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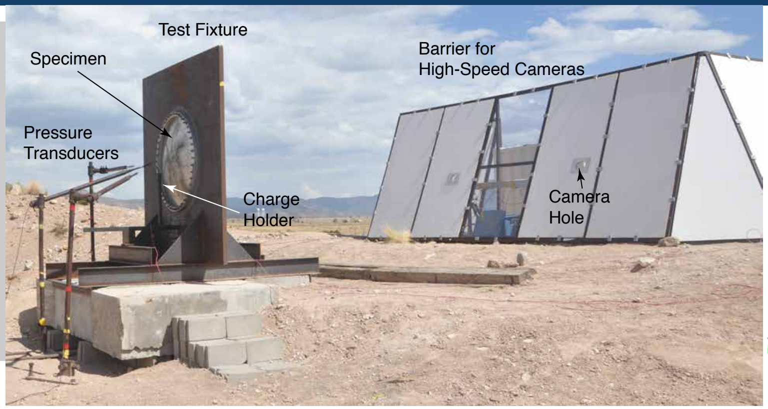

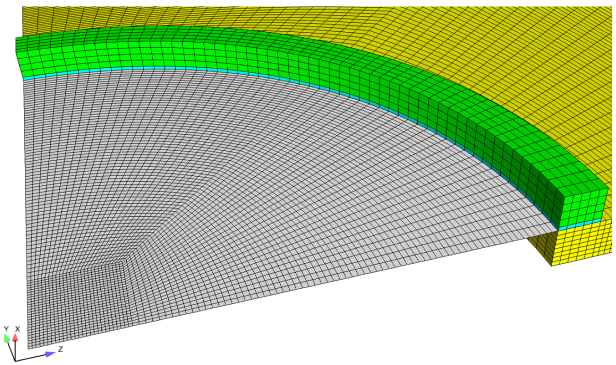

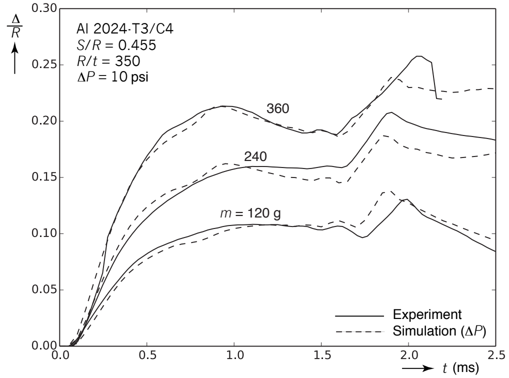

DIC Investigation of Aluminum Plate Tearing Under Blast Load and Comparison to Numerical Model Predictions

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Experimental Set-up

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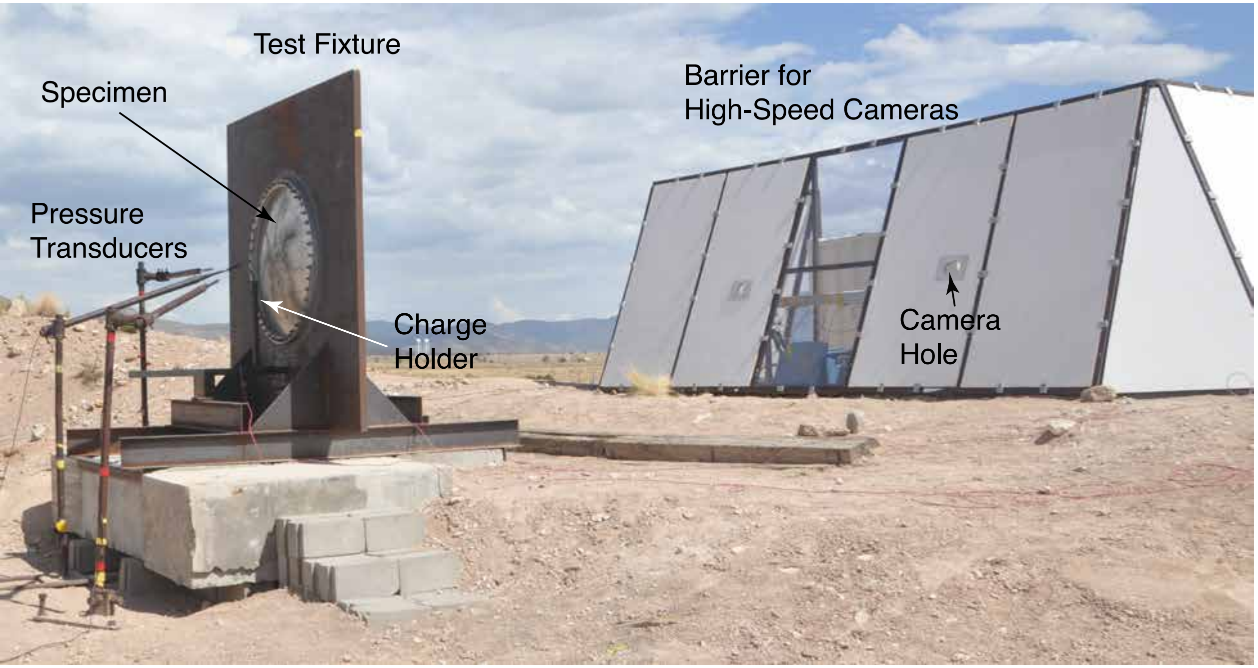


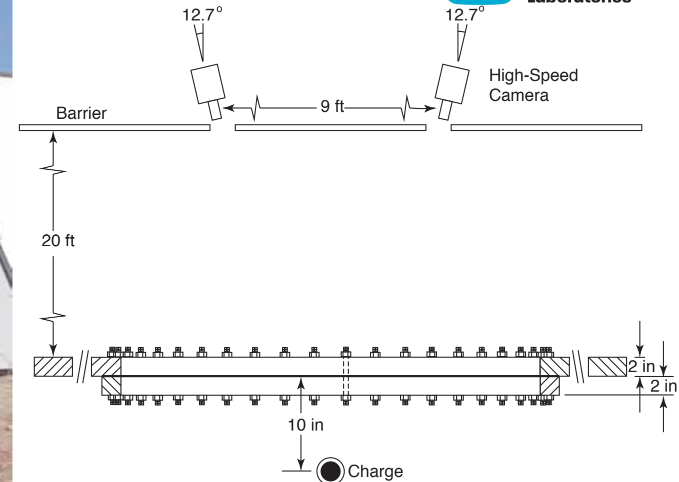
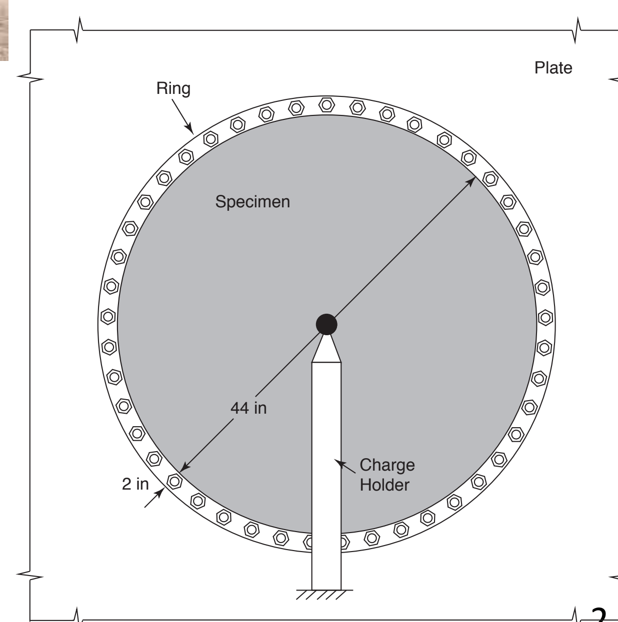


Plate:
Al 2024-T3
t = 0.04 and 0.063 in.
D = 44 in.

Charge:
C4
S = 10 in.



