Validation of Simulation Results Through Use of DIC Techniques

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DatapointLabs

ANSYS Conference & 32nd CADFEM Users' Meeting 2014
June 4 – 6, 2014, NCC Ost, Messe Nürnberg

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Poisson's ratio
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- 11 manufacturing verticals
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Materials
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Packaging

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ISO 17025 Quality

US Test Laboratory

Data Delivery

- 5-day turnaround for standard tests
- PDF reports downloadable from your account
- Free Matereality Personal Material Database for your digital data includes CAE Modeler software

Project Impetus

- Collaboration with Cornell University Mechanical & Aerospace Engineering program
- 4 distinct aluminum beam geometries loaded to 100 lbf
- Theoretical strains are calculated at certain locations along beam
- Strain gauges are attached at these locations to verify calculations
- Simulation of experiment performed in FEA software
- Discrepancies between simulation, theory and measurement often plague these experiments, especially with more complex beam design
- DIC was used to validate simulation and investigate sources of error

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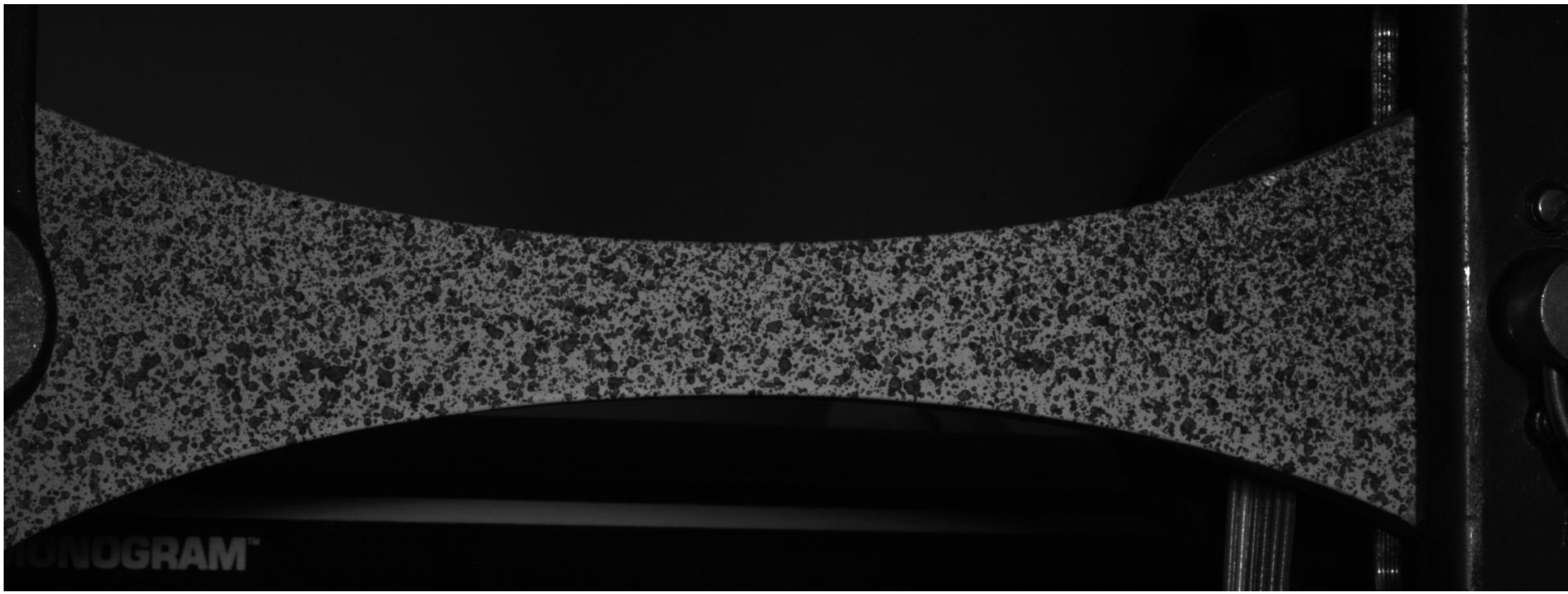
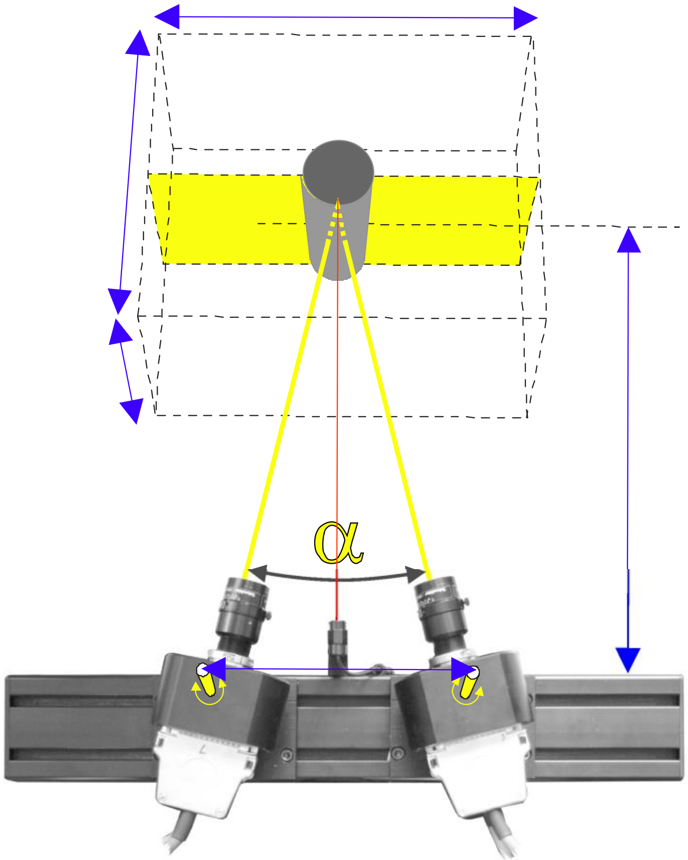
Digital Image Correlation



