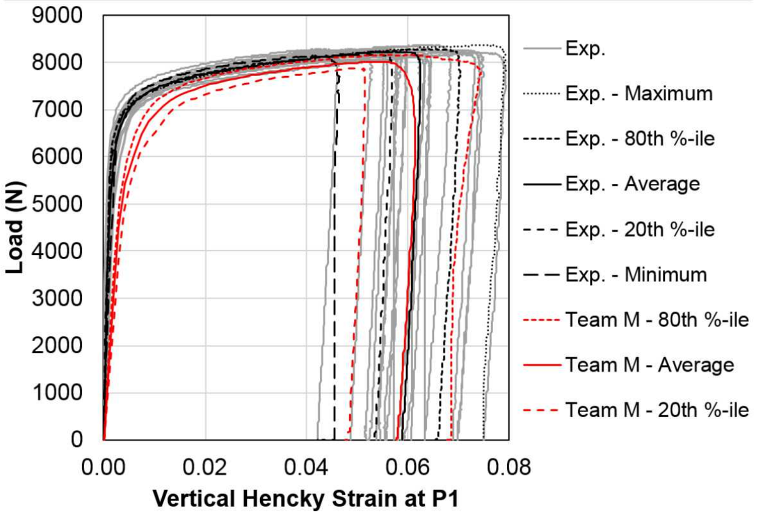


Questions asked to evaluate quality of predictions

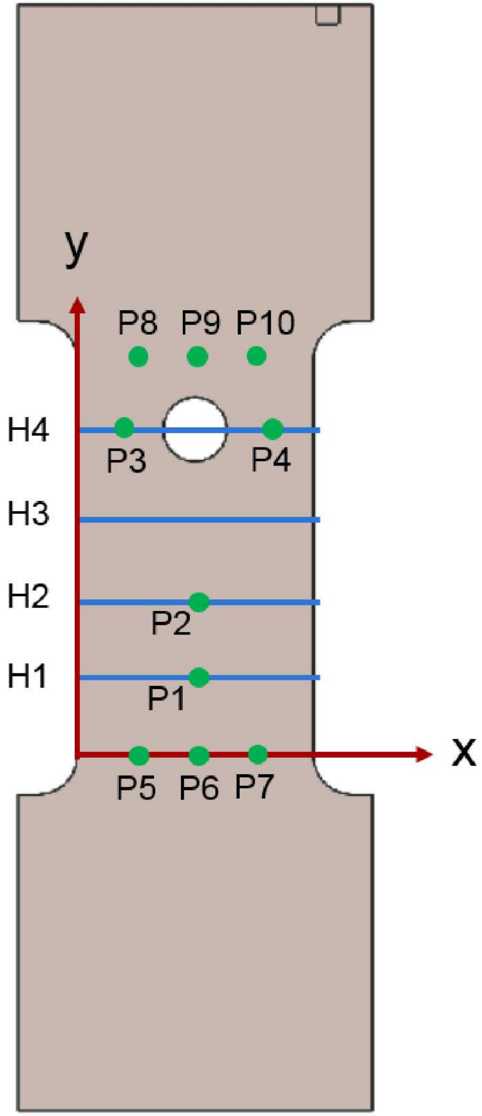
Load vs Displacement



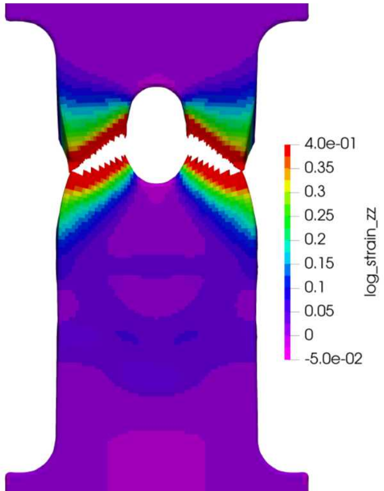
Load vs Strain



Local metrics

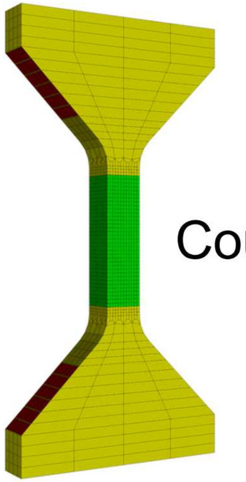


Fracture Path



Modeling fracture of the challenge problem using a nonlinear, rate- and temperature- dependent continuum model

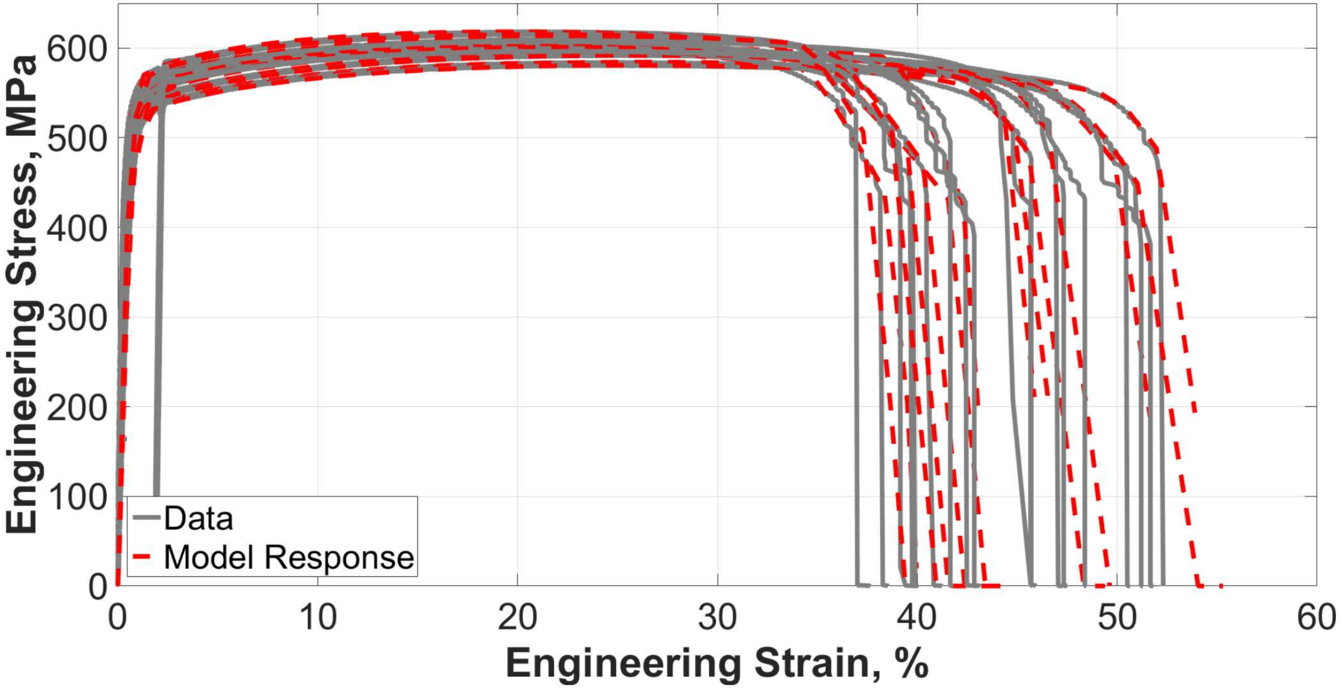
Hardening behavior: $\sigma = \sigma_y + A\epsilon_p^n$



