Using an Intermediate Validation Step to Increase CAE Confidence

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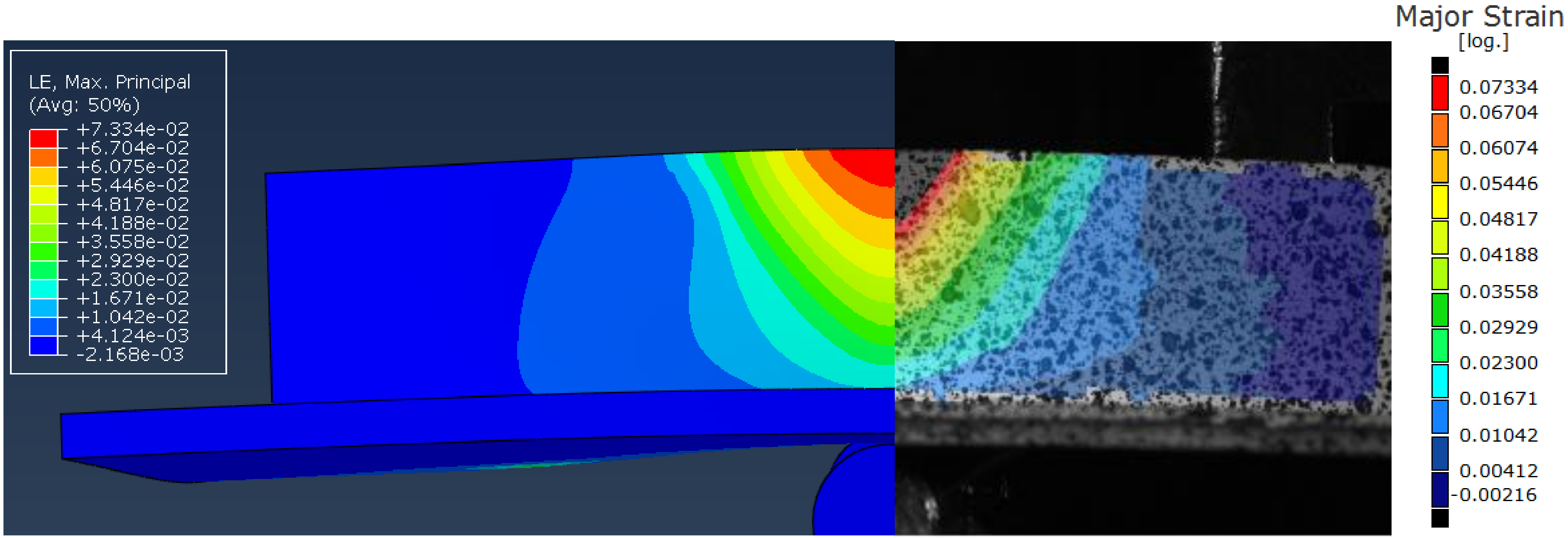
Matching Simulation to Reality



Project Impetus

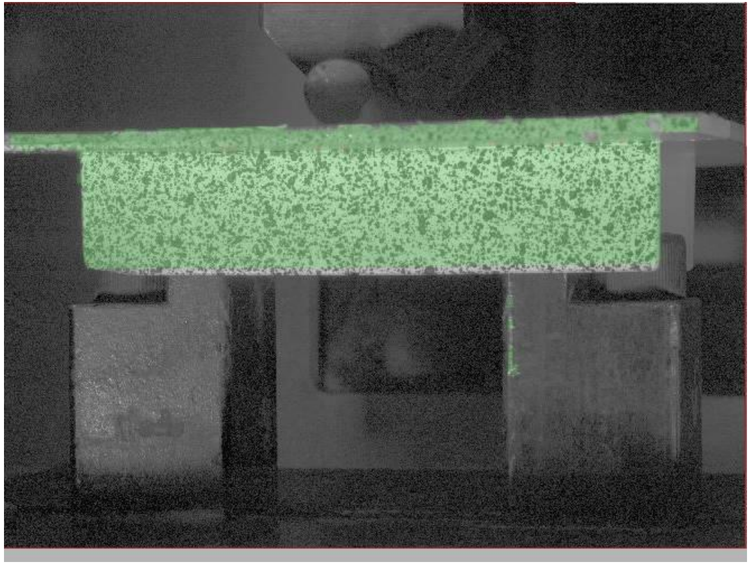
- Increase confidence in modeling complex load conditions of polymer materials
- Develop a well constrained experiment that allows for repeatable and clean simulation
- Streamline the process of material model validation