- Specimens are coated with a speckle pattern

DIC Operation



- As the specimen is loaded, stereo pairs of pictures are taken and the software is able to track the movements of the facets. Facets = elements.

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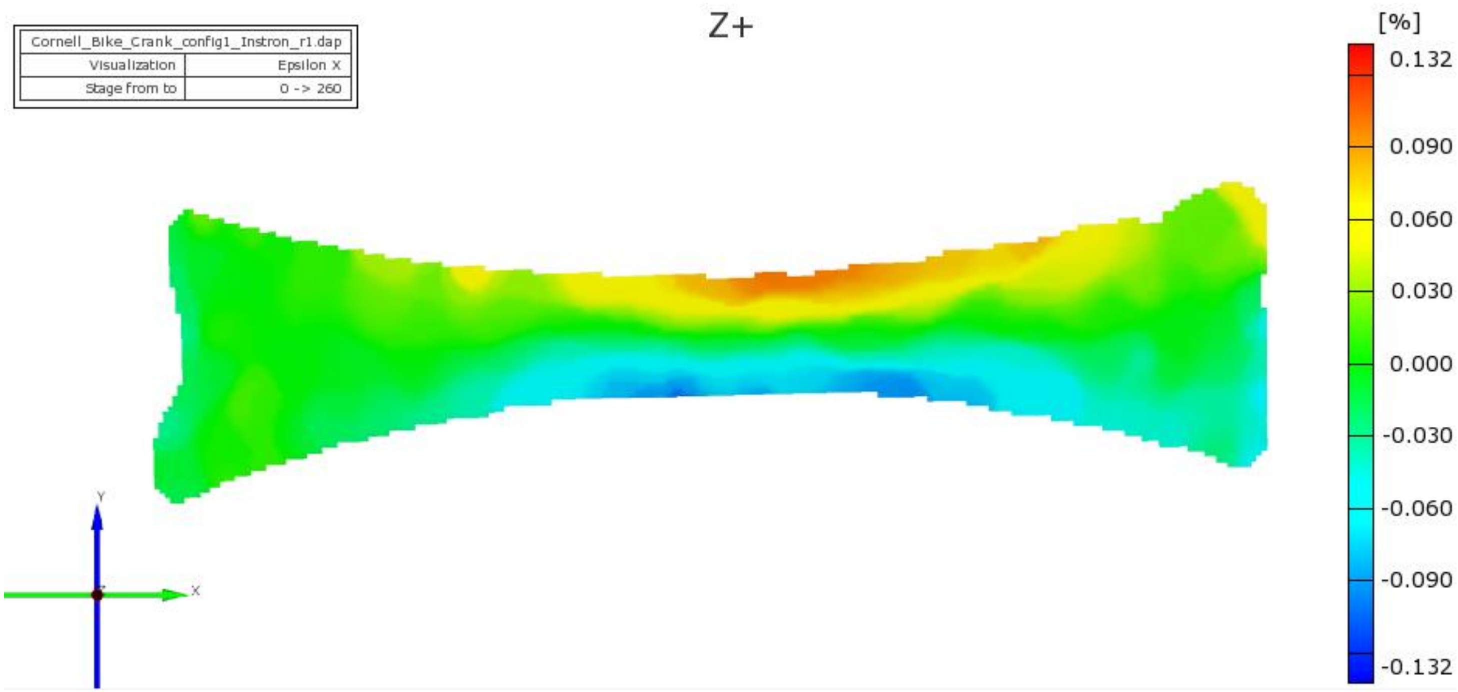
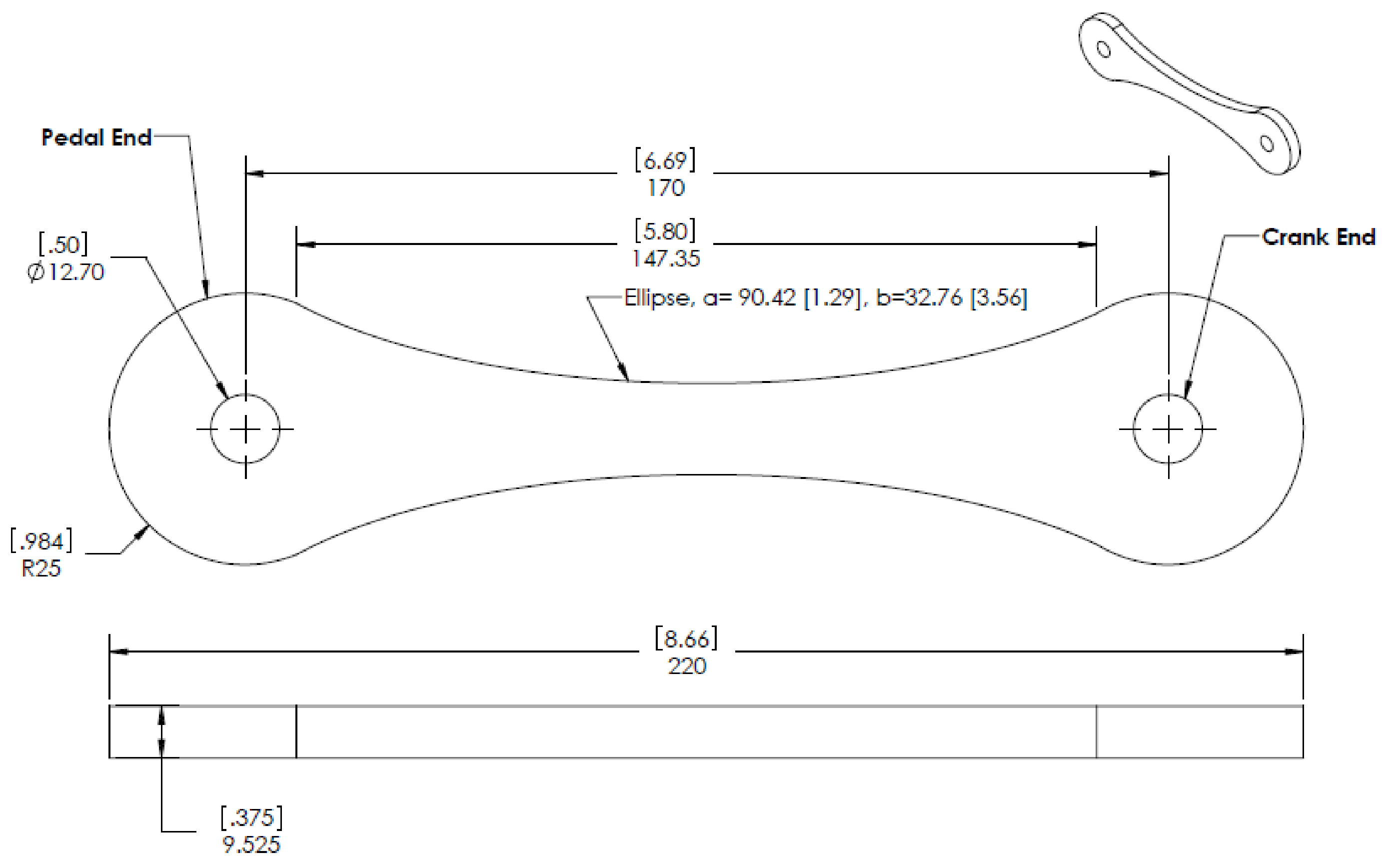
Strain Field Map

