Using Mid-stage Validation to Increase Confidence in Simulation of TPOs

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Objective

- Create a process to validate solver+ simulation inputs before real-life application
- Benefits
  - increase confidence
  - reduce risk
  - save time

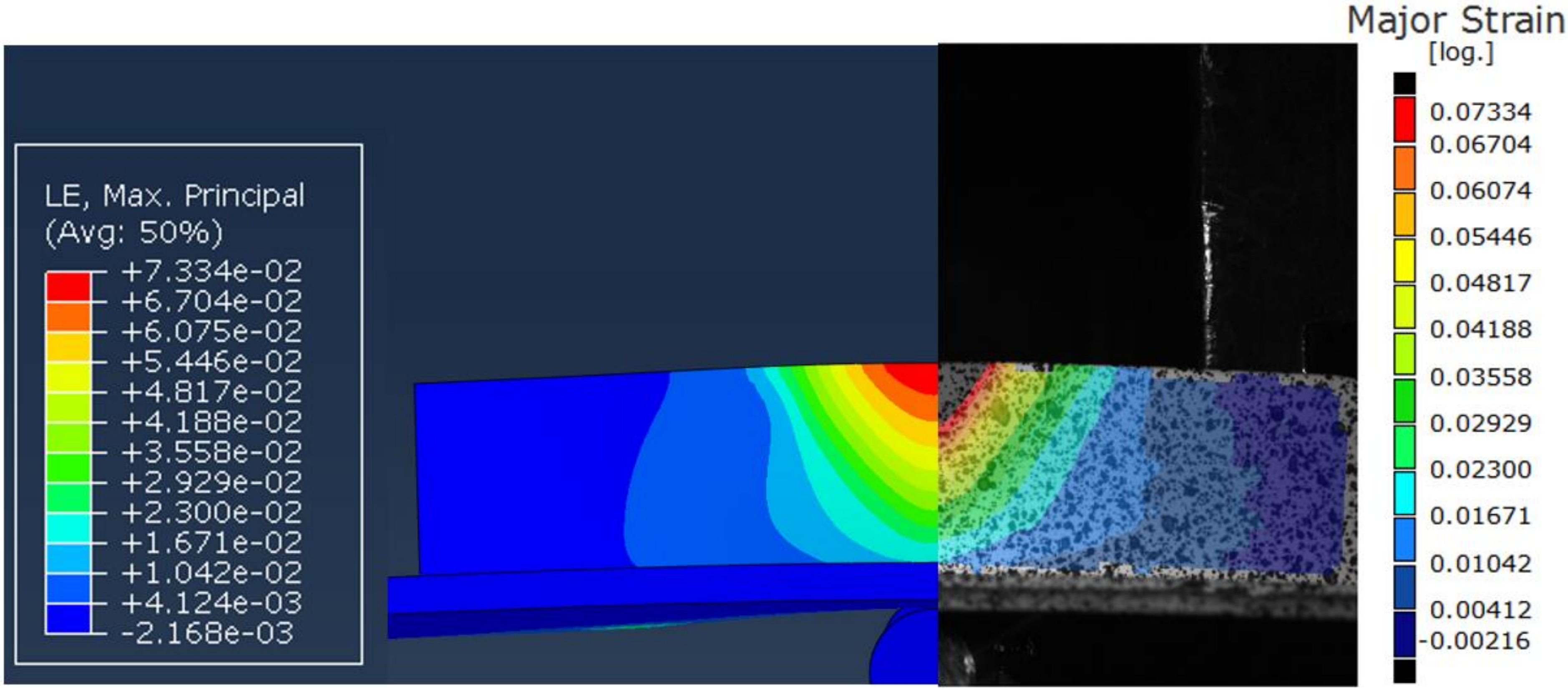
CAETestBench Validation Mechanism

- Use a standardized geometry
  - May not be real-life part
- Test must be ‘perfect’
  - Boundary conditions can be correctly simulated
  - Load case can be correctly simulated
- Comparison
  - Obtain test output that is also available in simulation
  - For example, DIC strain pattern, force v. time…