Parameters Determined through Calibration:

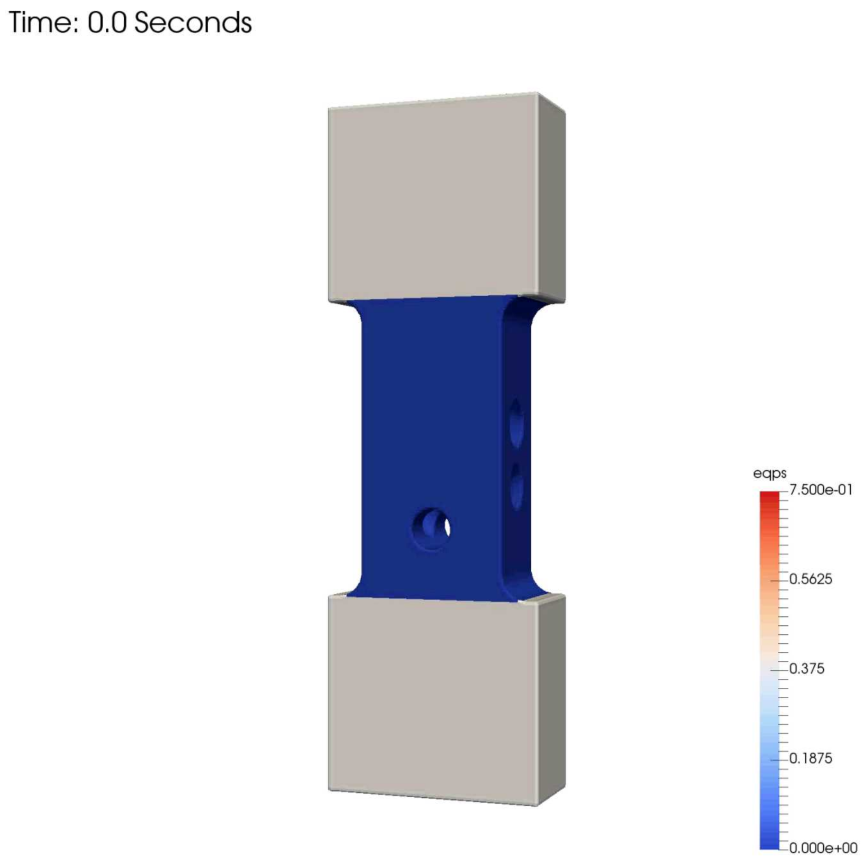
Parameter	Upper	Lower	Mean	Std. Dev.
A (MPa)	666.0	578.3	633.9	21.0
n	0.80	0.66	0.76	0.03
σ_y (MPa)	533.9	495.7	512.5	12.4
E (GPa)	189.0	83.9	129.5	26.2
f_d	0.90	0.55	0.80	0.12
f_ε	0.75	0.38	0.54	0.12
f_t	140.0	80.0	102.6	17.4

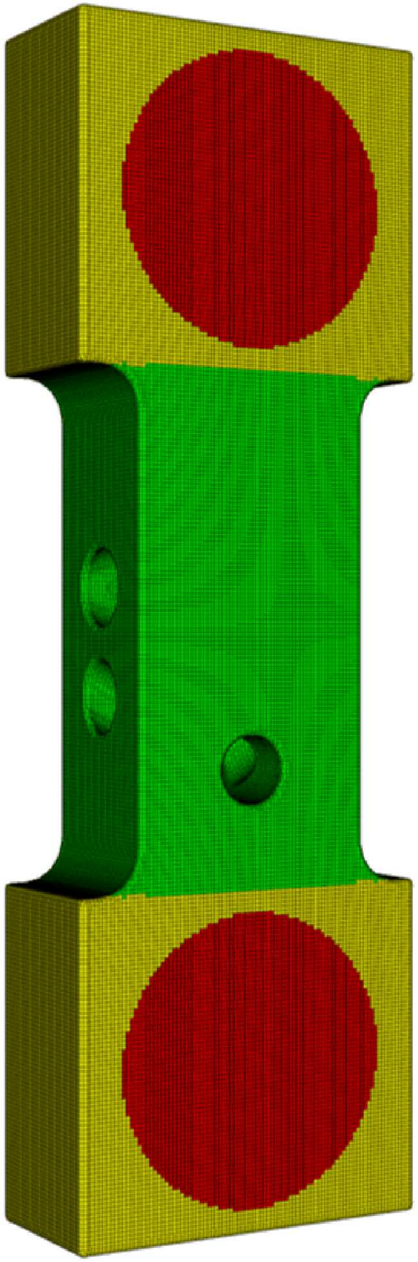
Coupon A Longitudinal Tensile Test Data and Model Results



Modeling approach for challenge coupon

- Implicit
- Thermally-coupled
- Transient dynamic model for challenge geometry.