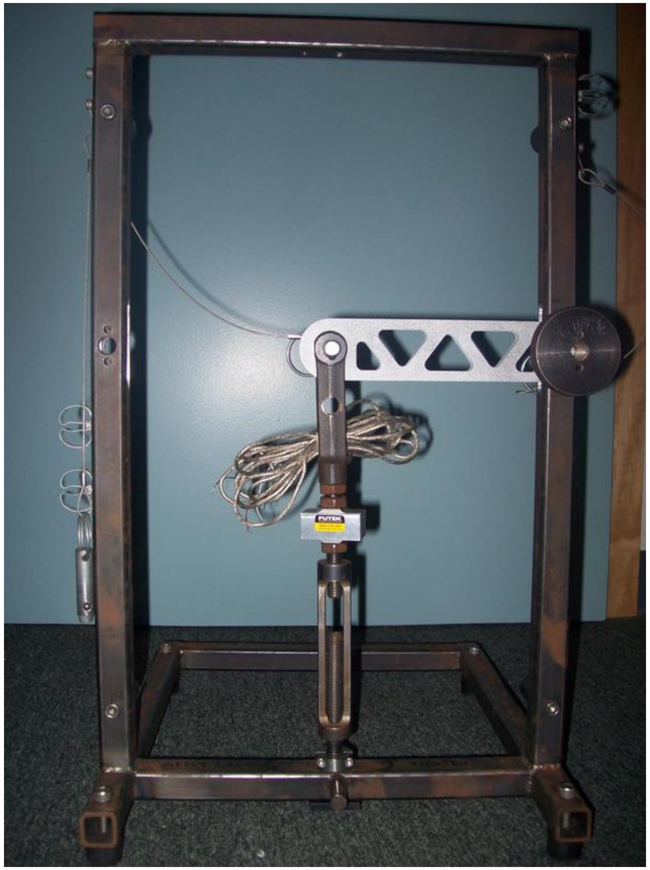


- From the displacements of the facets, the software calculates the strain field across the part