Experiment Description

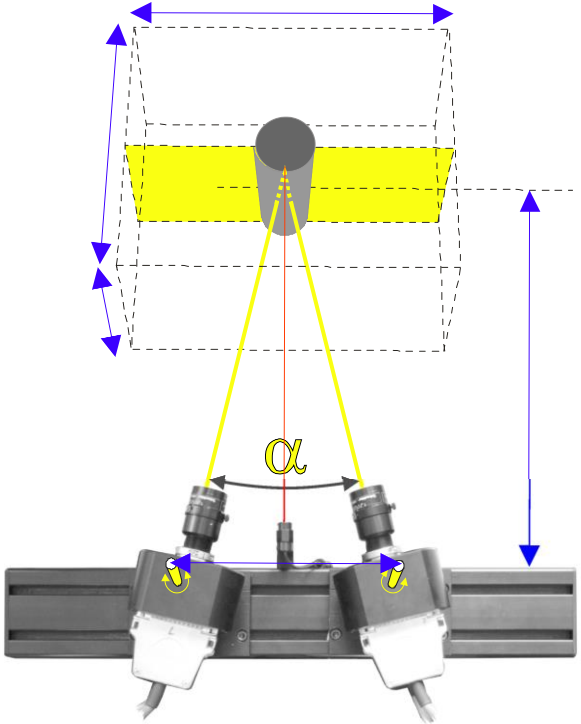
- Perform flexural test to impart complex loading of a polymer part
- Use ribbed geometry to further complicate load case and induce buckling
- Fully define boundary conditions and geometry including all contact points and loading conditions
- Capture full strain fields on the geometry and record applied forces