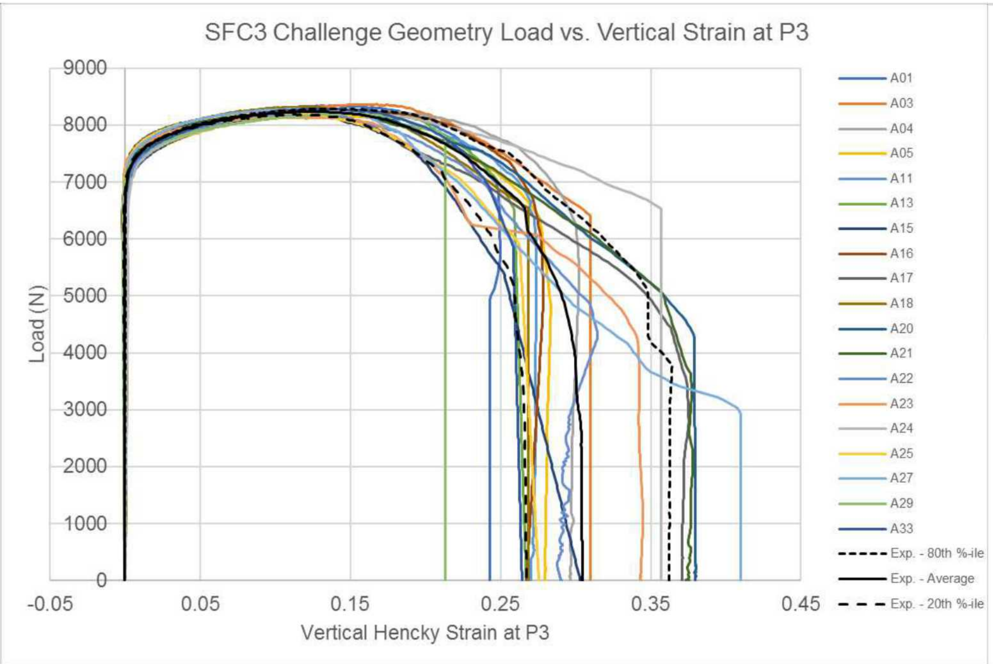


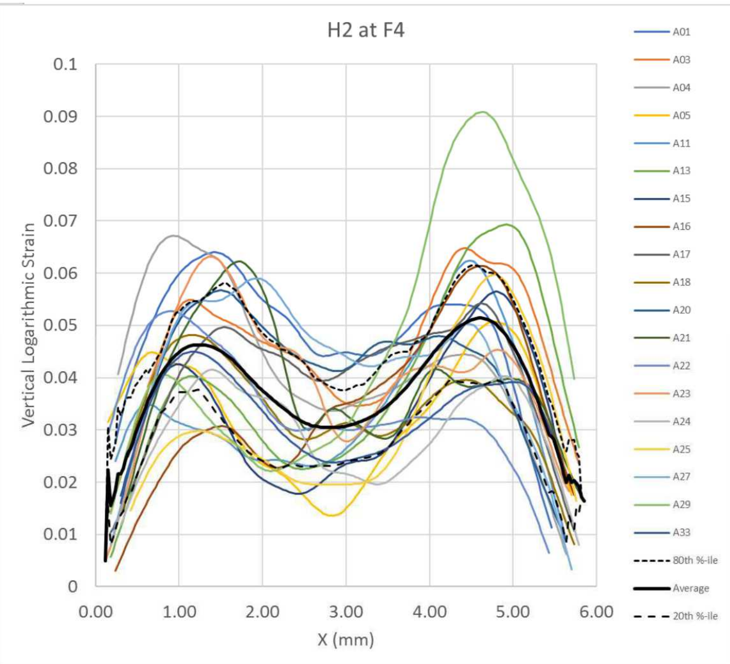
Challenge Experimental Results

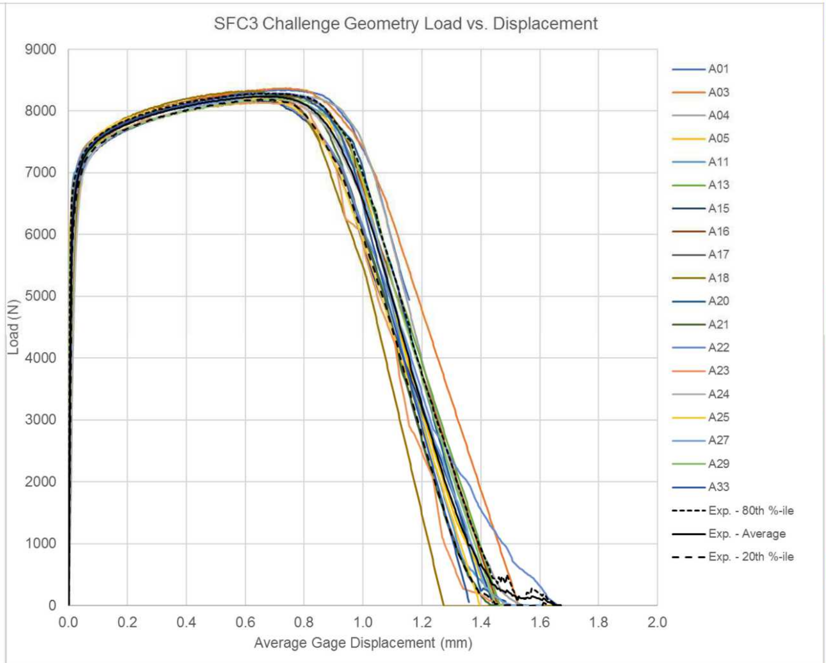
- 19 sets of experiments
- Load displacement curves
- Digital Image Correlation (DIC) strain gauges
- Line samples at force levels
- DIC at crack initiation and failure