Sample Geometry



Cornell University
Load Application Frame



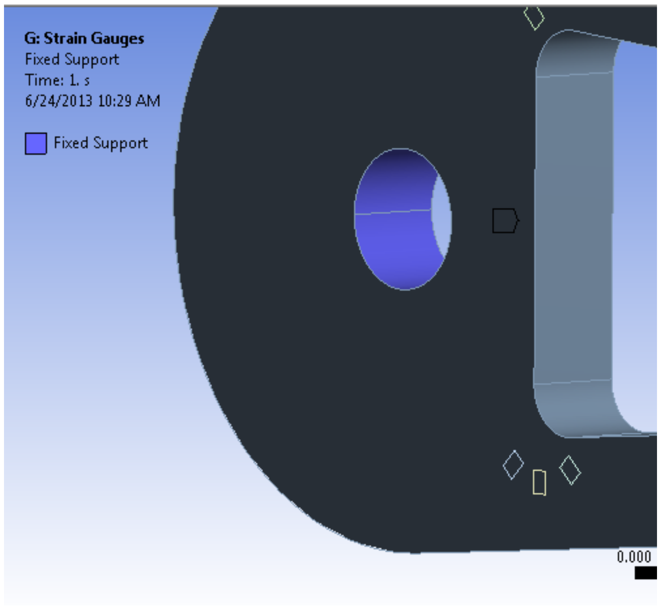
ANSYS Simulation Setup

- Material: Al 6061 T6

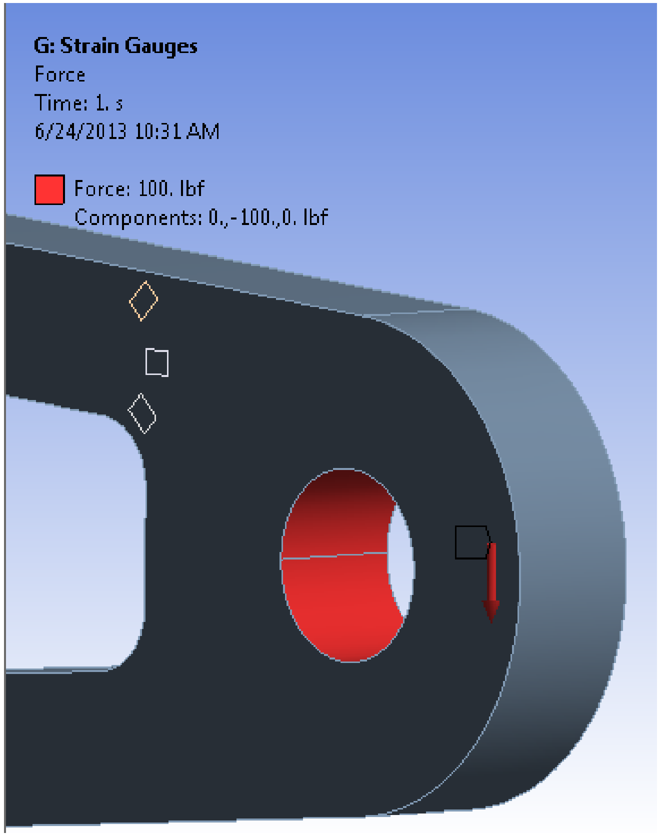
  E = 68900 MPa   ν = .34
- Boundary Conditions:
  - Fixed Support around inside of support hole; no rotations, no displacements
  - 100 pound force in y-direction along inside of pin hole.