Experimental 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

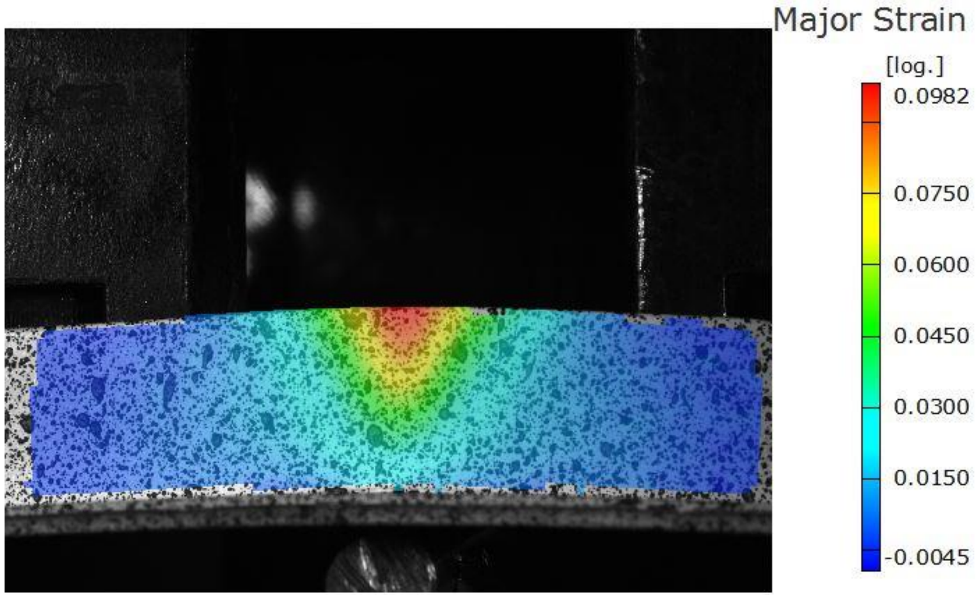


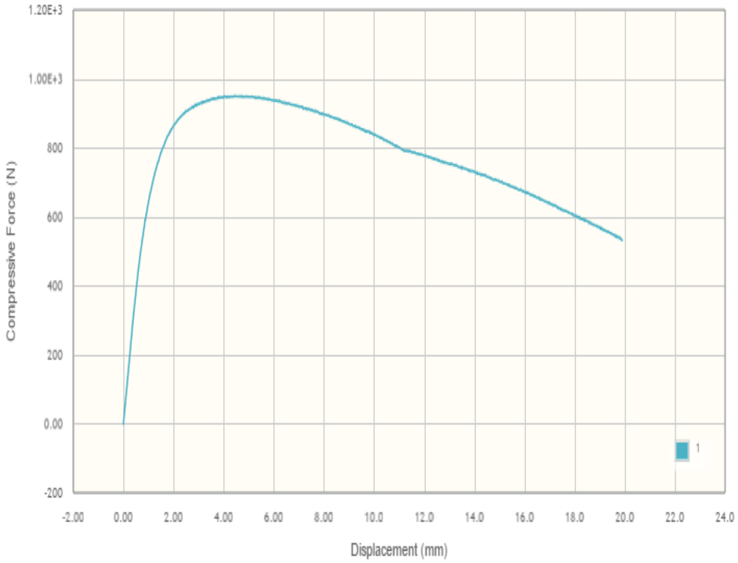
DIC Operation



- Speckle pattern is broken into facets (elements)
- Speckle pattern is tracked frame to frame
- Calibration of a volume is performed through measuring calibration panel in various orientations in the test space.
- Strains can be captured on the micro-strain level
- Strain filed can be mapped over the actual part image

Experimental Results

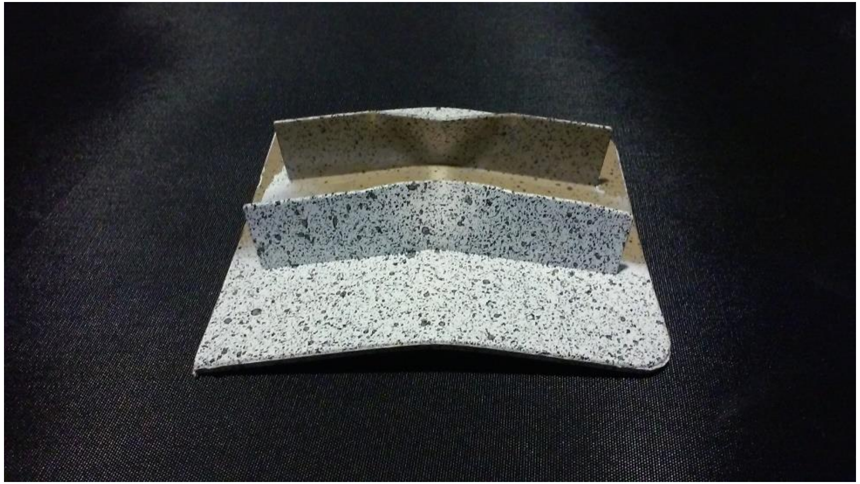




- Max. strain: 0.098 mm/mm
- Max. Force: 952N at 4.3mm deflection

Deformed Part

- Loaded past yield
- Observed symmetric buckling inwards
- Slight indentation of support pins causing stress whitening on the reverse side of the part