Experiment: Side View

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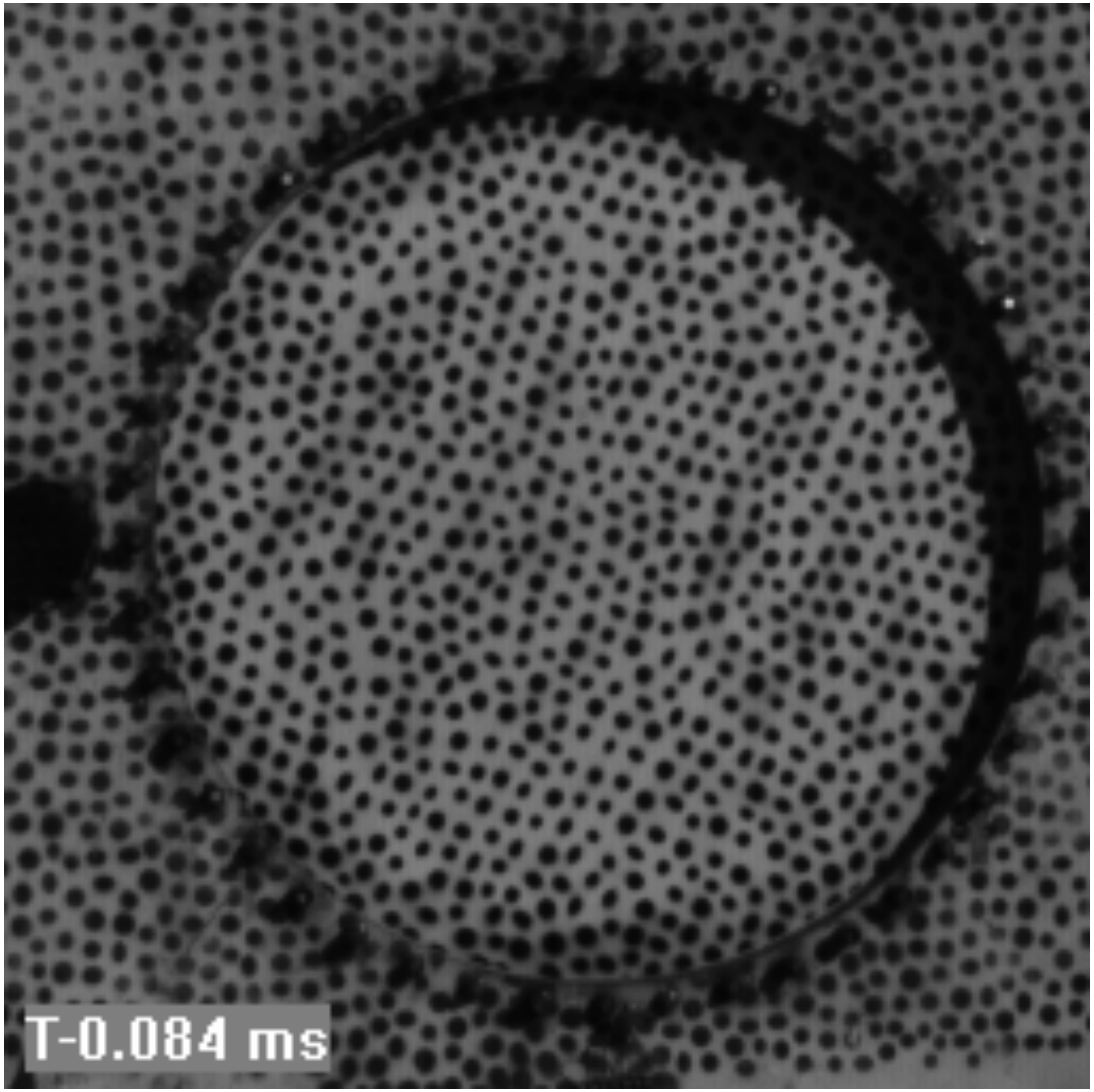
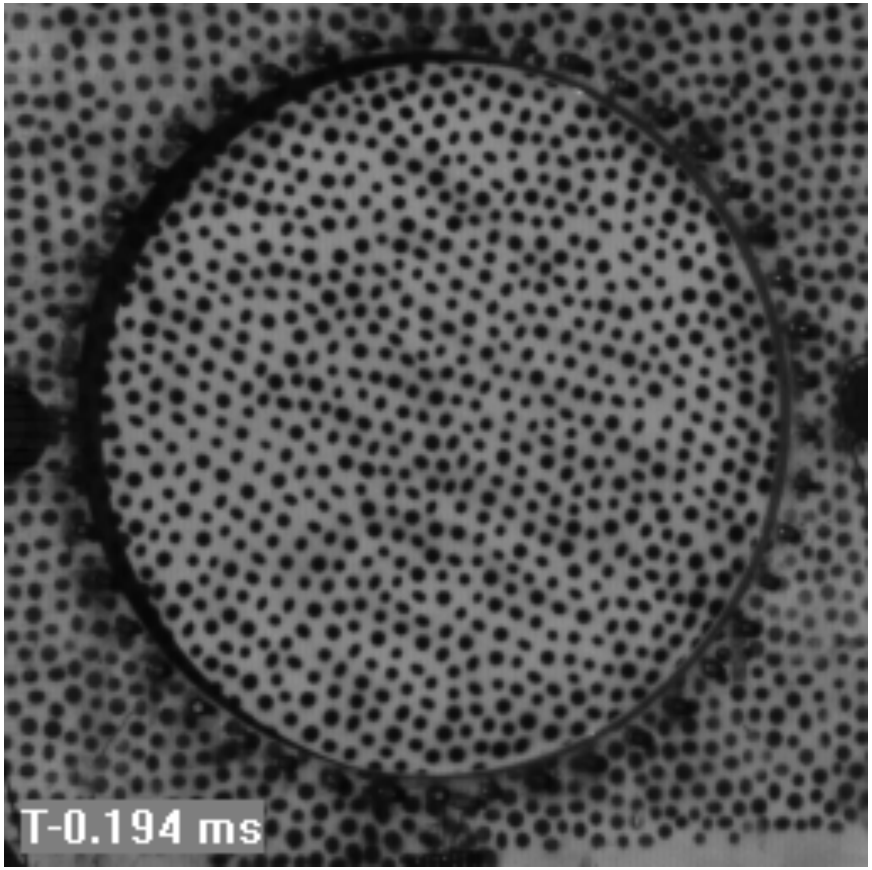
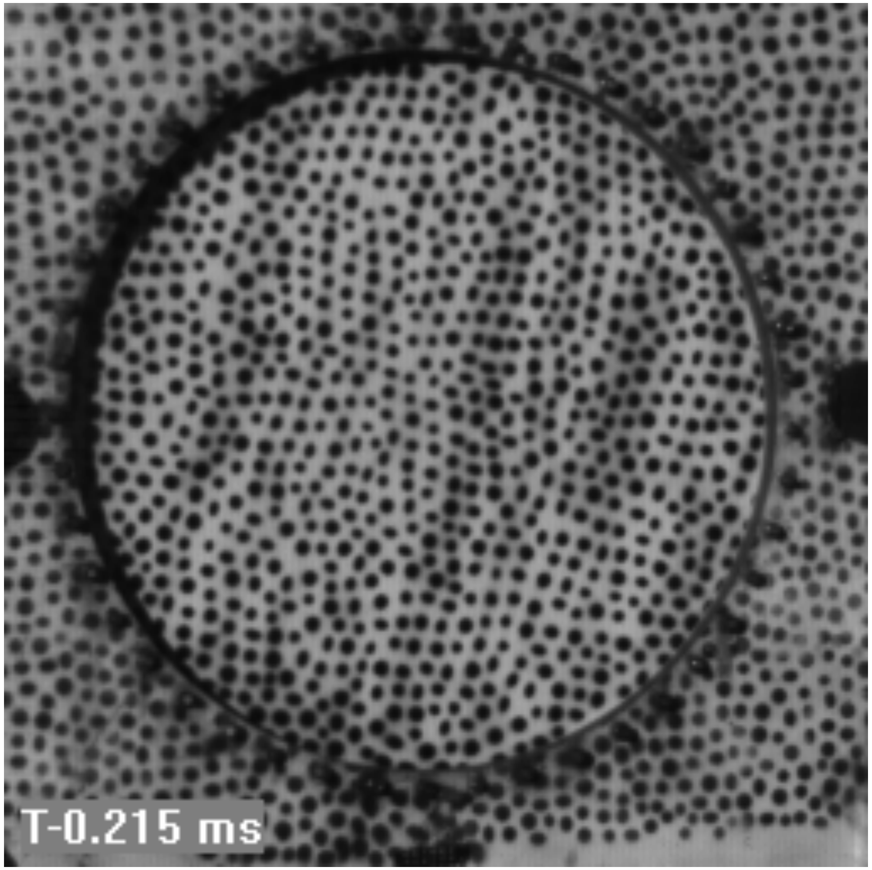
Experiment: Front View