Crack Initiation

Failure

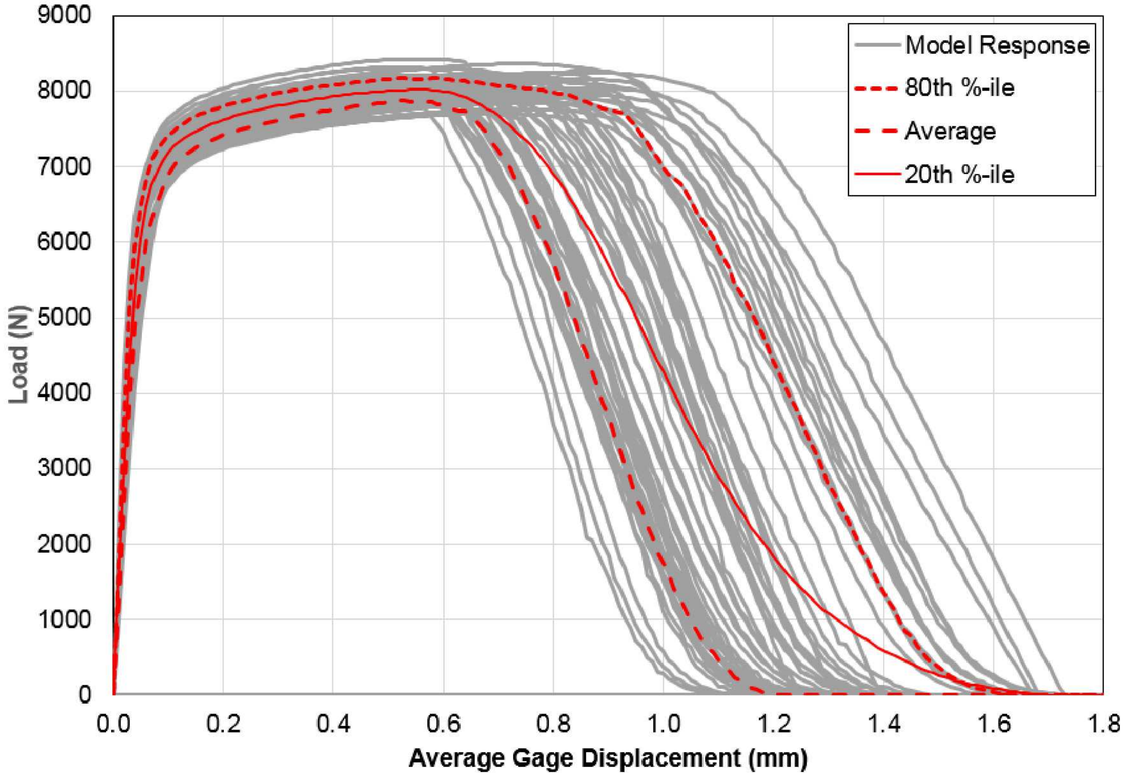




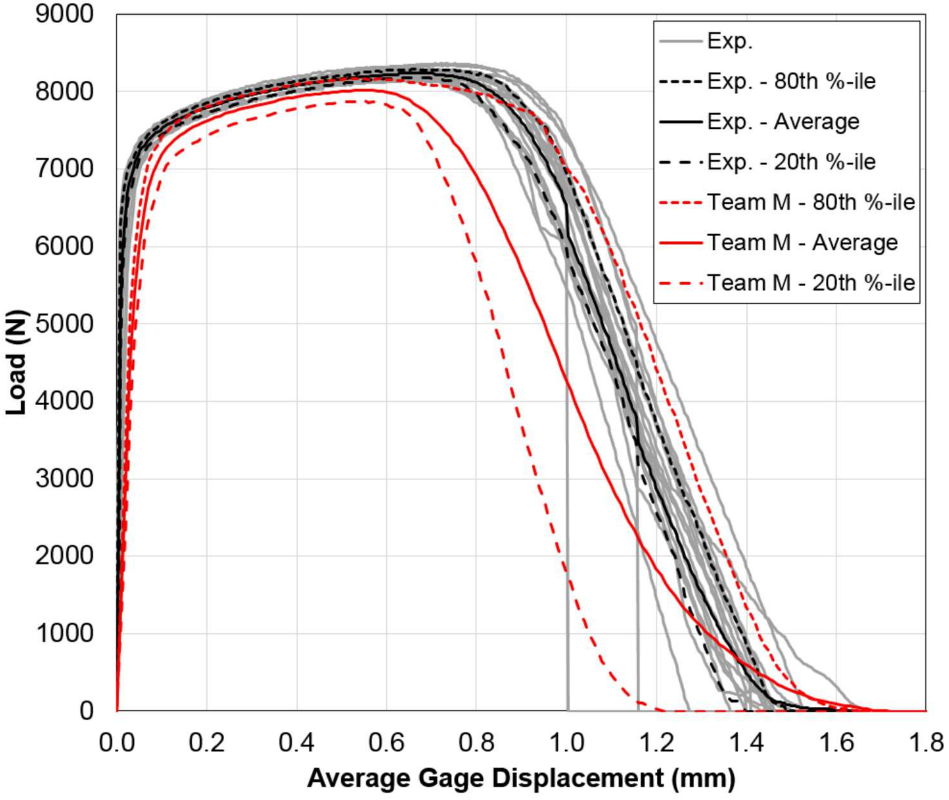


Comparison with blind prediction: Applied load vs. gauge displacement

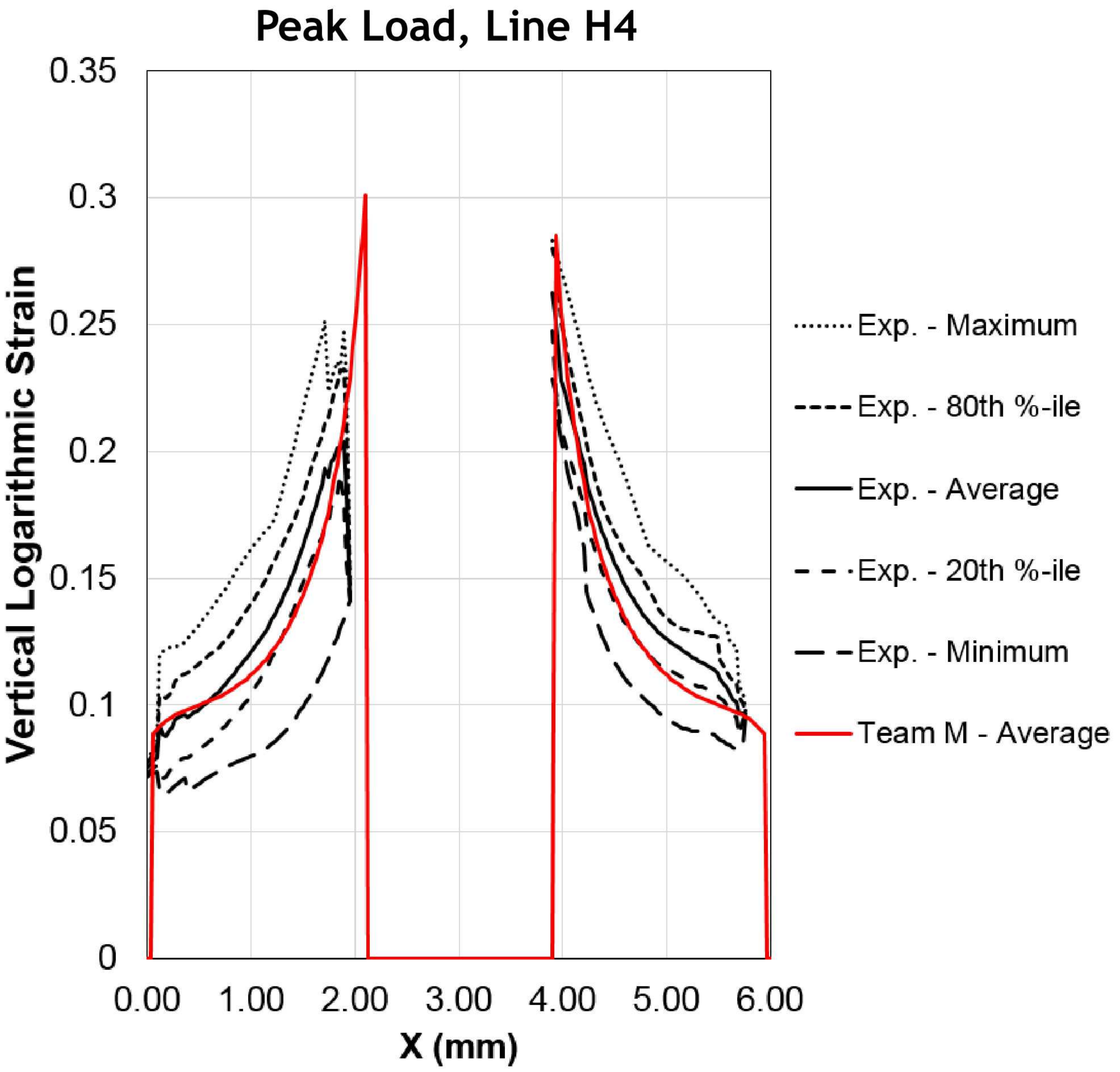
Challenge Coupon Blind Prediction Model Results