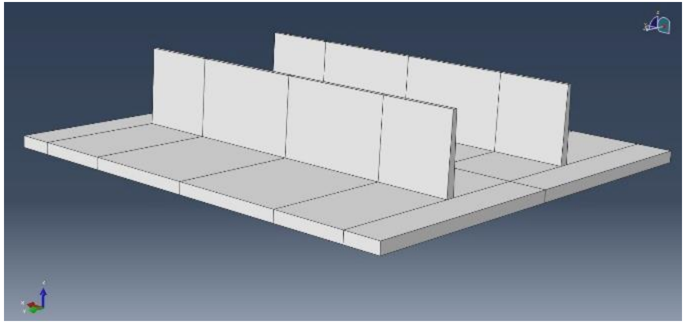


Geometry of Plate

- Fins:
  - Fin length = 83.4mm
  - Fin tip thickness = 1mm
  - Fin base thickness = 2mm
  - Distance between fins = 35.7mm

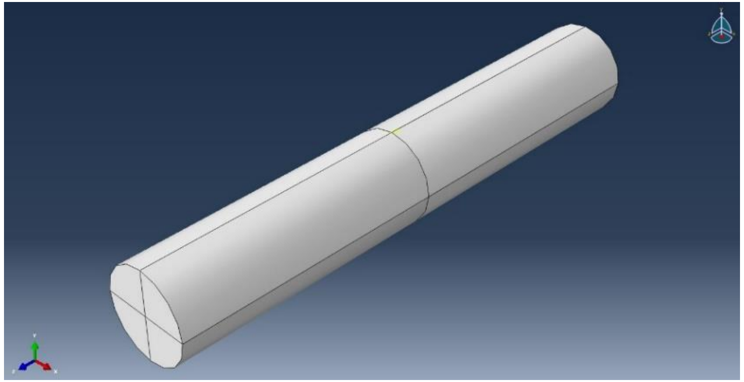
- Measurements taken from actual part rather than from mold geometry

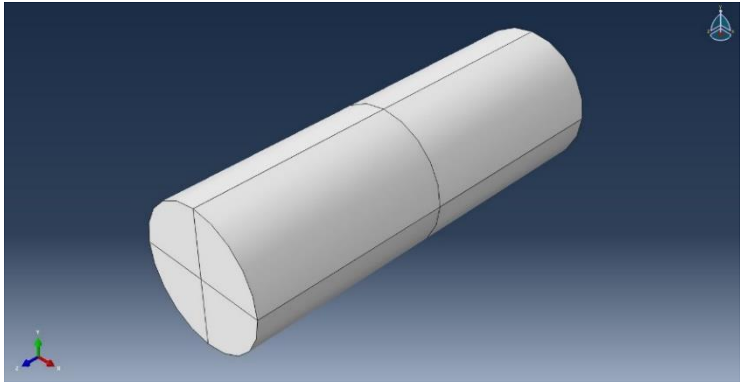
- Plate:
  - Thickness = 2.7mm
  - Length = 100mm
  - Width = 96.2mm



Geometry of Pins

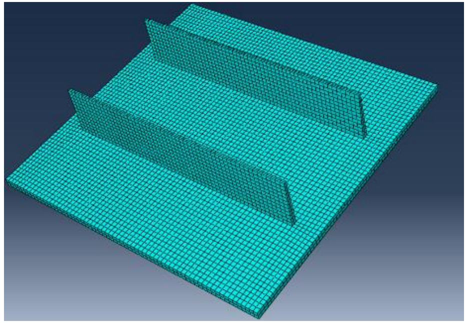
- Nose pin:
  - Length = 60mm
  - Radius = 5mm
- Support pins:
  - Length = 30mm
  - Radius = 5mm