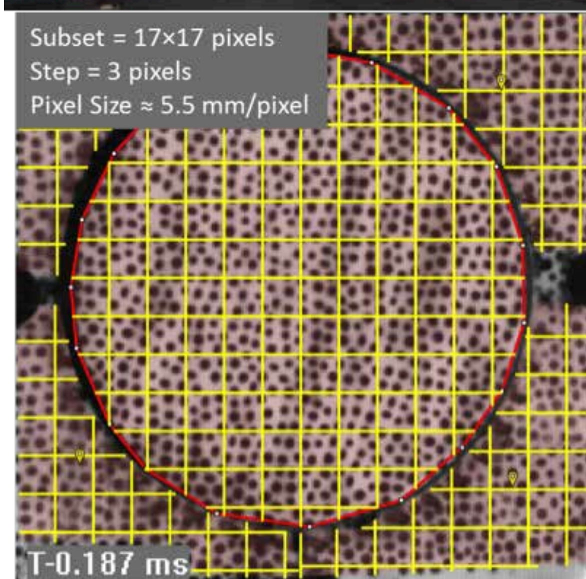


Higher Charges Lead to Plate Tearing





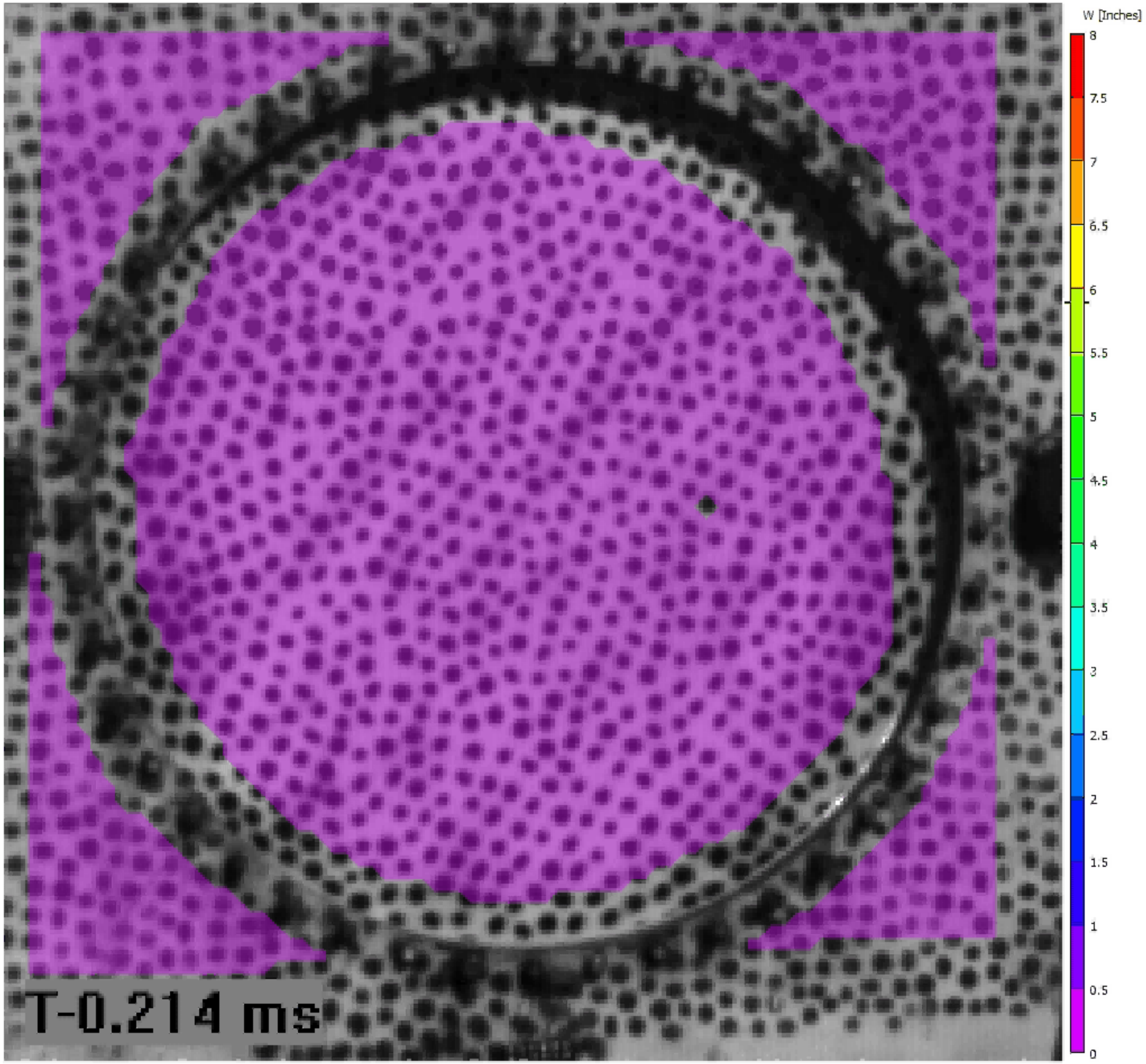
Experimental Set-up (DIC Particulars)



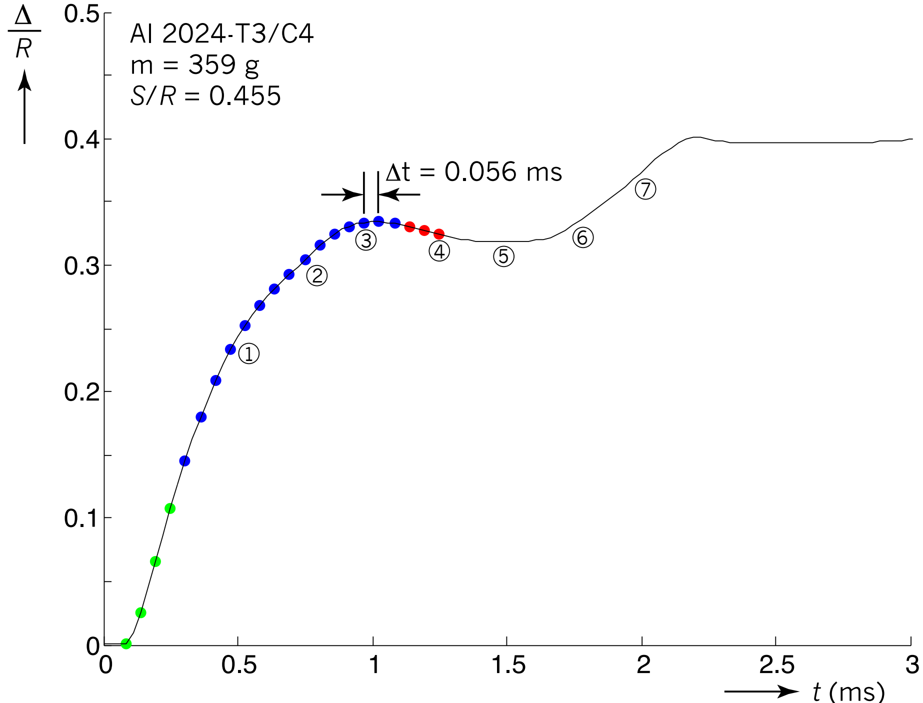
DIC Parameters for displacement measurement:

- Spatial Resolution: 0.22 in/pixel (5.5 mm/pixel)
- Subset: 3.7 in. (94 mm)
- Step Size: 0.65 in. (16.5 mm)
- Average Noise Floor: 0.08×10^{-3} in. in-plane [O(0.25 in.)] and 3.5×10^{-3} in. out-of-plane [O(5 in.)]
- Frame Rate: 36,000 frames/sec. (27μs/frame)