Overview of this Validation

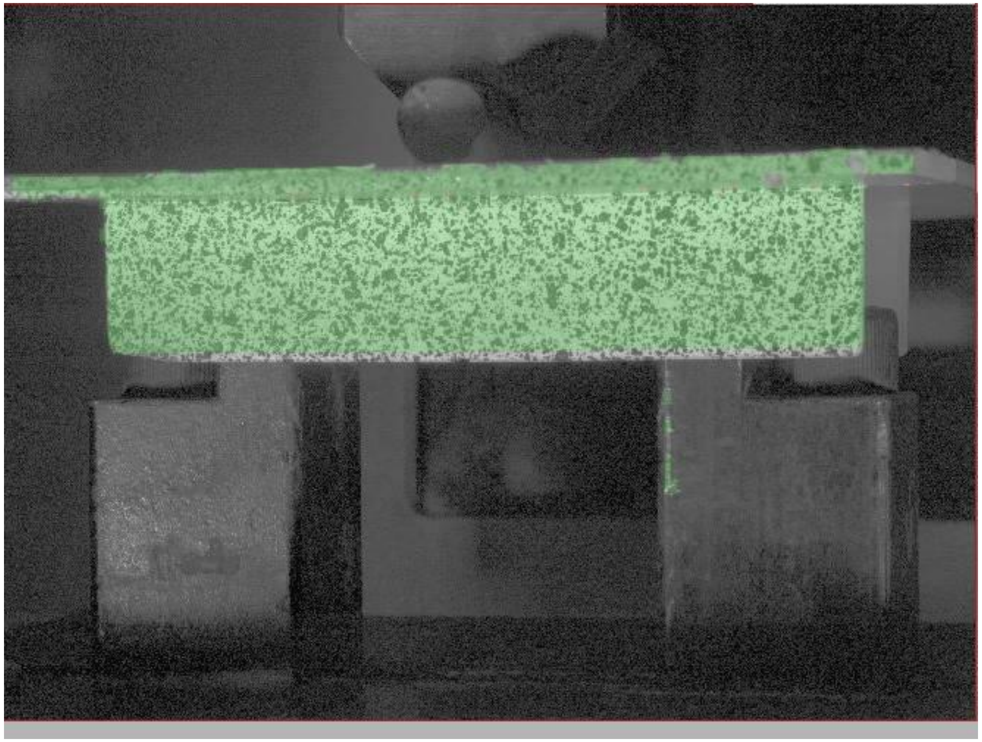
- Measure properties
- Obtain material model parameters
- Perform open loop validation
  - not a test used to create the material model
- Simulate and compare to experiment with DIC
- Quantify simulation accuracy

Case 1: Ribbed Plaque 3 Point Bend



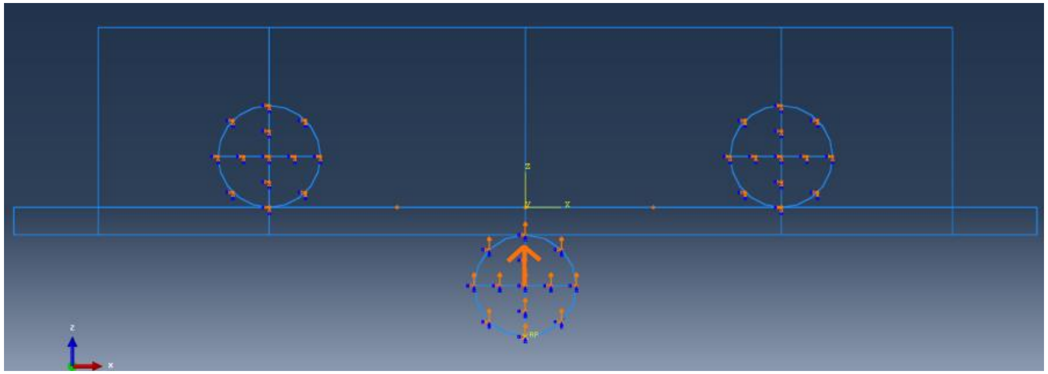
Test Setup

- Instron 8872 universal testing machine (UTM)
- 1 mm/min displacement of nose
- Apply speckle patter to part to allow use of DIC strain capture
- Two camera DIC to capture 3D strain