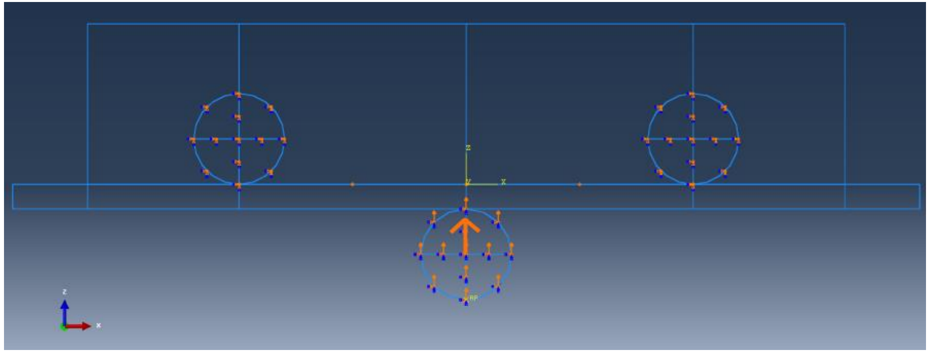
Mesh Settings

	Nose Pin	Support Pin	Plate
Element Type	C3D8R	C3D8R	C3D8R (Hex)
Size	1.5mm	1.5mm	1.5mm
Element Library	Explicit	Explicit	Explicit
Hourglass Settings	Enhanced	Enhanced	Enhanced



Boundary Conditions

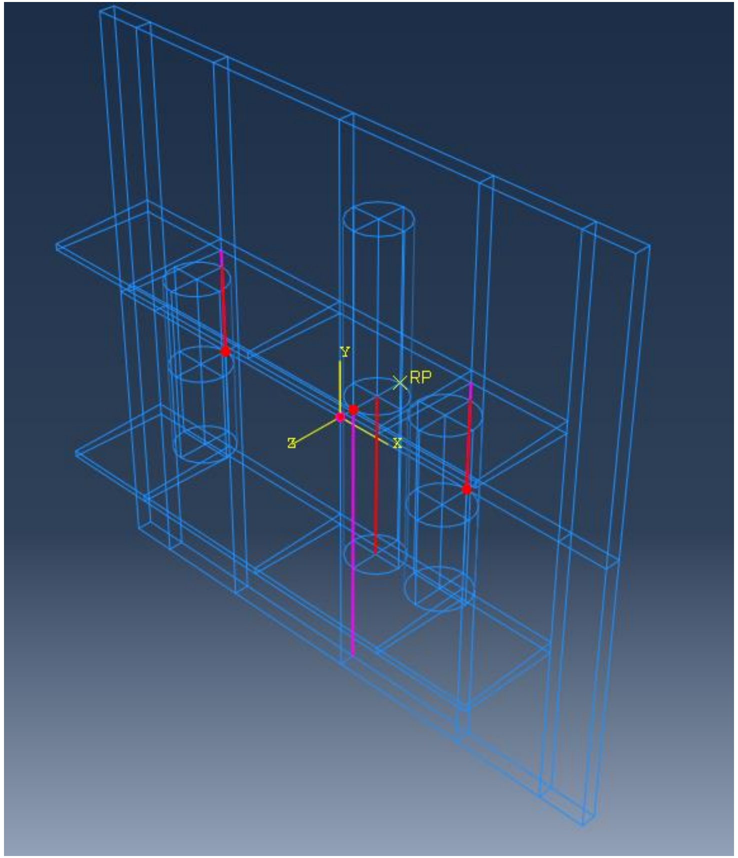
- Nose pin:
  - Constrained in all DOF with 2.5mm displaced in Z (Quasi-Static)
- Support pins
  - Constrained in all DOF
- Part geometry constrained to prevent rigid body movement in the x y direction
- Contact applied in initial step