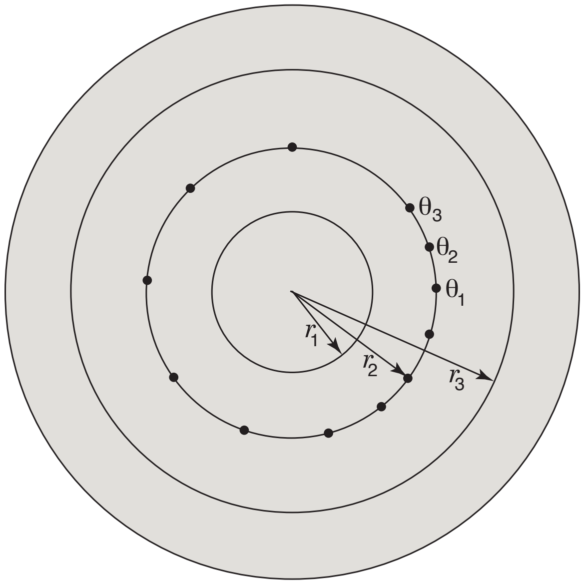
Displacement Measurement Example



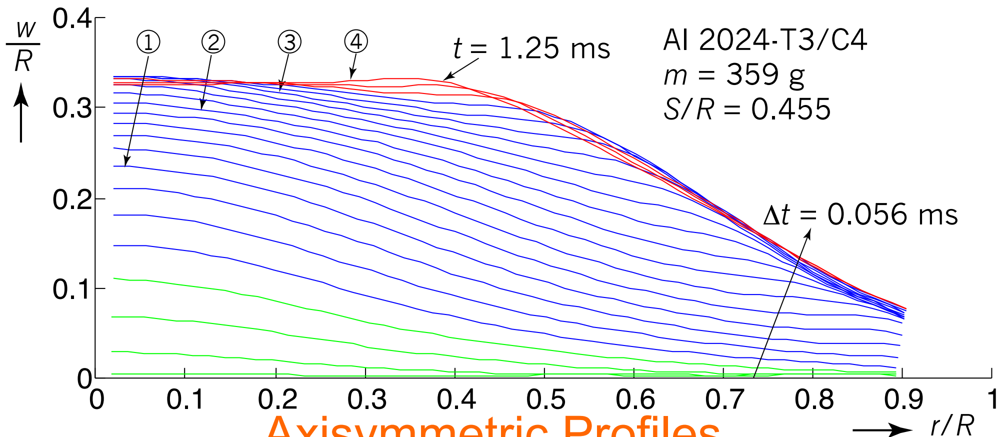
Displacement Measurements (Axisymmetric Average)



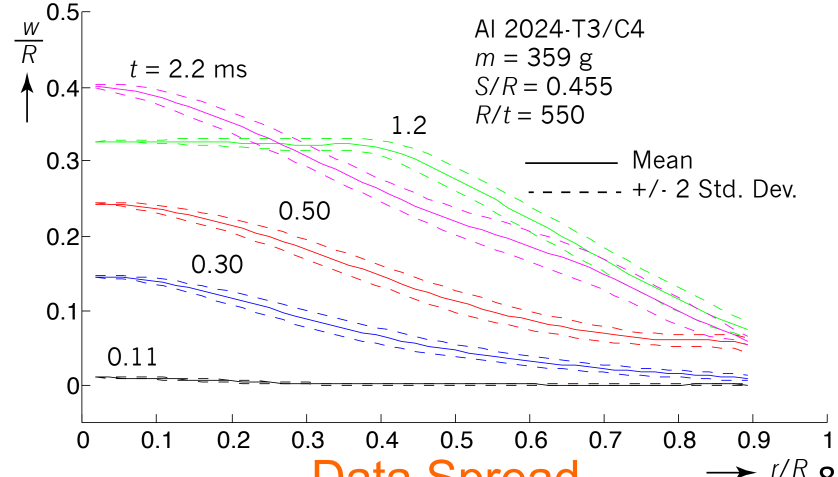
Center Displacement



Axisymmetric Averaging



Axisymmetric Profiles



Data Spread

Strain Measurements

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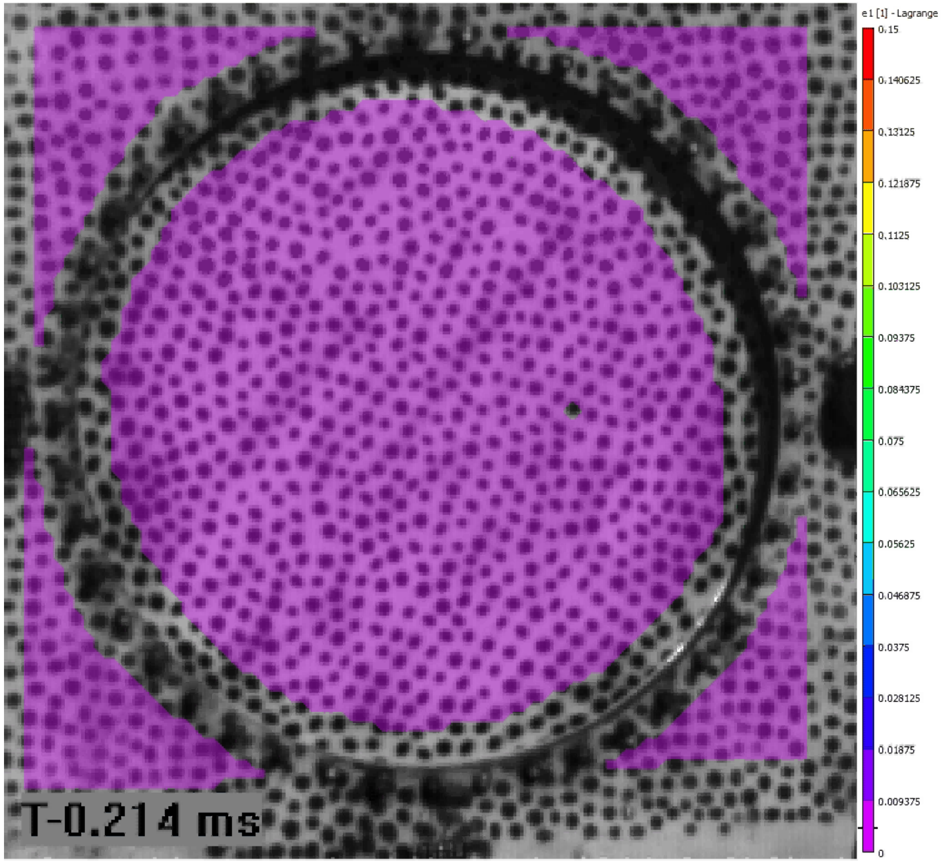
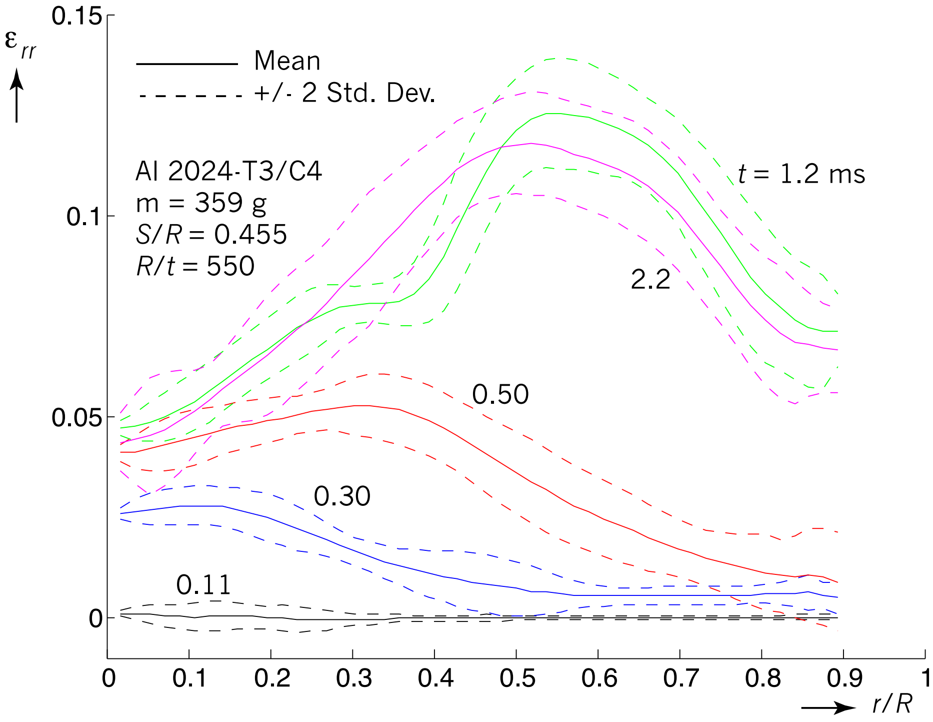
Parameters for Strain Measurement:

- Lagrangian Strain
- First Pass: Calculate strain by averaging 4 constant strain triangles
- Second Pass: Use 5x5 strain window with Gaussian averaging
- Virtual strain gage size is 2.86 in. (73 mm).
- Region of influence for strain calculation is 6.4 in. (163 mm)

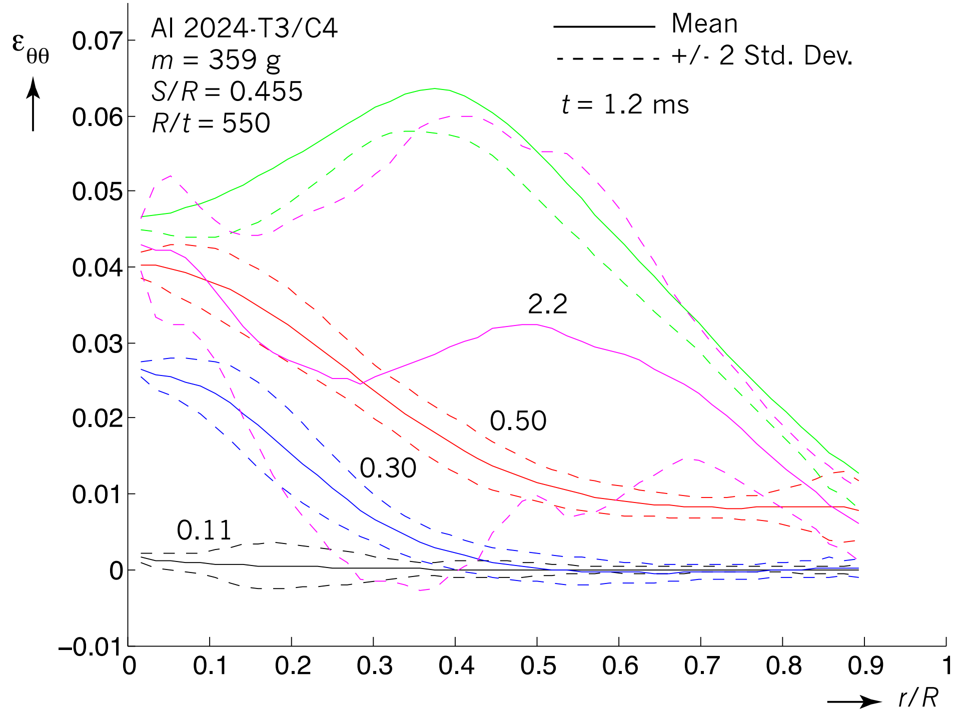


First Principal Strain

Strain Measurements (Axisymmetric Average)



Radial Strain



Circumferential Strain

Computational Approach

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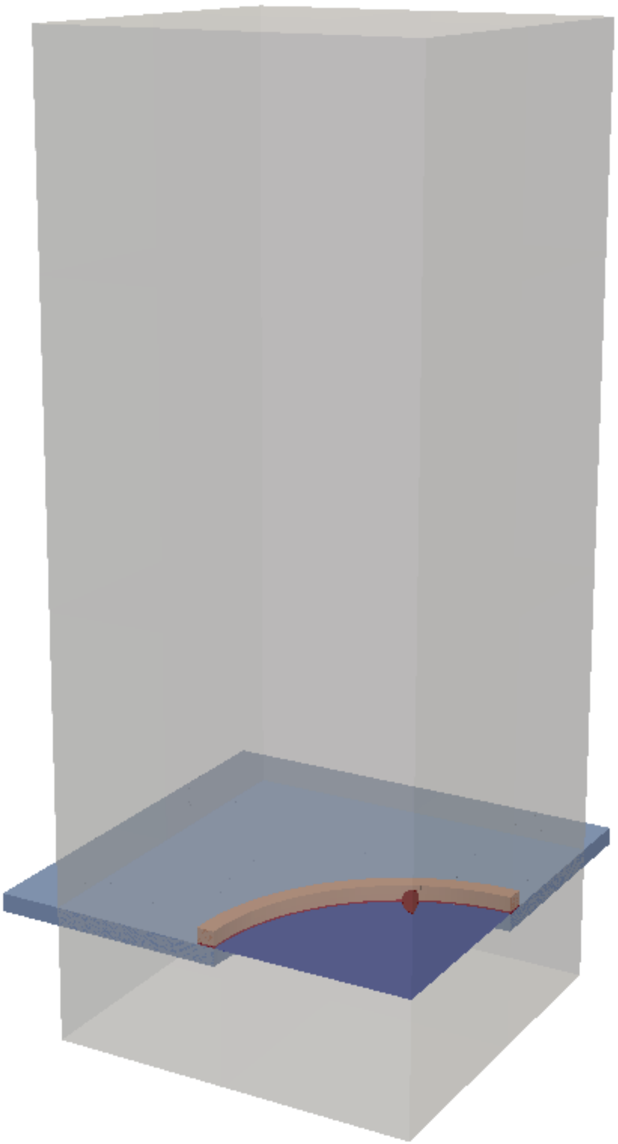
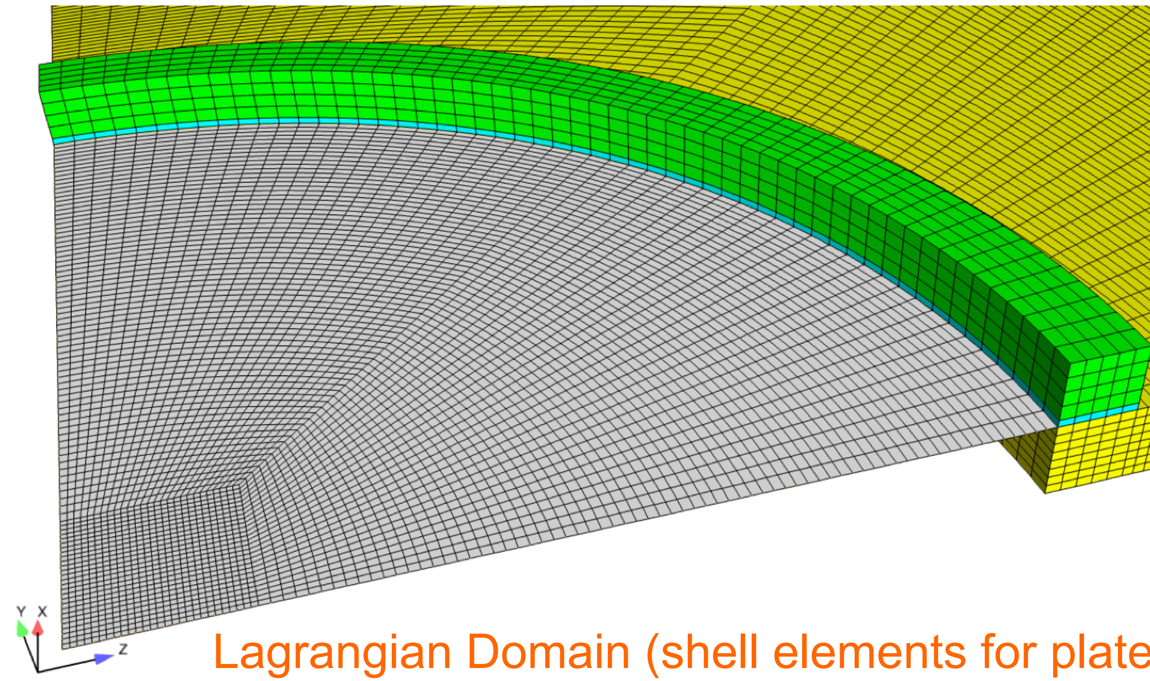