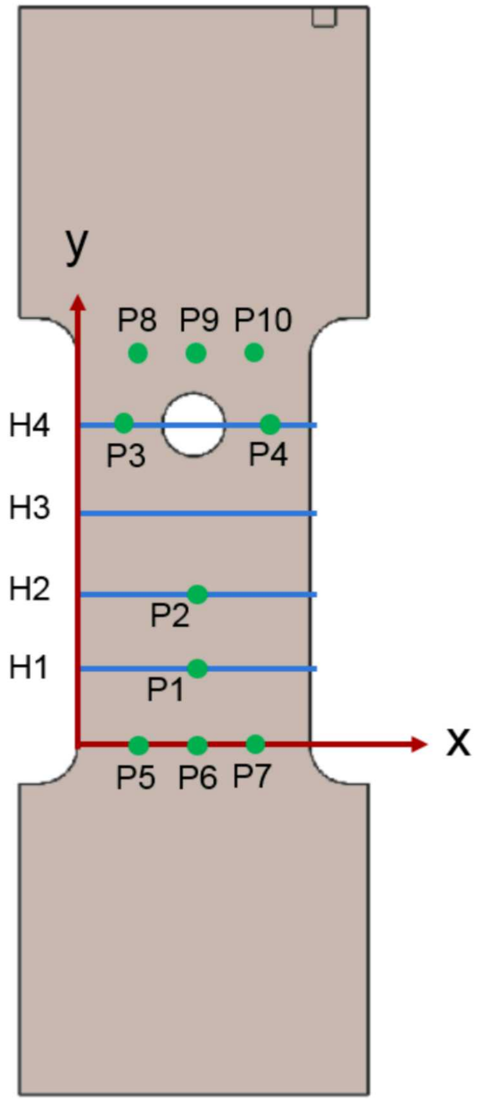


Challenge Coupon Experimental and Model Results



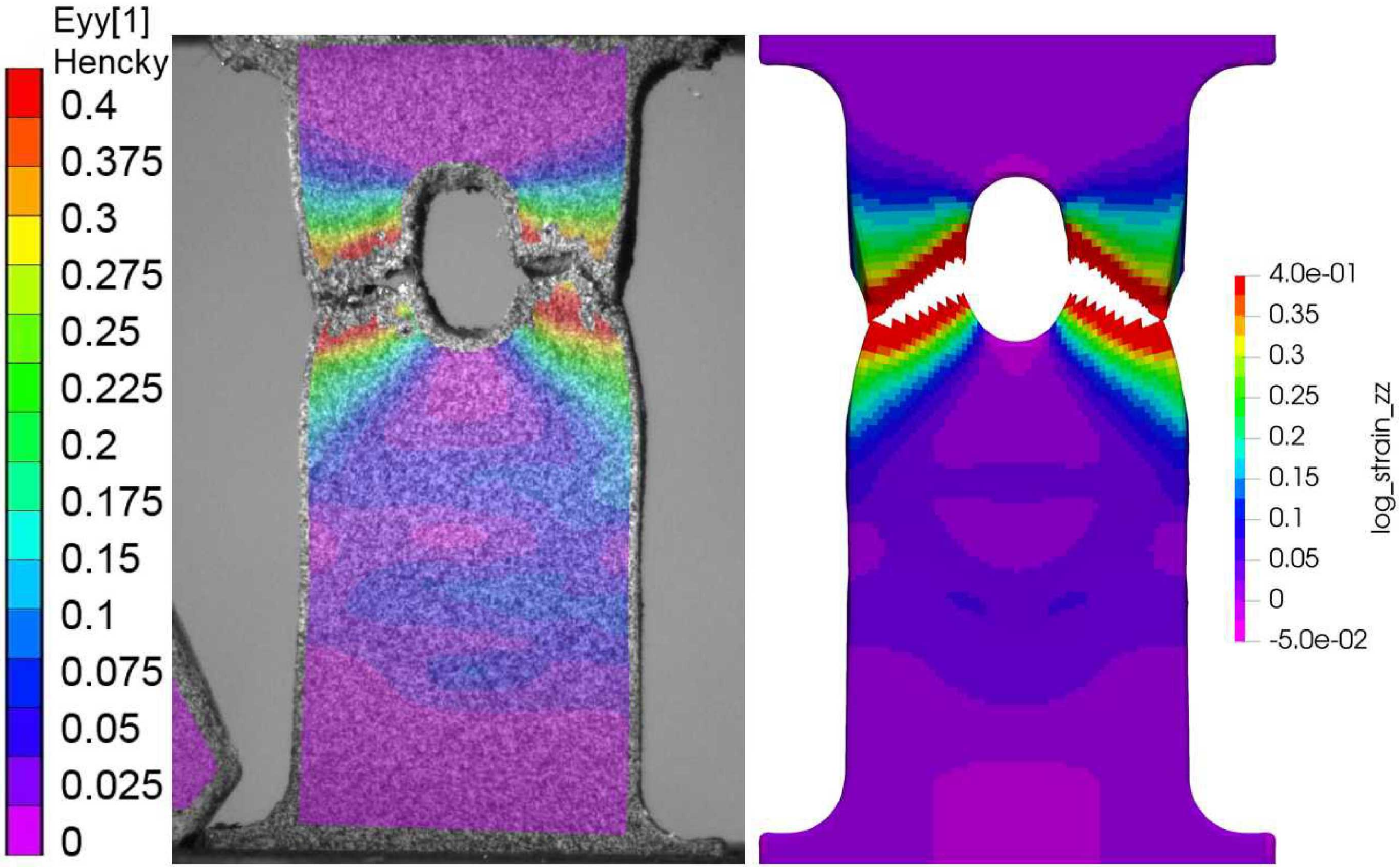
Comparison with blind prediction: Load concentration