Interaction Properties

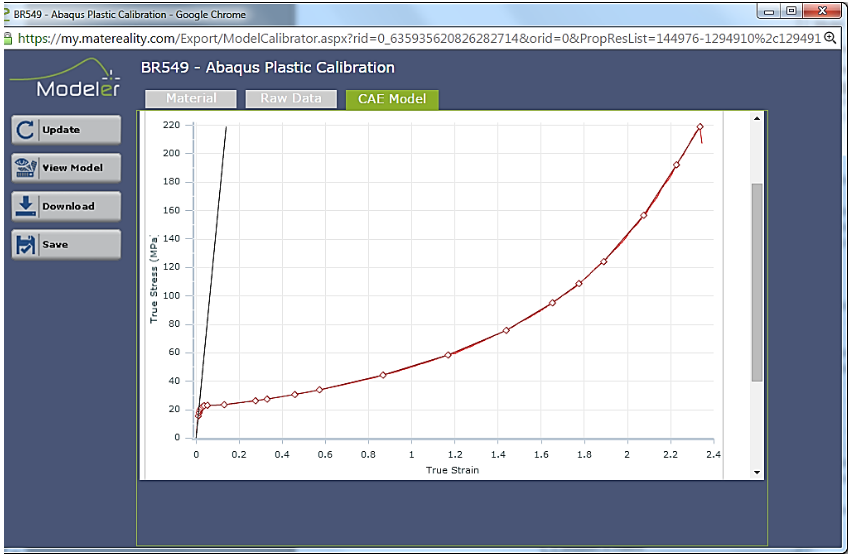
- Loading nose to plate
  - Coincident
  - Edge to edge
- Supports to plate
  - Coincident
  - Edge to edge

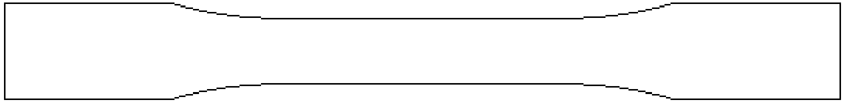
- Contact settings
  - Friction coefficient = 0.2
  - Hard contact



Material Model: Plate (Polypropylene)

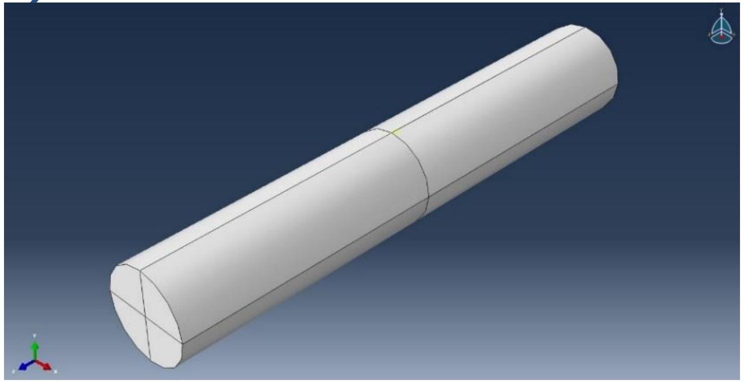
- Tensile and Density Test
- Elastic
  - E = 1572 [MPa]
  - υ = 0.29
- Plastic curve (Right)
- Density
  - ρ = 7.9 E-06 [tonne/mm^3]
- Measured at QS speeds