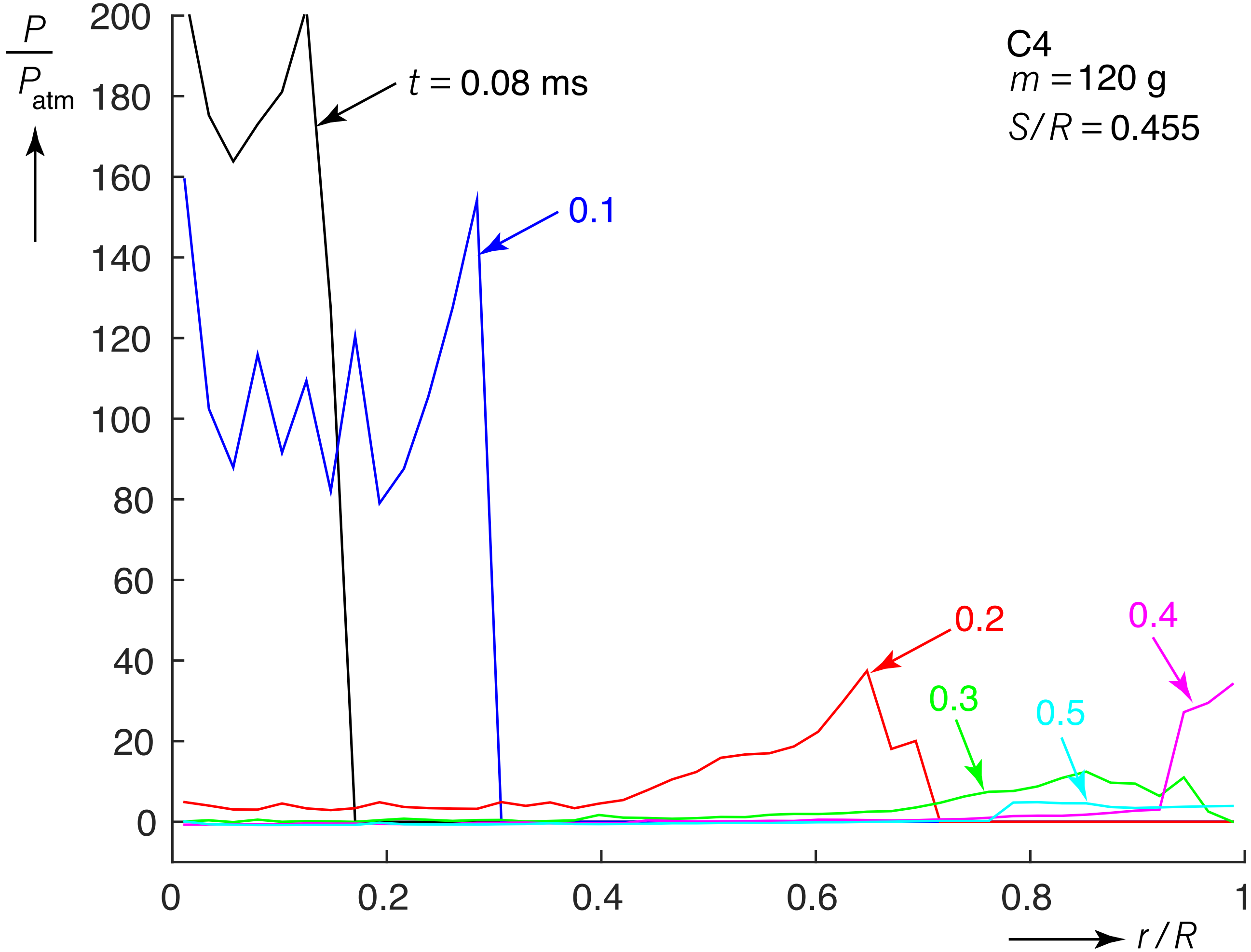
Eulerian Domain



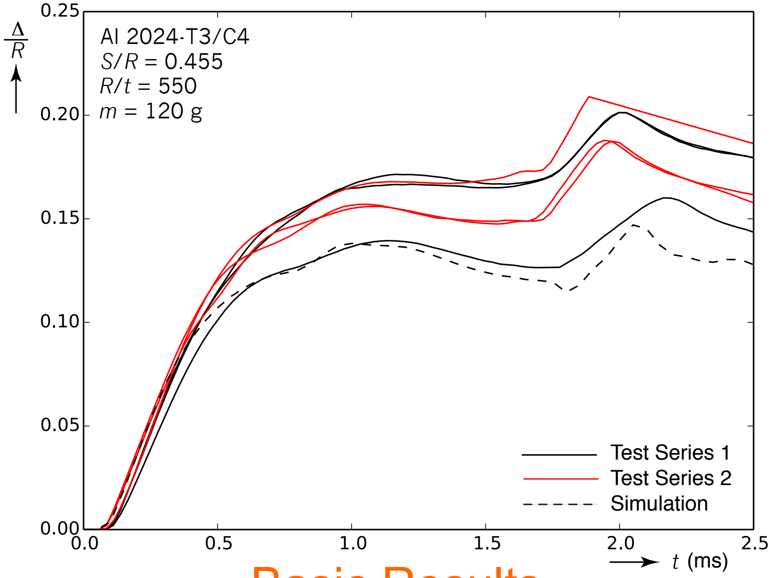
Lagrangian Domain (shell elements for plate)

- Fully coupled Eulerian/Lagrangian analysis via Zapotec
- Eulerian domain contains air, explosive, plate, fixture
- Lagrangian domain has plate and fixture
- 2-step incremental explict coupling approach
- Step 1. Insert Lagrangian material into Eulerian domain
- Step 2. Transfer Eulerian pressures to Lagrnagina domain

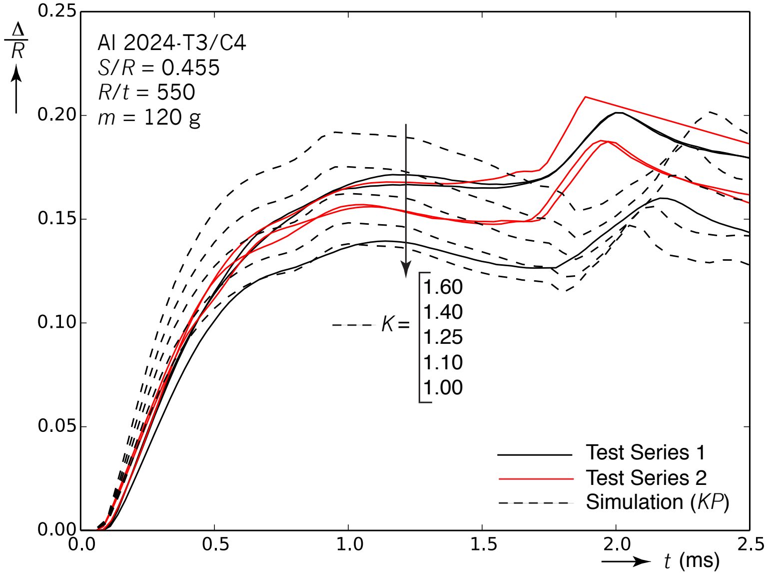
Pressure Distribution at Different Times (from calculations)