Boundary Conditions

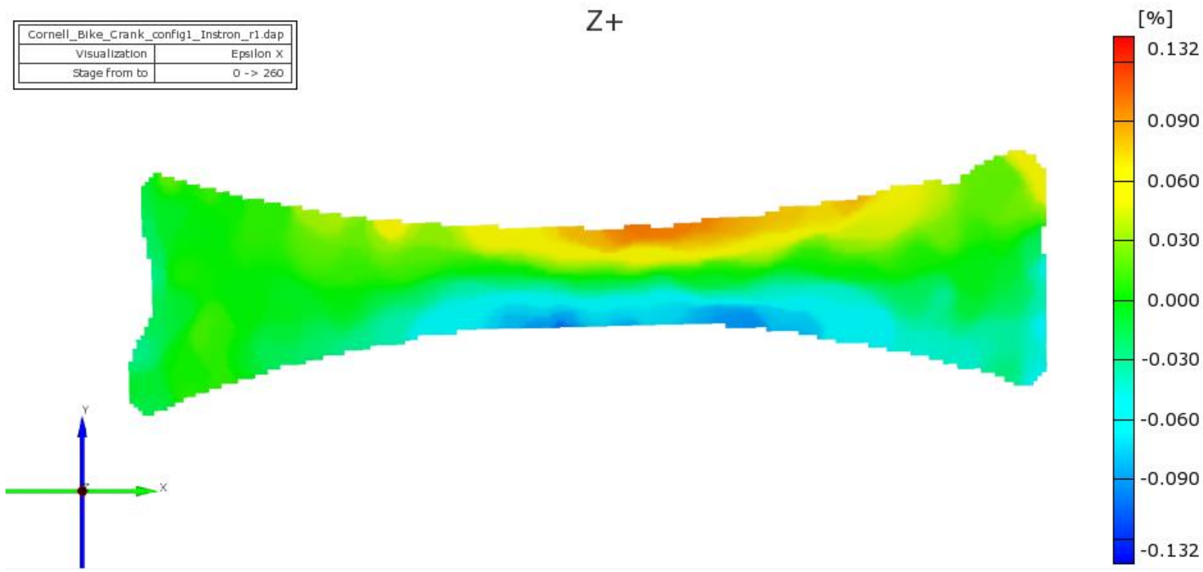
- Fixed Support

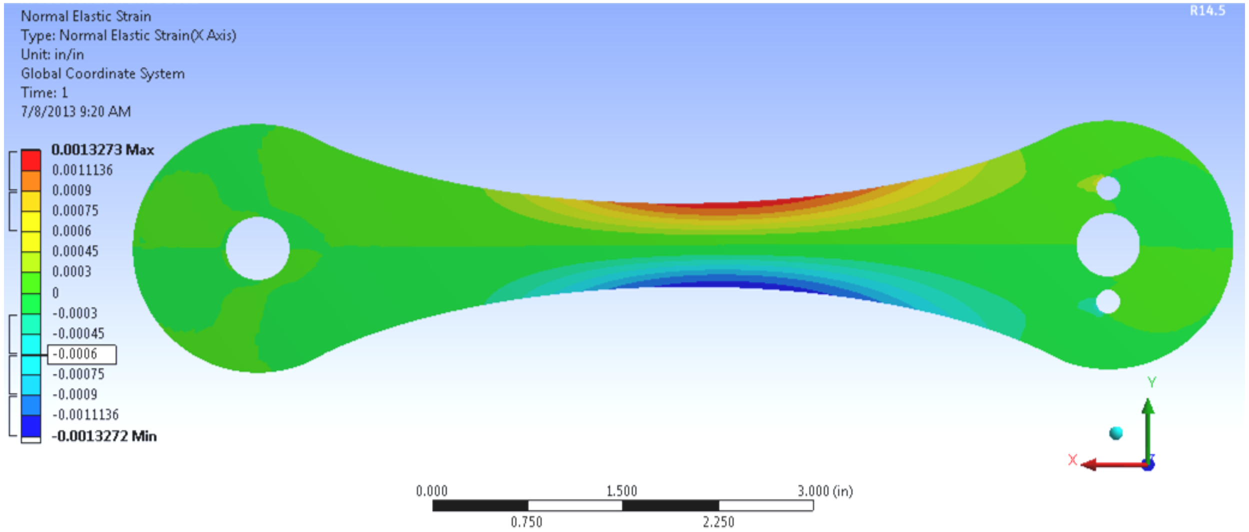


- Force



Compare Between DIC and ANSYS

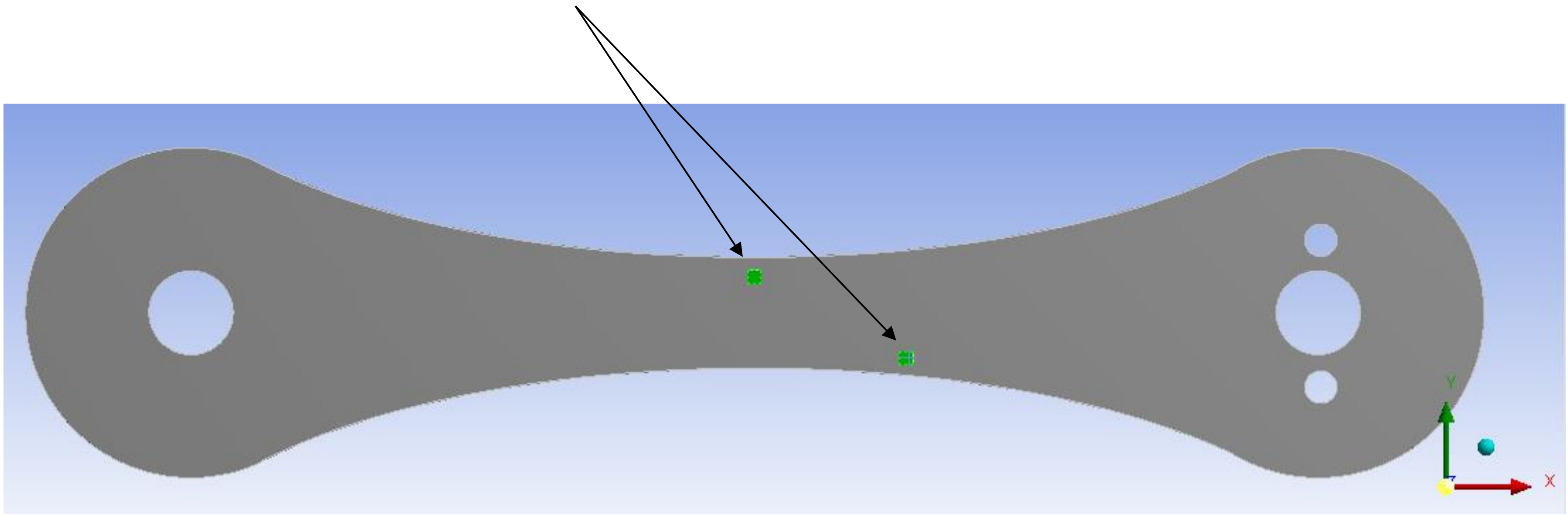




Application of Virtual Strain Gauges to ANSYS Model

- Modeled as shell elements with zero stiffness
- Created in CAD as a plane with zero thickness
- Meshed as one element overlaid on surface mesh
- Strain is calculated based on the average strain from the surface mesh below the gauge