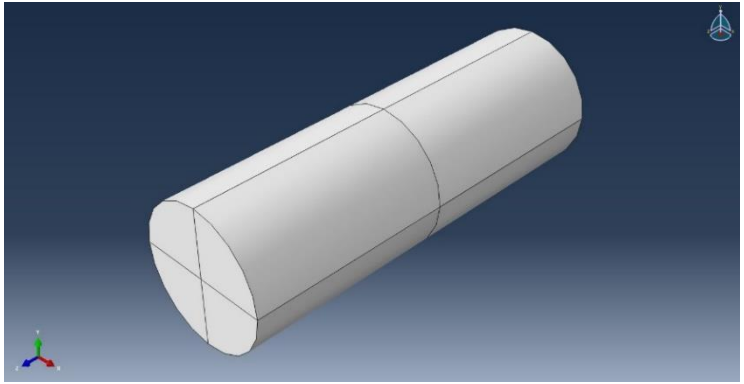




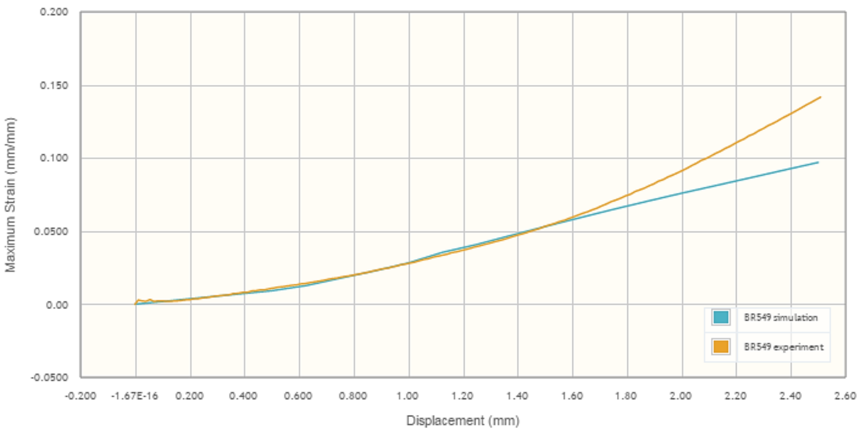
Material Model: Pins (Steel)

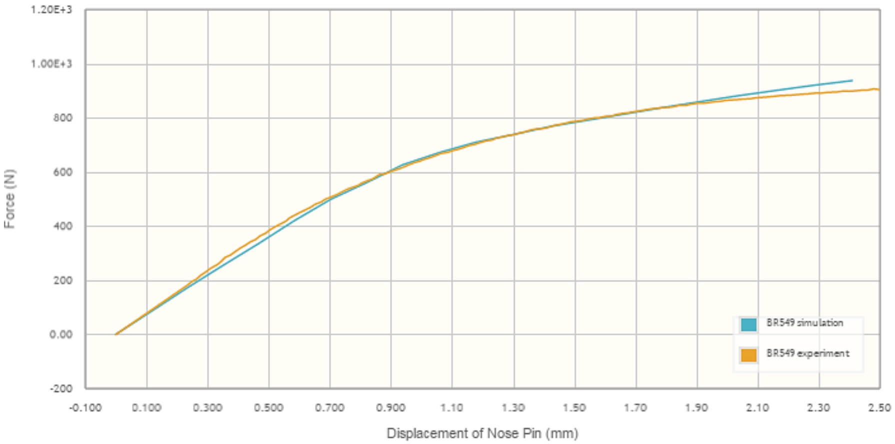
- Pins:
  - Elastic
    - E = 230,000 [MPa]
    - υ = .29
  - Density
    - ρ = 7.9 E-09 [tonne/mm^3]