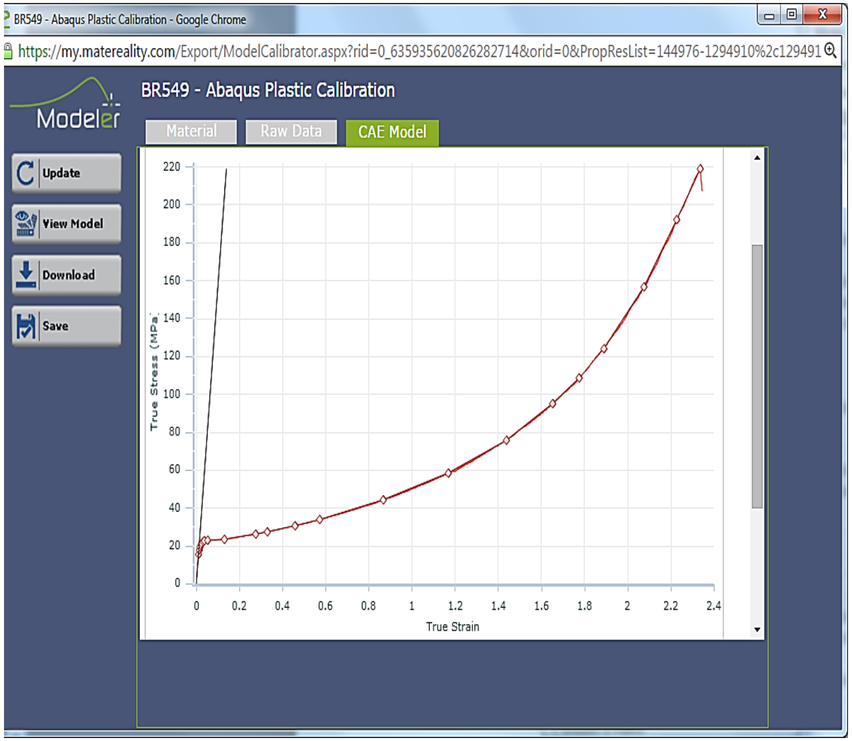
Simulation Setup

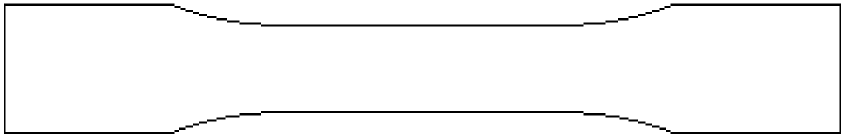
- Nose pin:
  - Constrained in all DOF with 2.5mm displaced in Z (Quasi-Static)
- Fixed Support pins
- Part geometry constrained to prevent rigid body movement in the x y direction
- Contact applied in initial step
- Element Formulation: C3D8R (Hex)
- Mesh: 2.25 mm^2



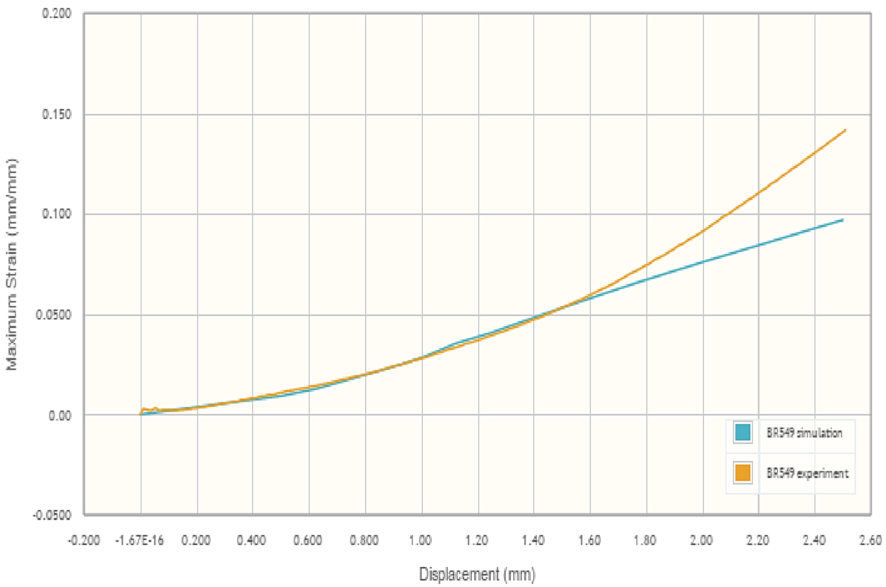
Material Model

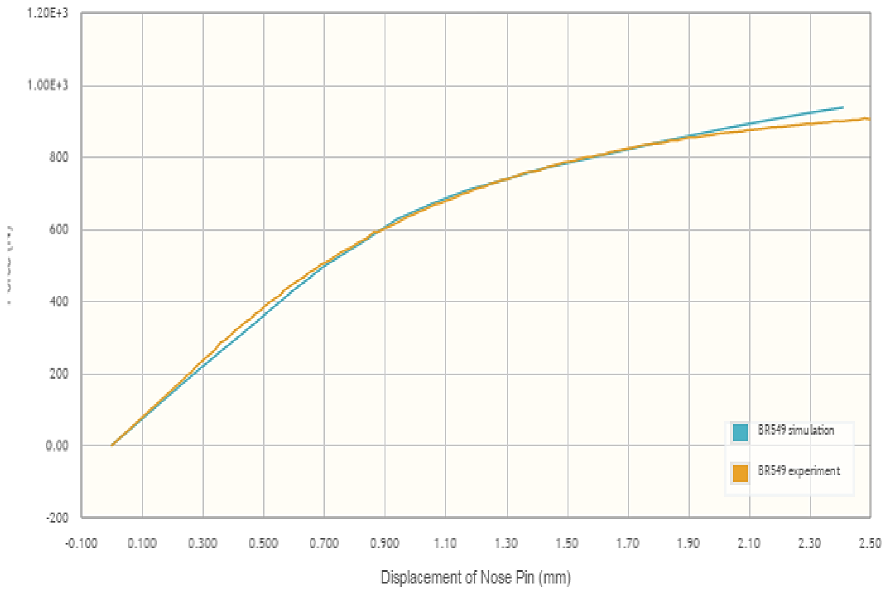
- Tensile and Density Tests
- Elastic
  - E = 1572 [MPa]
  - υ = 0.29
- Plastic curve (Right)
- Density
  - ρ = 7.9 E-06 [tonne/mm^3]
- Measured at QS speeds