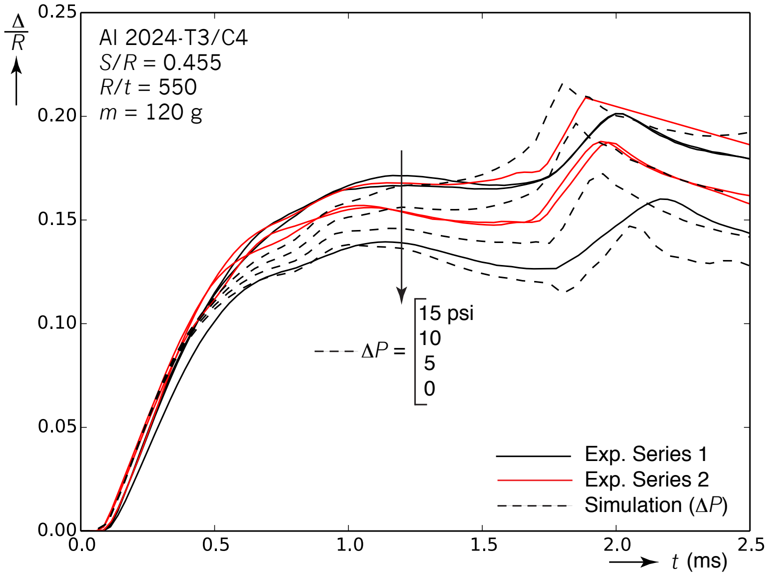
Computational Approach Results



Basic Results

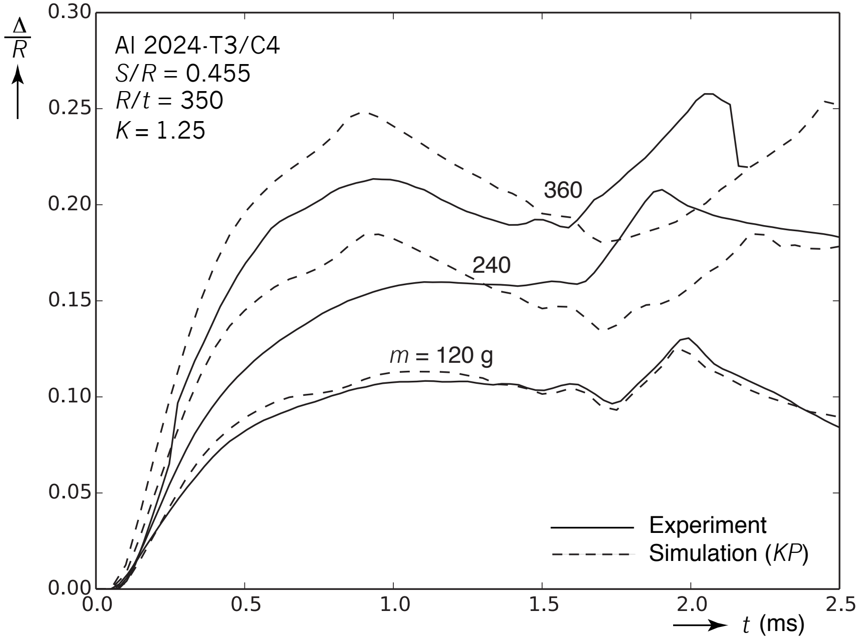


Pressure Multiplier

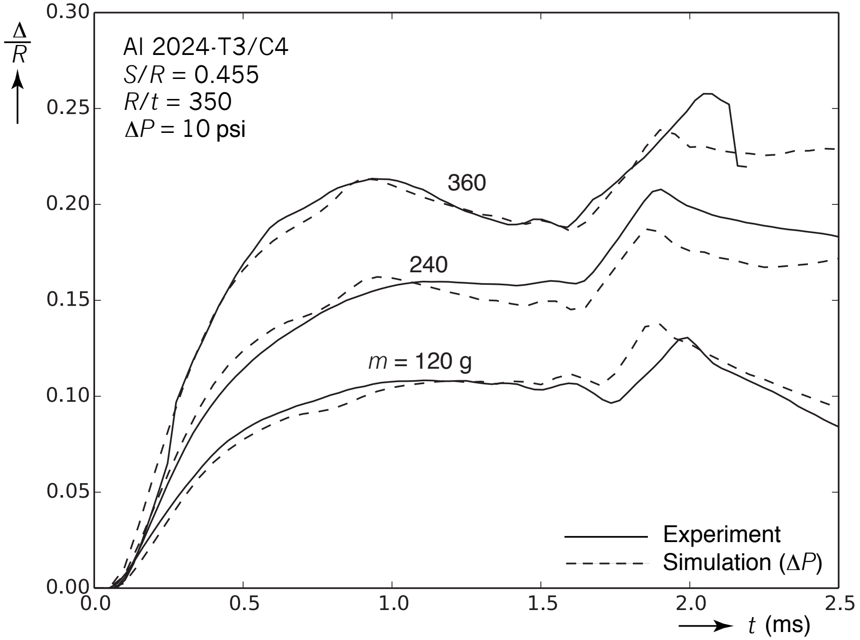


Additional Pressure

Comparison to Other Charges



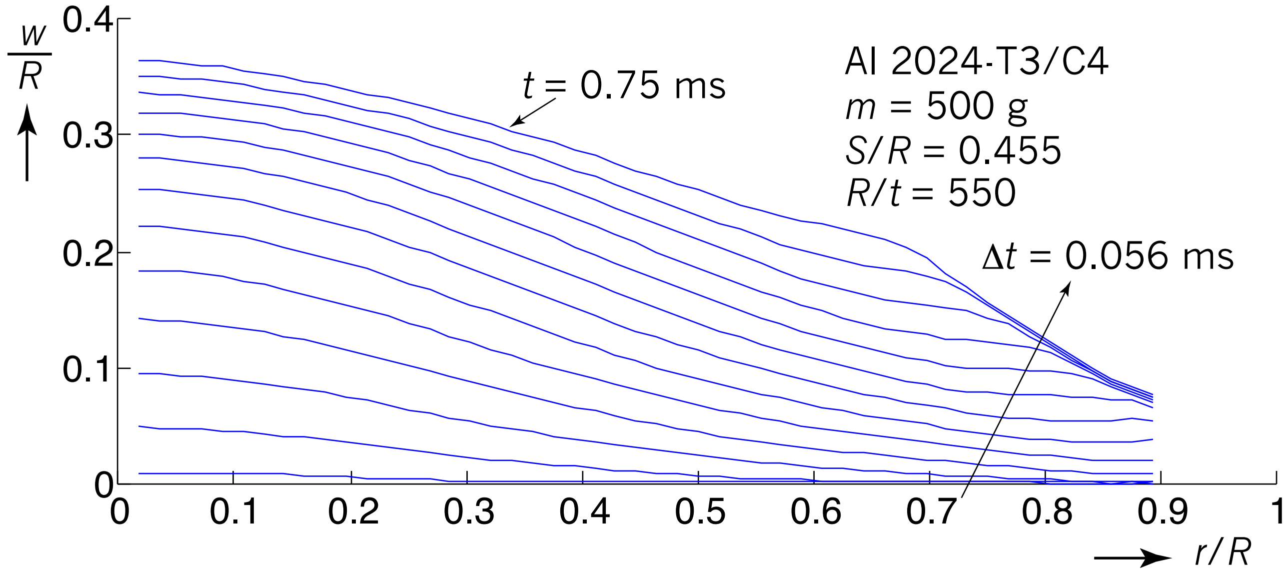
Pressure Multiplier



Additional Pressure

Plate Profile Comparison

DIC Measurement



Model Prediction

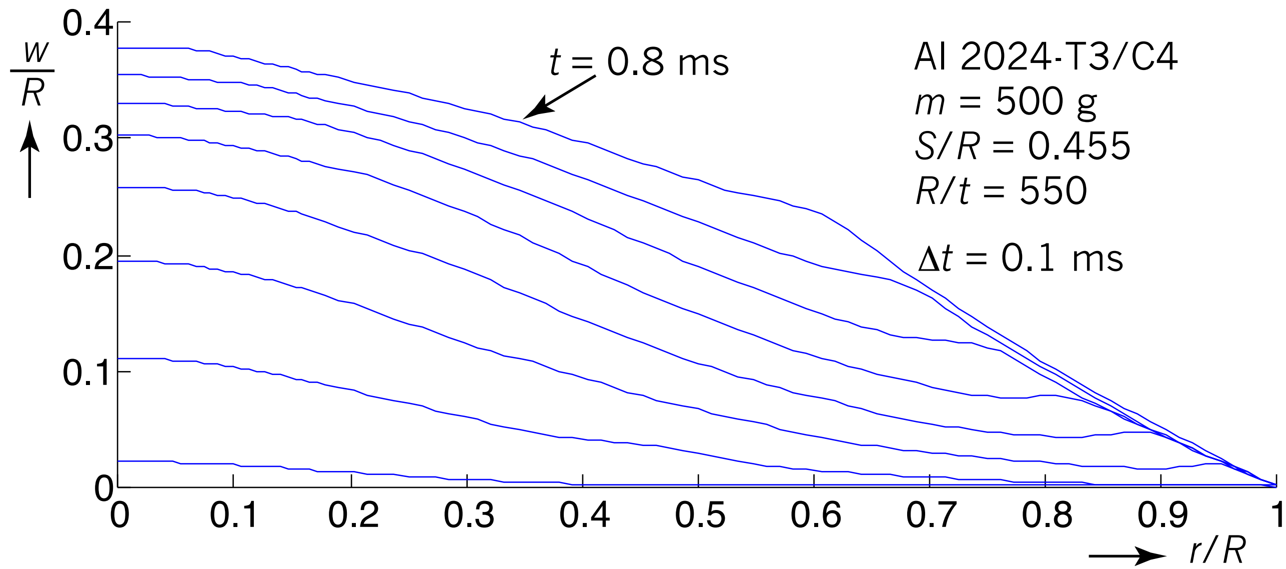
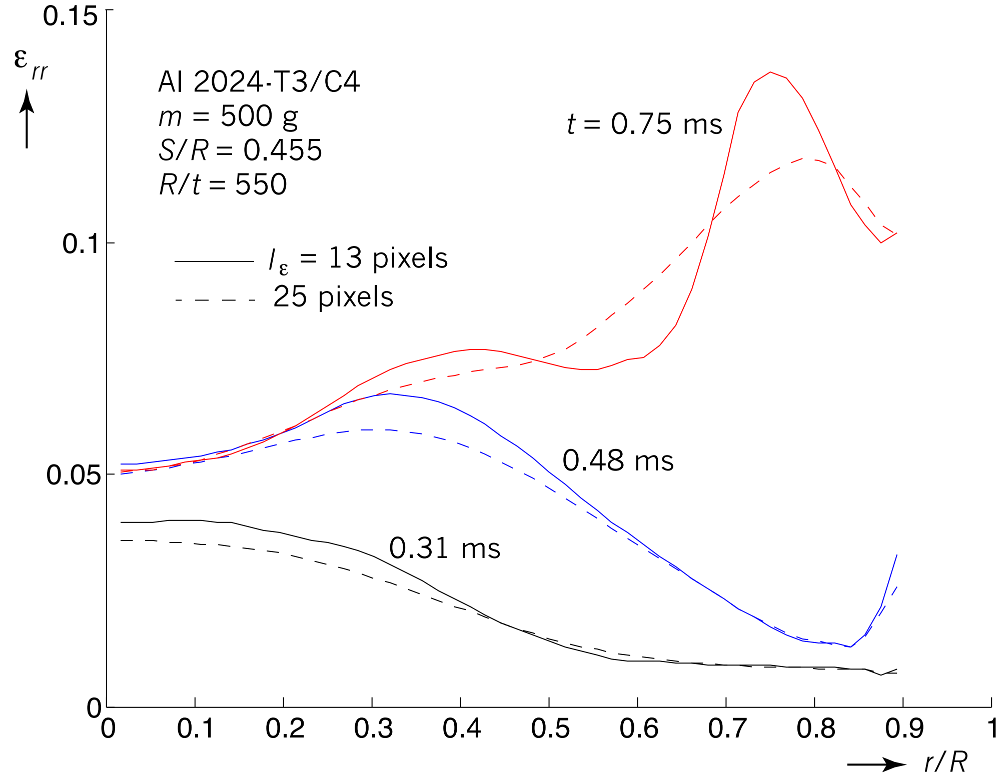


Plate Tearing: Strain Measurement

- Many ductile failure models for tearing are strain-based
- Strain measurements depend on the strain window size if gradients are present
- Likely that any strain localization that led to tearing was smaller than the speckles
- It can not be captured with present techniques.

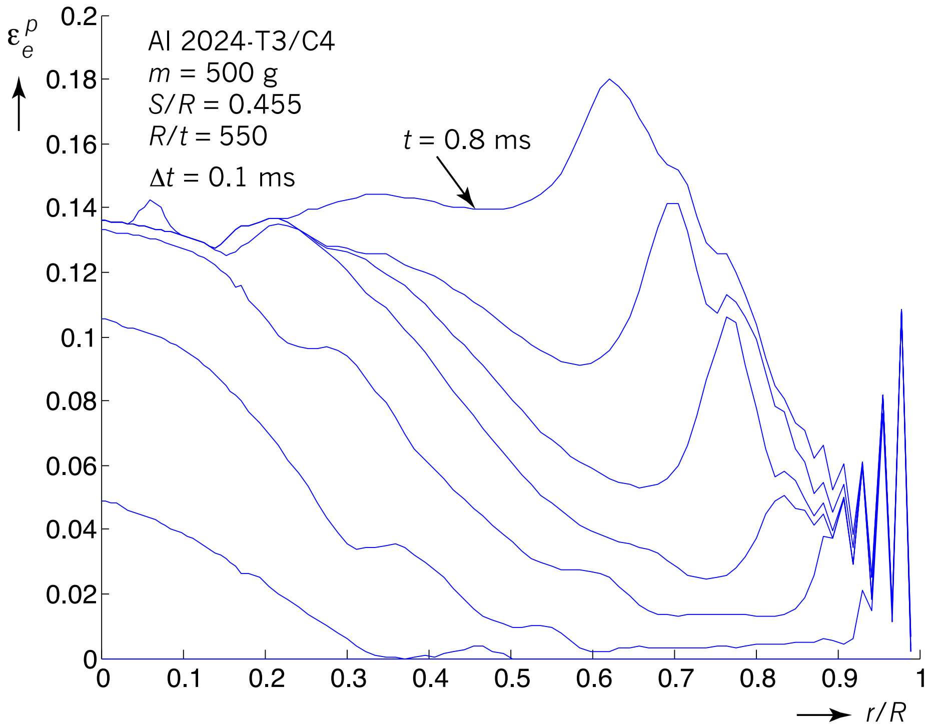