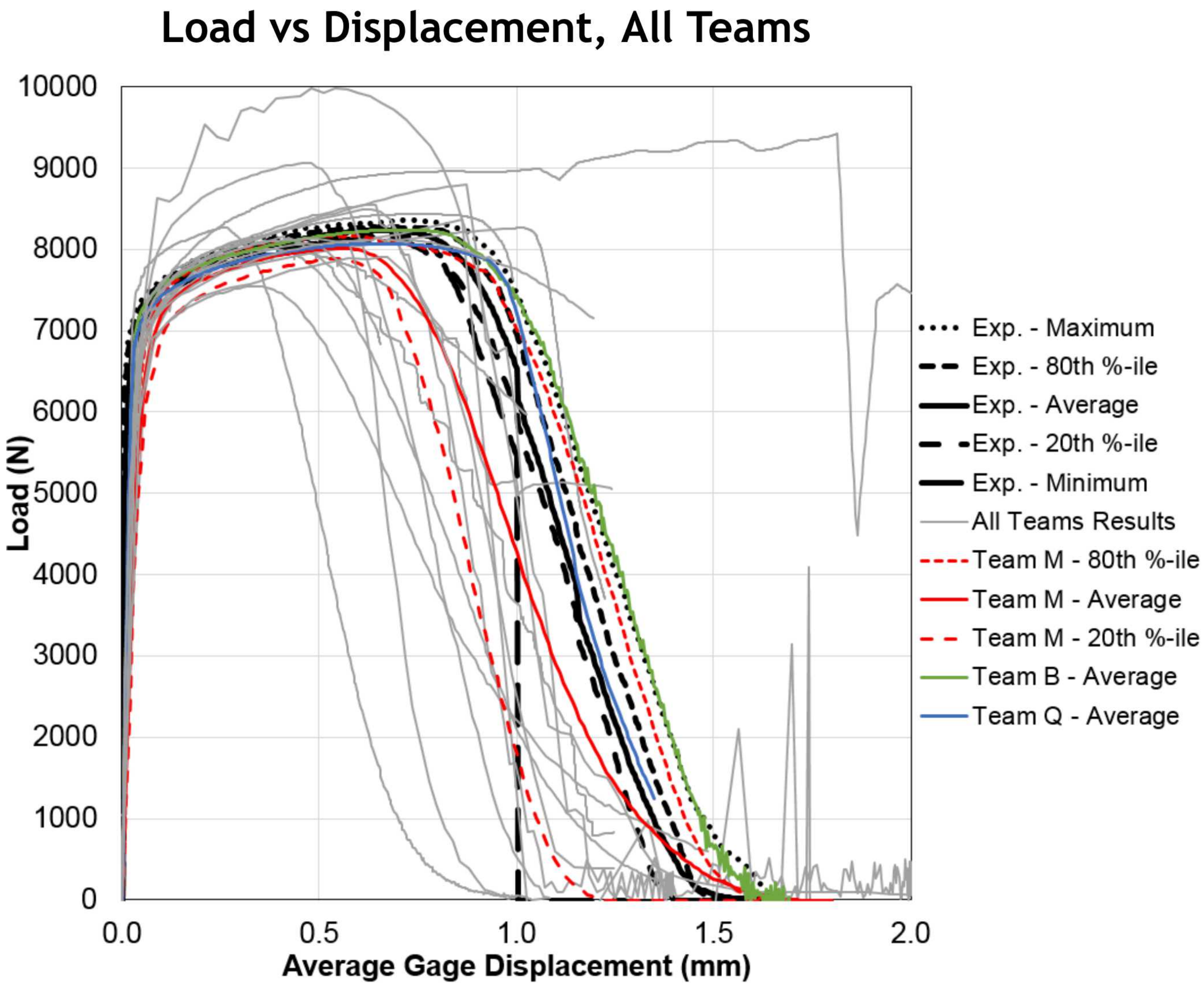
Comparison with blind prediction: Local strain field and fracture profile

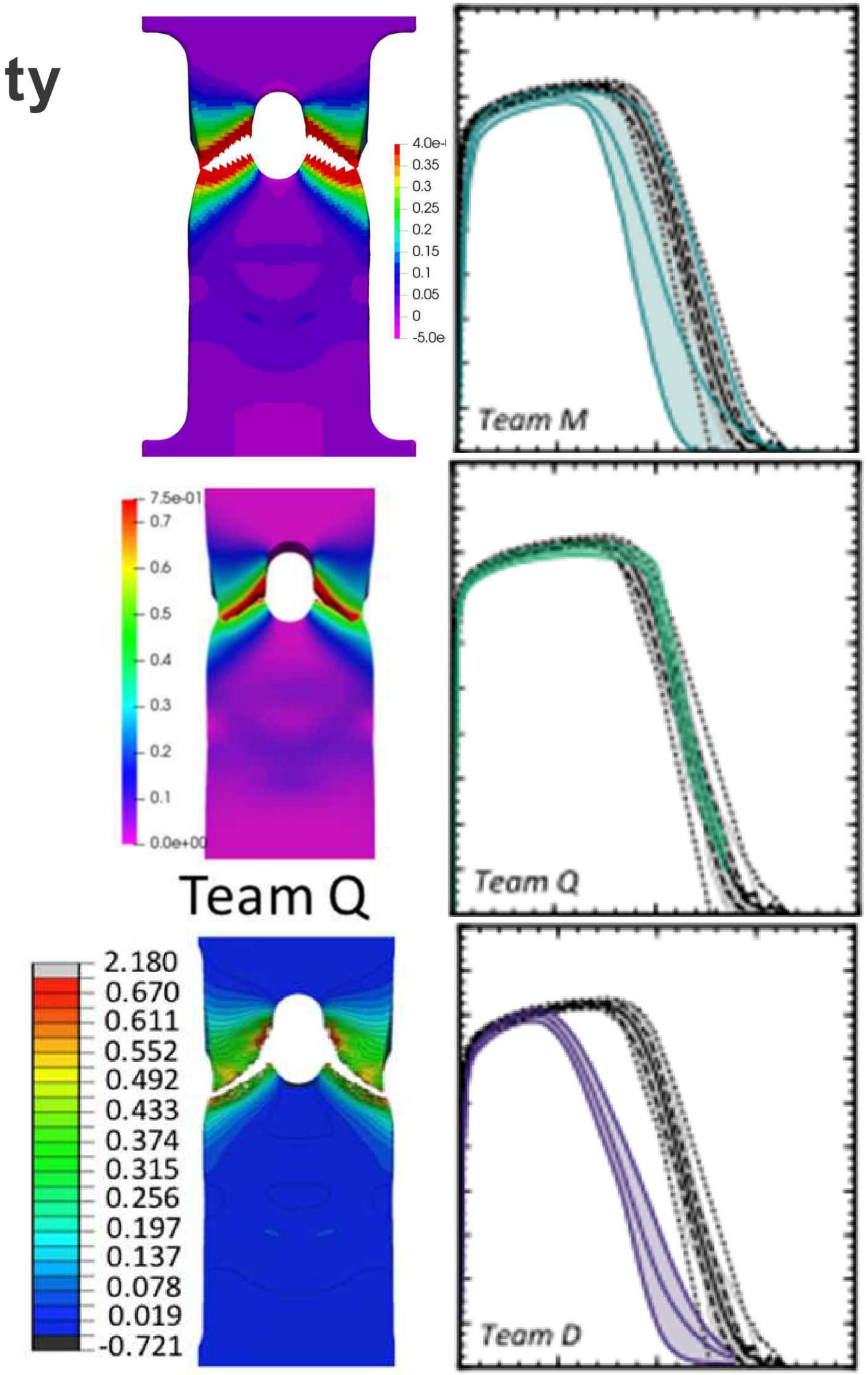
Challenge Coupon Surface Strain Profile at Coupon Failure



Comparison with the modeling community

21 teams participating.