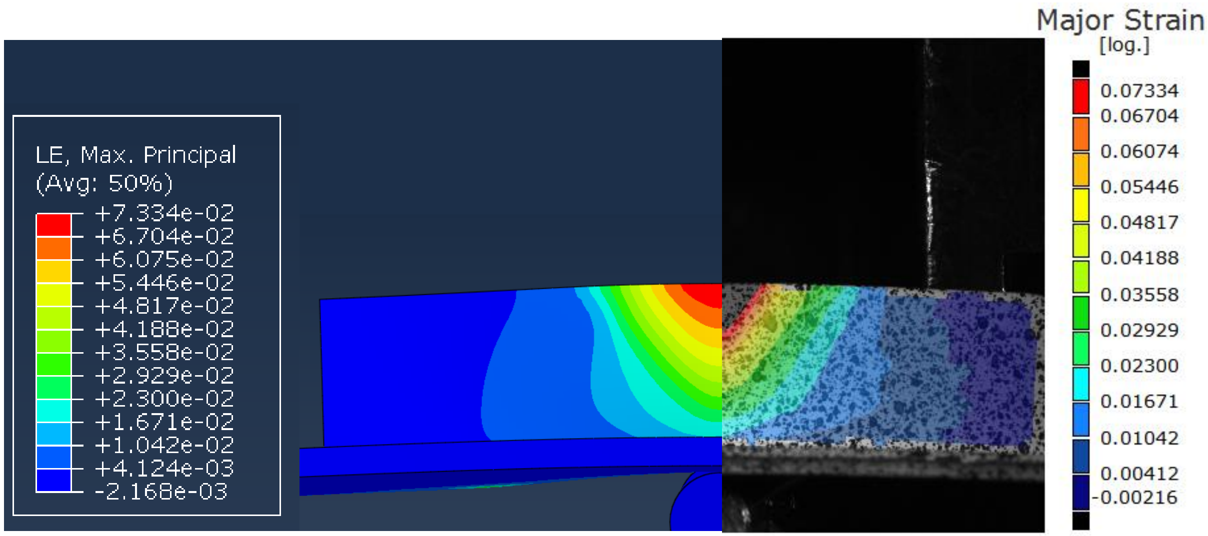
Comparison Simulation to Experiment





- Strain vs. Displacement
  - Diverges after 2 mm
- Force vs. Displacement
  - Similar response throughout

Side by Side Comparison of Strains

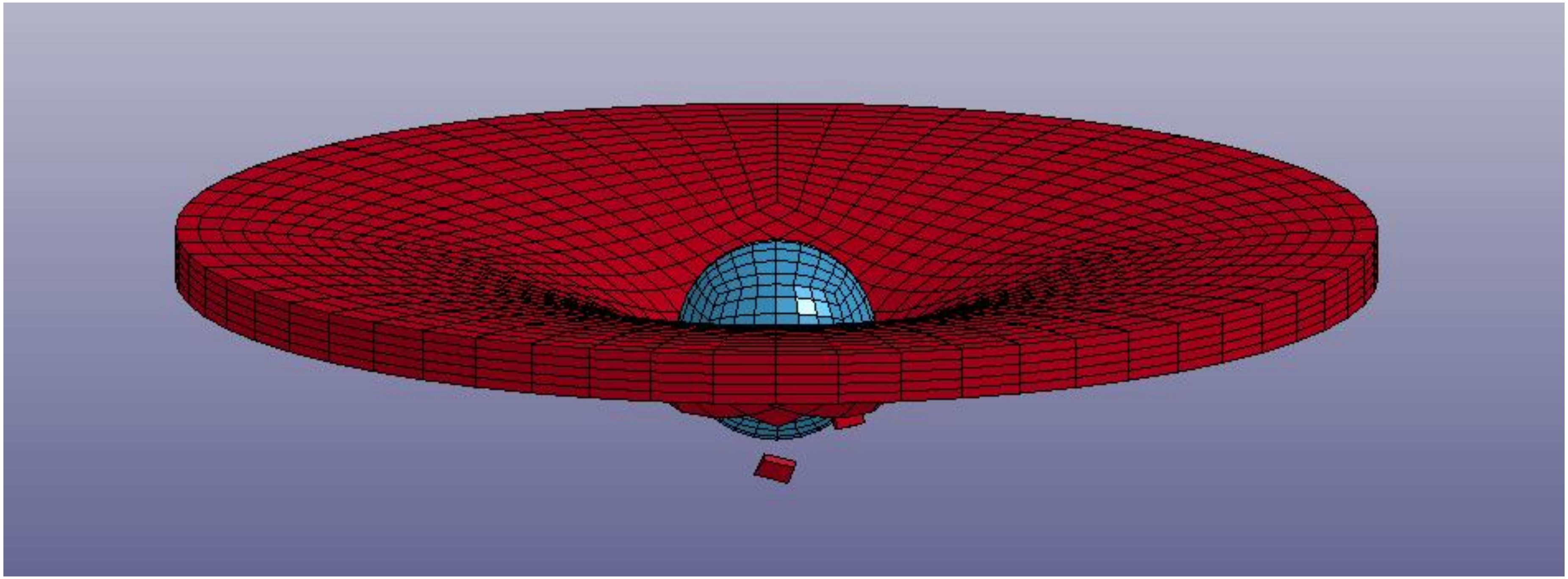


- Matched the strains in the legend for the DIC image for easy comparison
- The lower strains match closely but the shape of the higher strains on the experiment end up more triangular than the simulation