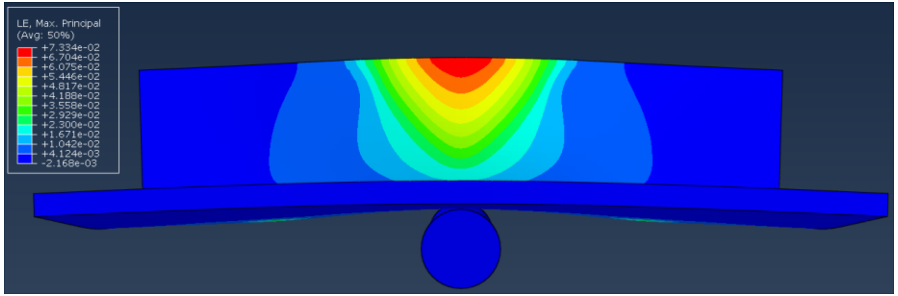
Comparison of Simulation to Experiment

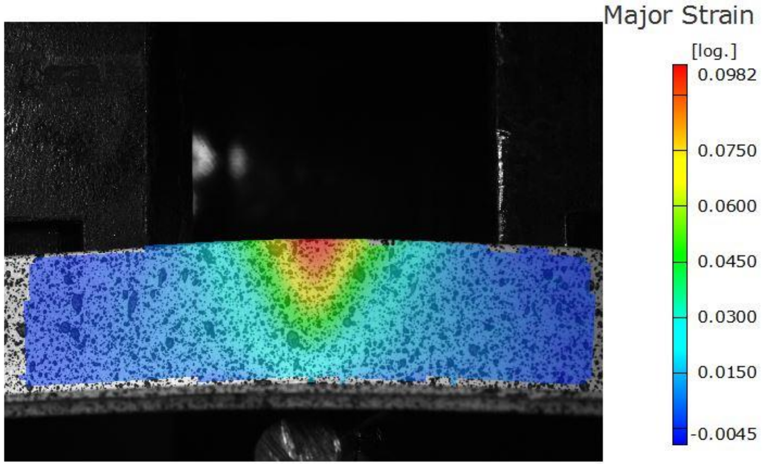




- Strain vs. Displacement
  - Diverges after 2 mm
- Force vs. Displacement
  - Similar response throughout

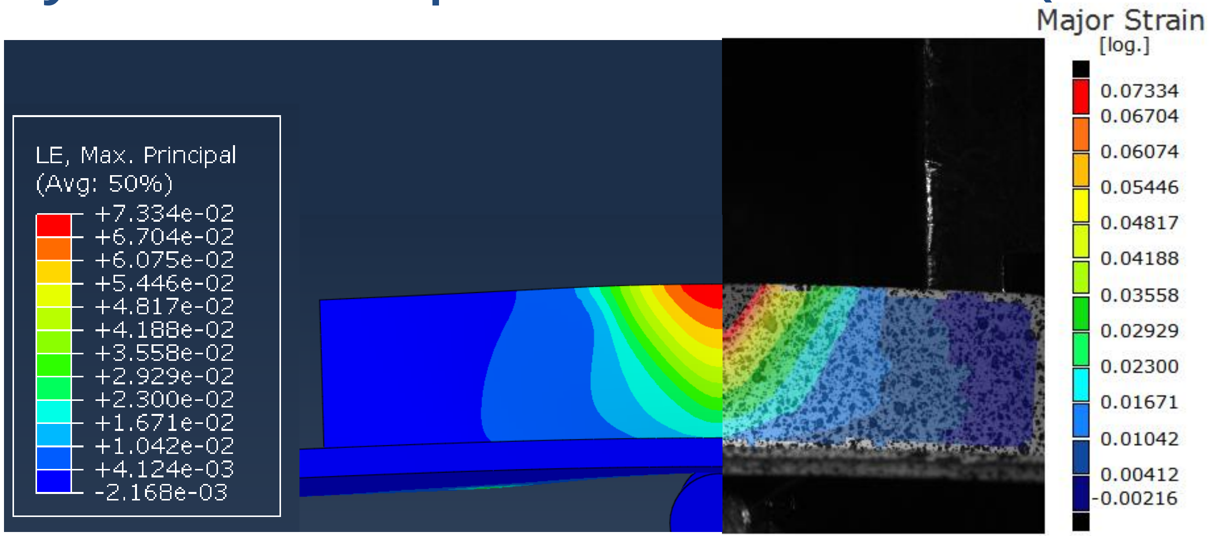
Visual comparison of Strains





- Set at a pin displacement of 2mm
- Both are using maximum principal (logarithmic) strains

Side by Side Comparison of Strains (2mm)



- 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

Conclusions

- 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.
  - Indentations were noted at support pins.
  - Some “scrub” at ends of support pin

Future Work

- Extend material modeling to more complex yield surface models such as Linear Drucker Prager
- Extending to fiber filled polymer materials
- Rate dependency

Acknowledgments

- DatapointLabs, for providing the facilities and guidance to complete the simulations and experiments
- Rick Dalgarno, Autodesk, for taking the time to comment on our paper