Observations and conclusions

Possible sources of **discrepancy between prediction and results**:

- Size effects.
- Surface finish.
- Variability of material properties.

Where are we in terms of modeling fracture?

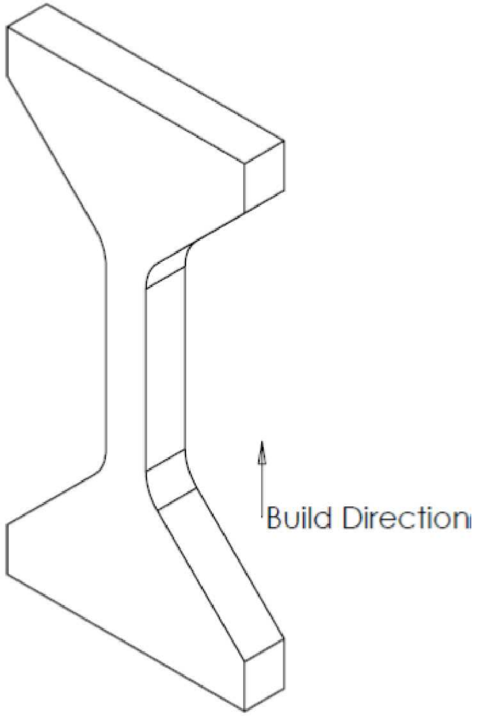
- Challenge did not capture coupling between material variability (AM processes) and complexity of geometry (AM components).
- Response of coupon insensitive to some of the characteristics of AM components.
- Some of the teams that did well used simple approaches.

EXTRA SLIDES

Parameter Determination

Parameters Determined Through Calibration:

A	Power Law Coefficient	Step 1
n	Power Lax Exponent	Step 1
σ_y	Initial Material Yield Stress	Step 1
E	Young's Modulus	Step 1
f_d	Failure Decay	Step 2
f_ϵ	Fracture Toughness	Step 2
f_t	Failure Strain in Uniaxial Tension	Step 2



Coupon A

Calibration Process:

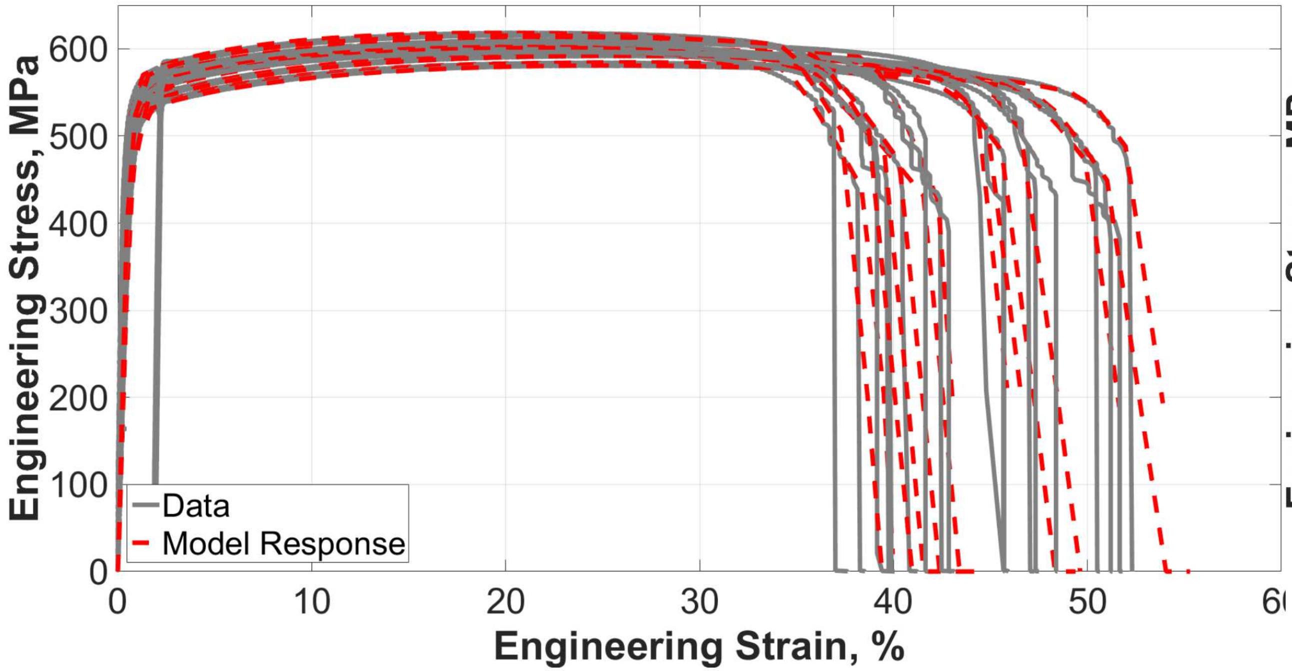
- **Step 1**: A, n, σ_y, and E values determined for each of the longitudinal tensile tests (Coupon A), failure disabled in model.
- **Step 2**: f_d, f_ϵ, and f_t determined based on failure response, using values found through Step 1.