Results

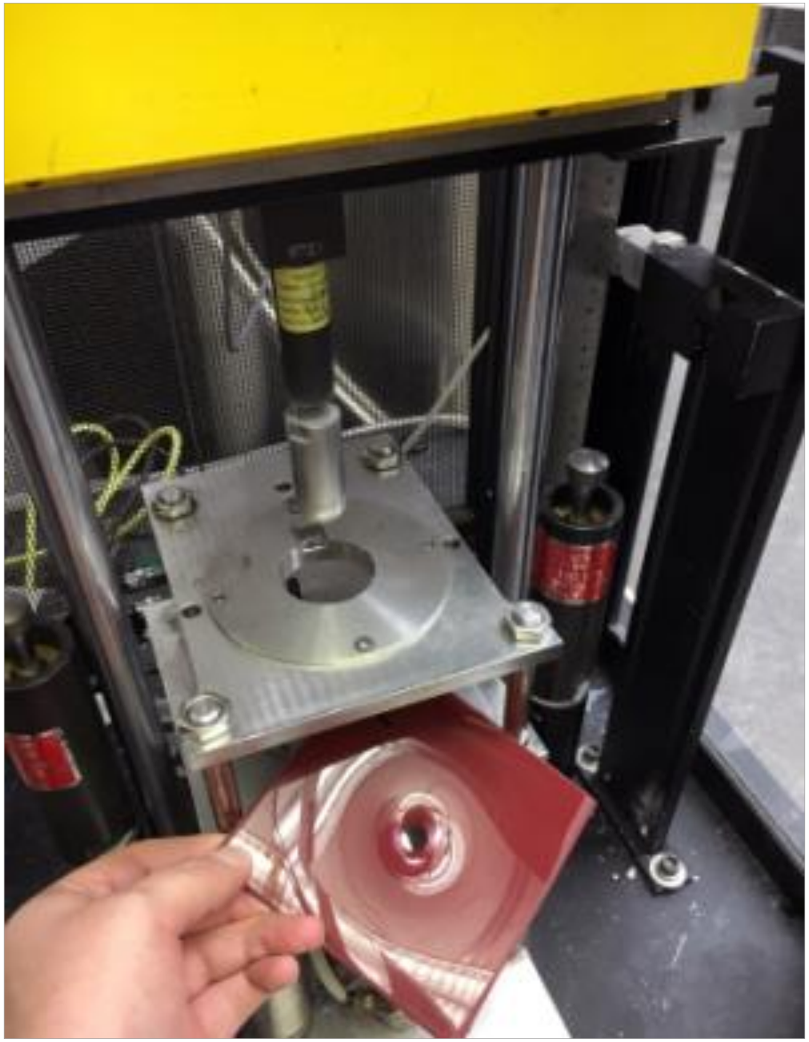
- Abaqus/Explicit models the elasto-plastic behavior of a ductile plastic up to moderate strains when complex modes of deformation are present (complex material model)
- At larger deformations the model deteriorates due to limitations of the elastic-plastic model (Lobo 2006)
- Limits of simulation validity can be applied. Deformations beyond 2 mm may produce inaccurate strain prediction.
- Although strains showed inaccuracy, force values were accurate to higher deformations.