Radial strain with strain windows of 2.9 and 5.5 in.

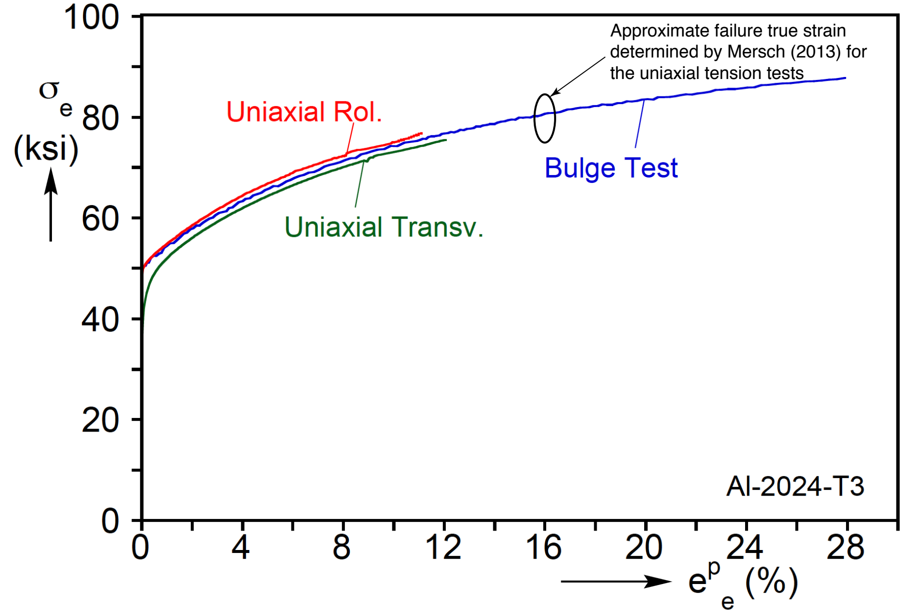
Plate Tearing: Current State

- Model predicts maximum equivalent plastic strain greatest in the vicinity of the location where failure started in the experiments

- Being able to predict under what conditions failure will occur based solely on the problem parameters, however, remains a challenge.



Predicted equivalent plastic strain



Bulge Test Results

Conclusions

- DIC displacement measurements provided a good description of the plate behavior
- Strains from DIC measurements not as accurate in regions of high gradients
- DIC measurements instrumental in finding a deficiency in the blast model
- Model predicts plate deflections very well
- Further work is ongoing to enable predictions of plate tearing.