Parameter Determination

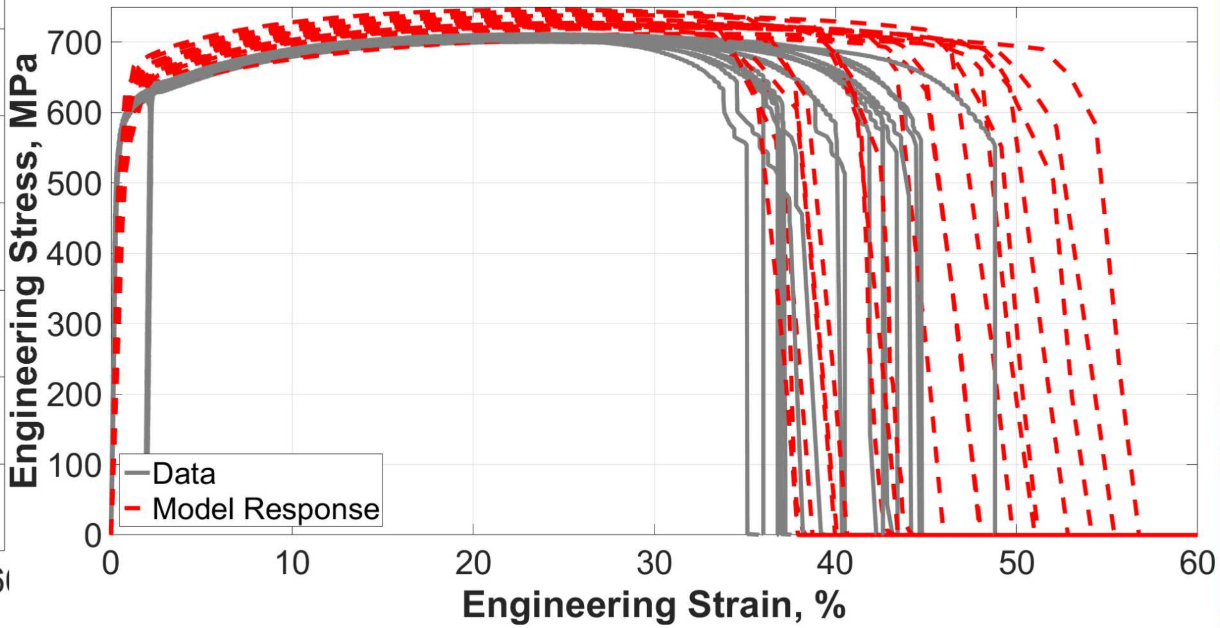
Transverse coupon A data was used to determine scaling parameters for the shape of the Hill yield surface.

- Model was revaluated for the transverse build direction using the previously determined parameters.

Coupon A Longitudinal Test Data and Model Results



Coupon A Transverse Test Data and Model Results

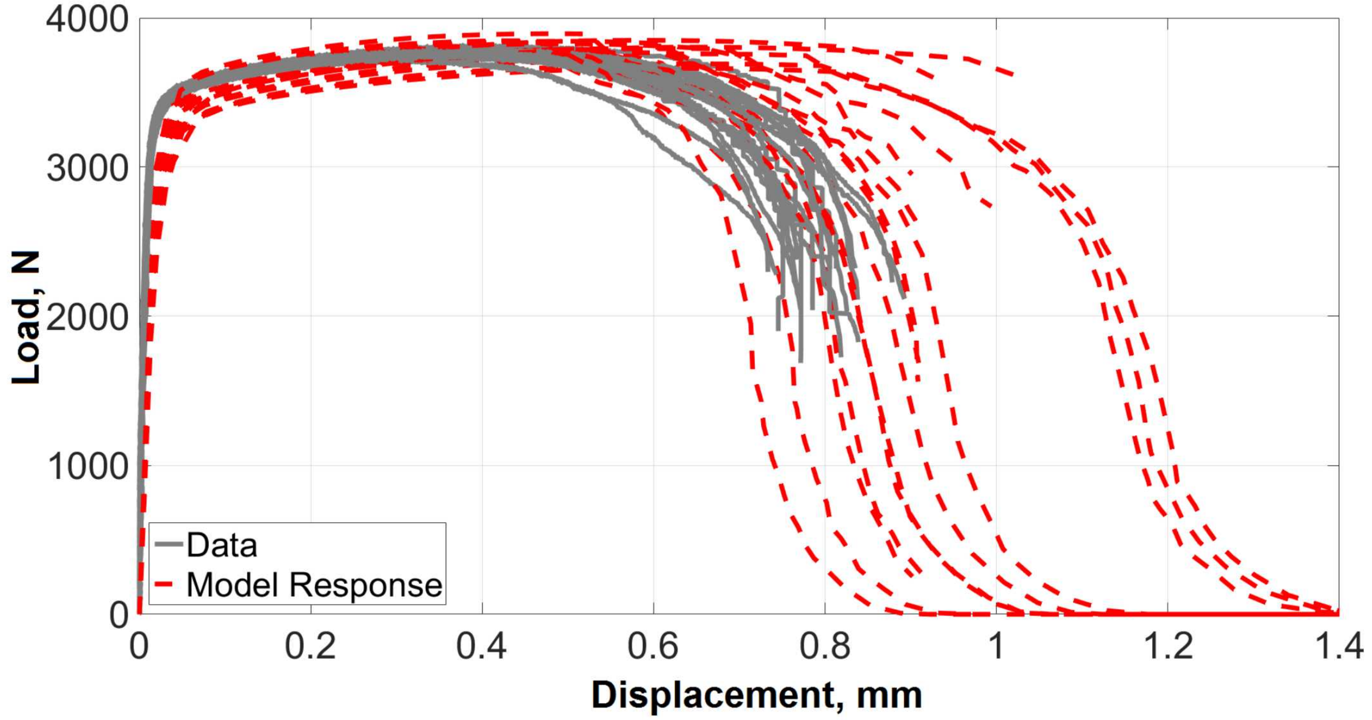


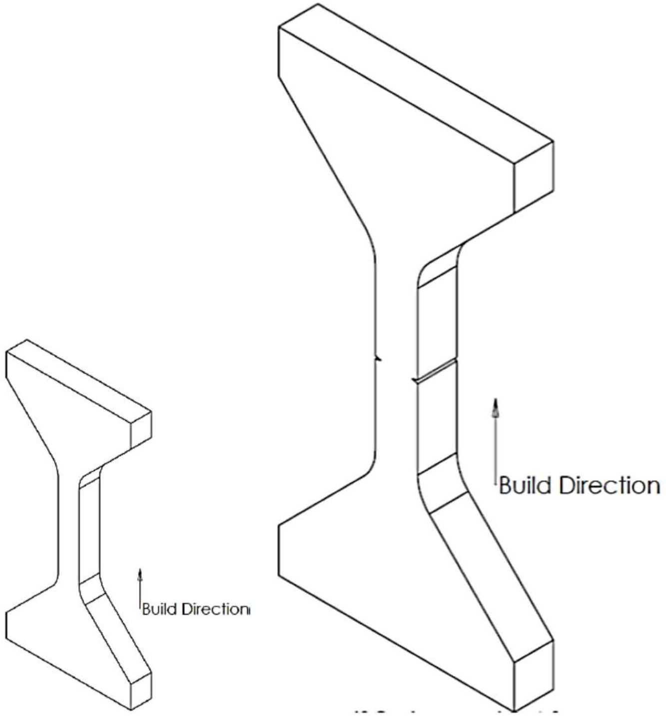
Parameter Determination

Coupon B used for comparative purposes.

- Similar size to challenge geometry
- Not used during parameter determination, model evaluated at previously determined parameters from Coupon A.

Coupon B (Notched) Test Data and Model Results





Coupon A

Coupon B