Case 2: Dart Impact

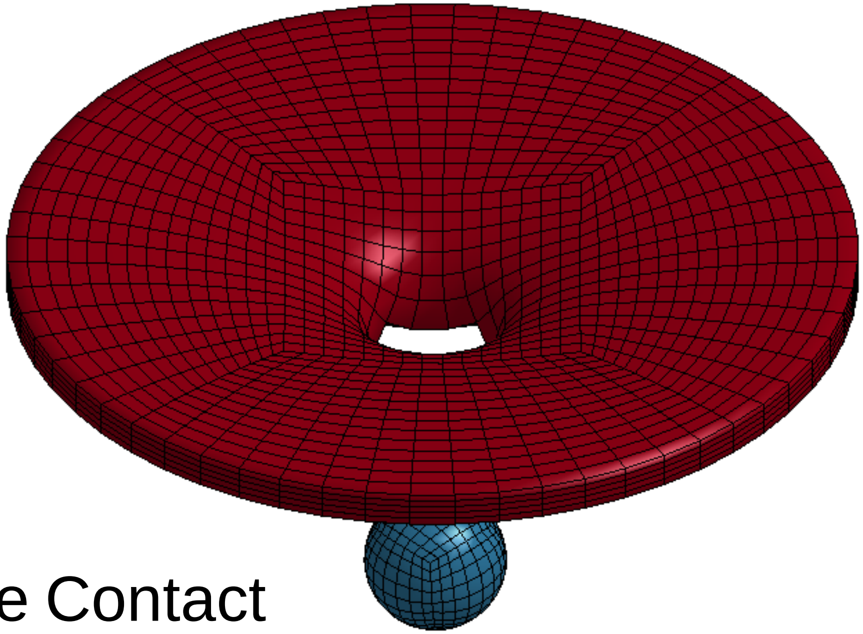


Test Setup

- Dynatup 8250 Impact Tower
- Plate thickness: 3.175 mm
- Clamp Diameter: 76 mm
- Dart diameter:12.7 mm
- Dart weight: 23 kg
- Impact velocity: 3.35m/s



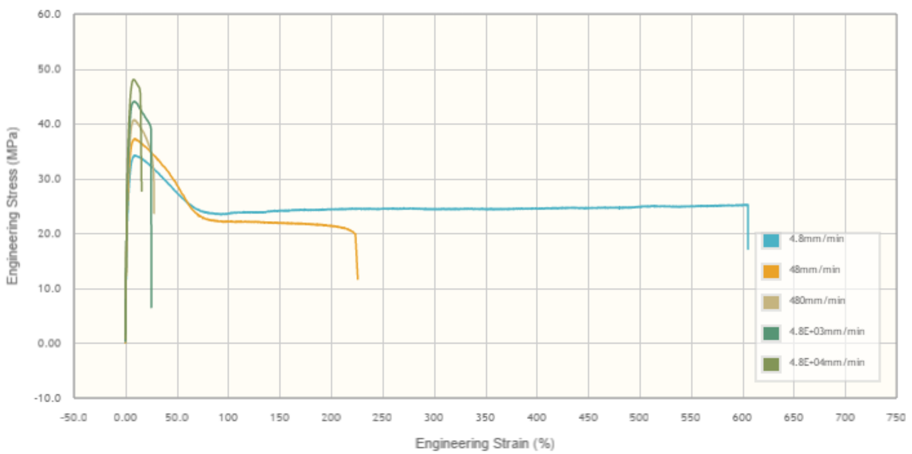
Simulation Setup



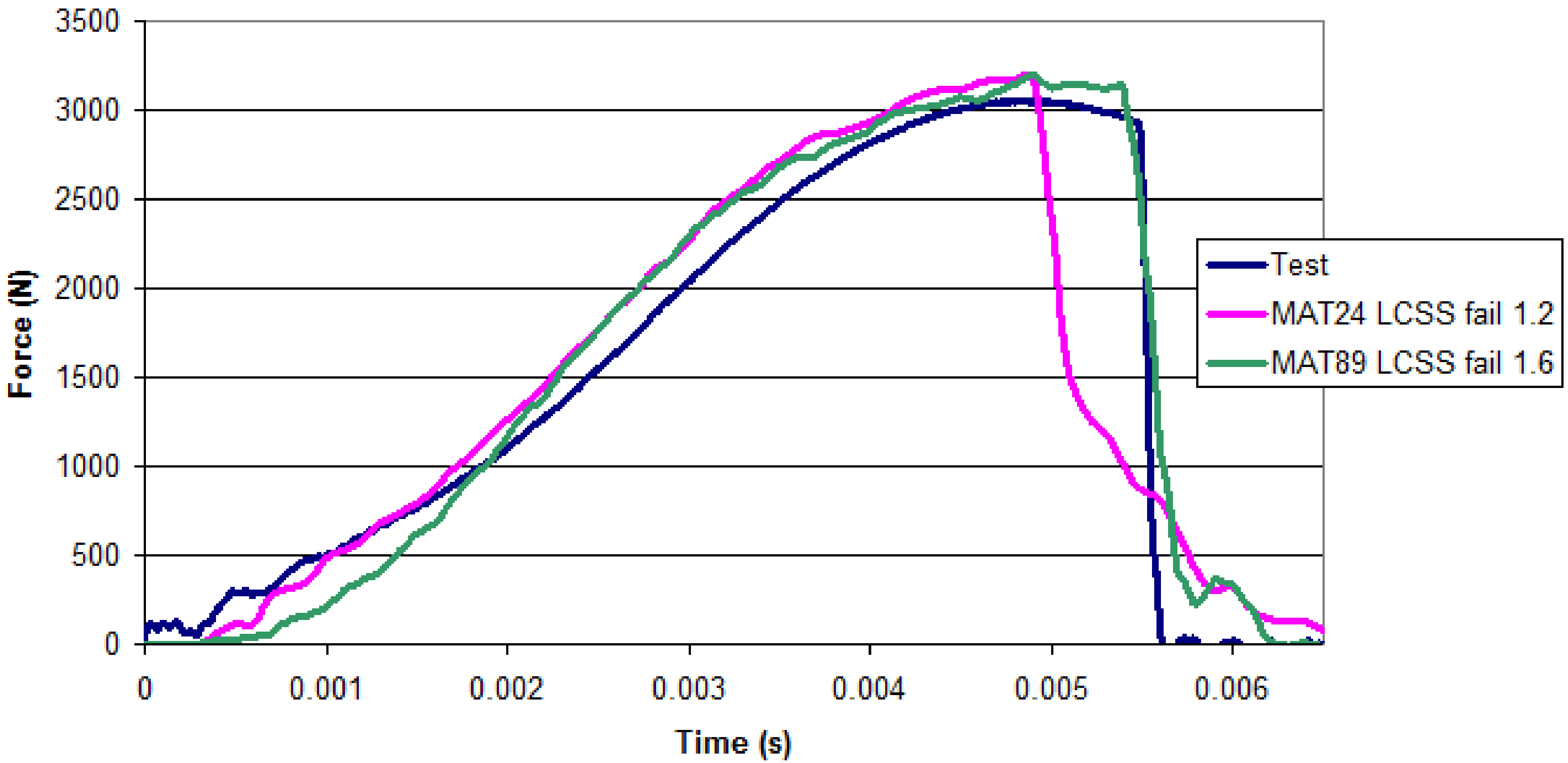
- Plate diameter: 76 mm
- B.C.s: fixed sides
- Impact velocity: 3.35m/s
  - Initial velocity rigid body of dart
- Eroding Surface-to-Surface Contact
- Element formulation: -1 (fully integrates S/R solid)
- Mesh: 3.21mm^2

Material Model

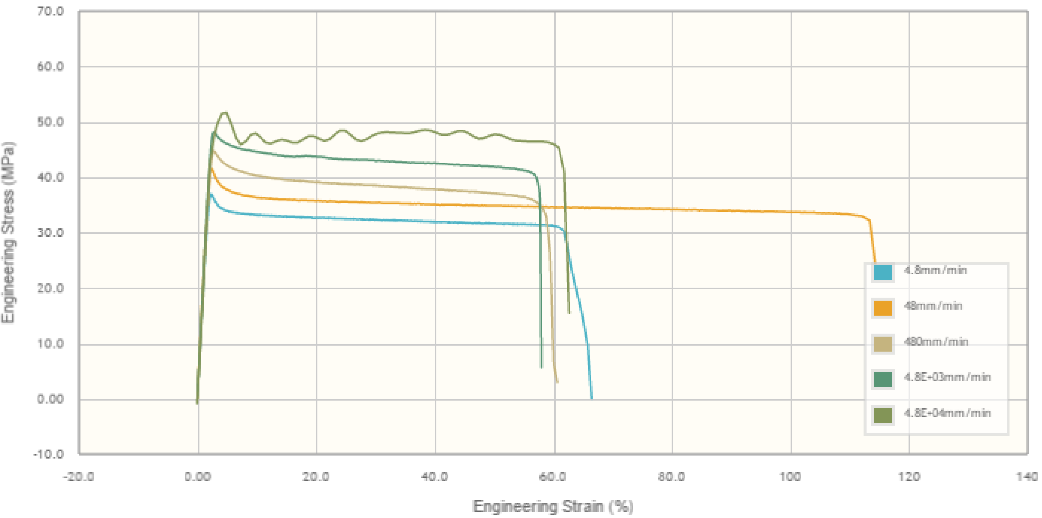
- Tensile and Density Tests
- Elastic
  - E = 2117 [MPa]
  - E = 1664 [MPa] (mat89)
  - $\upsilon = 0.45$
- Density
  - $\rho = 9.09$ E-10 [tonne/mm^3]
- Strain Rate (0.01/s-100/s)

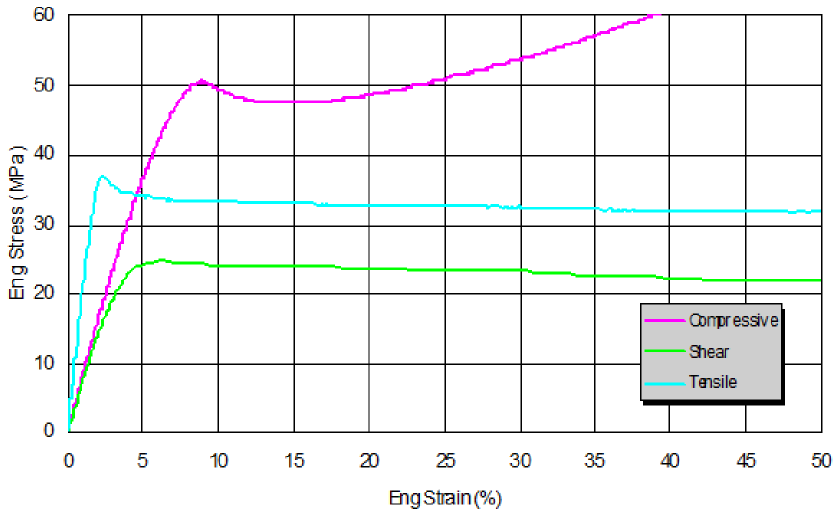


Comparison Simulation to Experiment



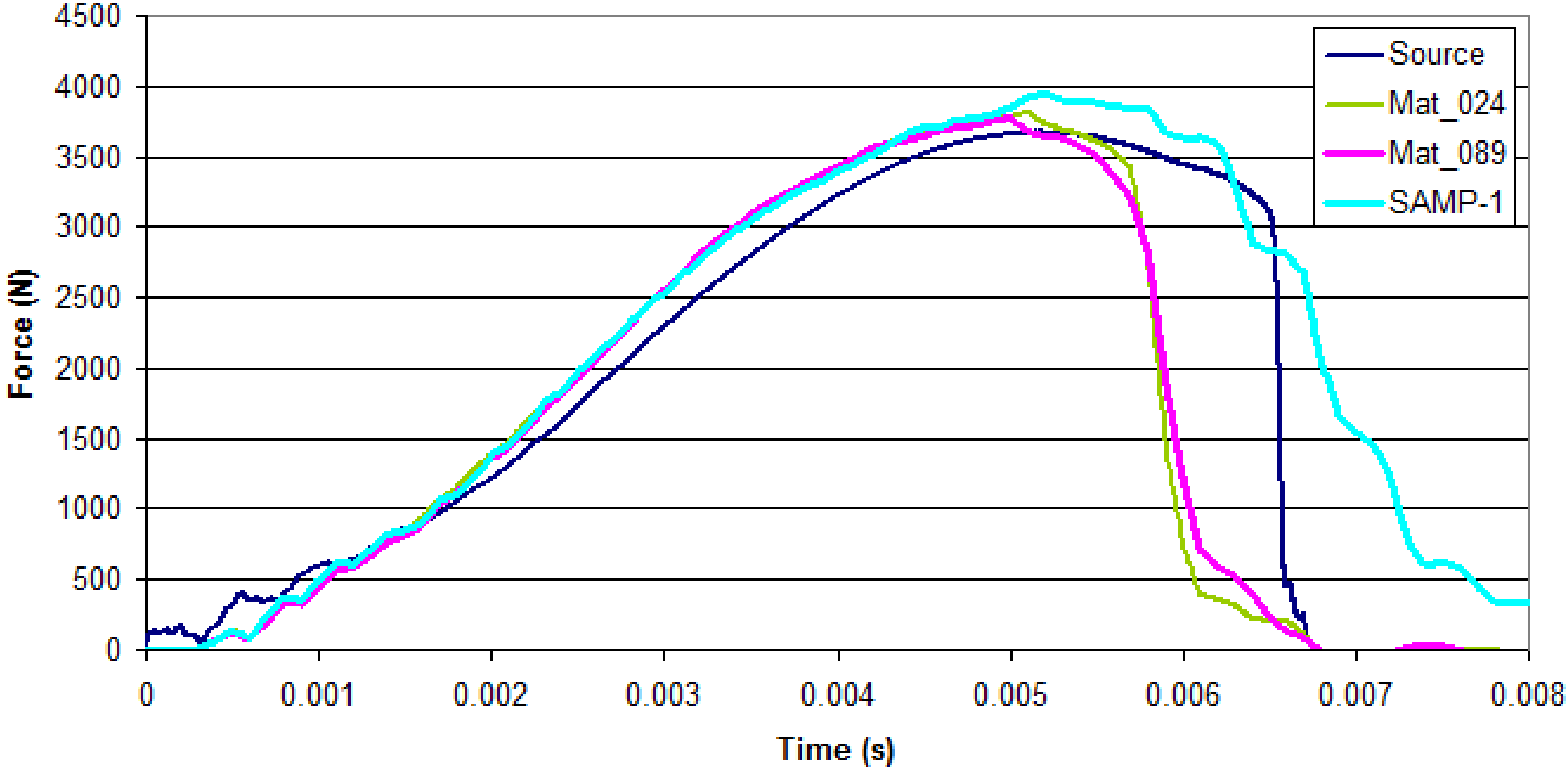
Additional Testing for MAT187: ABS





- SAMP-1 allows user to include many different options
  - Post yield Poissons
  - Yield surface
  - Failure based on Triaxiality

Comparison Simulation to Experiment



Results

- MAT_089 performs well in cases where the modulus is not rate-dependent
- MAT_187 modeled the softening behavior prior to failure best
- Measured tensile failure strain cannot be used for FAIL
  - Extrapolation needed to simulate failure
  - Measurements showed that biaxial strain at failure was close to simulation failure strains
  - Without testing the strains for a failure mode, the somewhat arbitrary choice of failure strain seems to be unavoidable with our approach.

Conclusions

- Validation of simulation quantifies the difference between virtual world and reality
- Should be performed each time a material is being tested for use in simulation
- Data, model, and simulation can be checked using test cases that contain real-life behaviors, giving confidence to the analyst