- Strain gauges placed in areas of high tensile and compressive strain



Theory

- Cantilever beam with constant cross-section
- Isotropic material
- Plane stress
- $\sigma_x >> \sigma_y$
- ε_x calculated according to Hooke's Law:

$$\begin{bmatrix} \varepsilon_x \\ \varepsilon_y \end{bmatrix} = \frac{1}{E} \begin{bmatrix} 1 & -\nu \\ -\nu & 1 \end{bmatrix} \begin{bmatrix} \sigma_x \\ \sigma_y \end{bmatrix}$$

Numeric Comparison

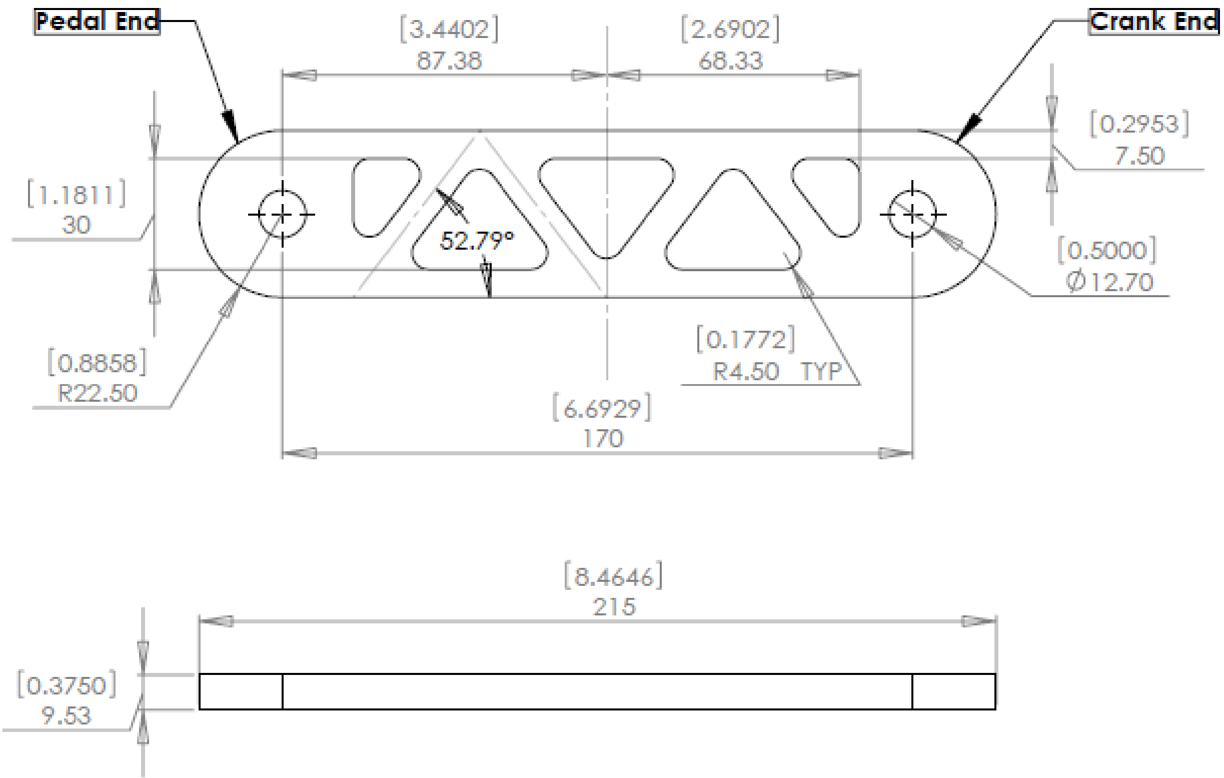
Simulation, DIC, and Theoretical ε_x Values

	Simulation	DIC	Theory
Upper gauge (με)	782	932	789
Lower gauge (με)	-883	-918	-893

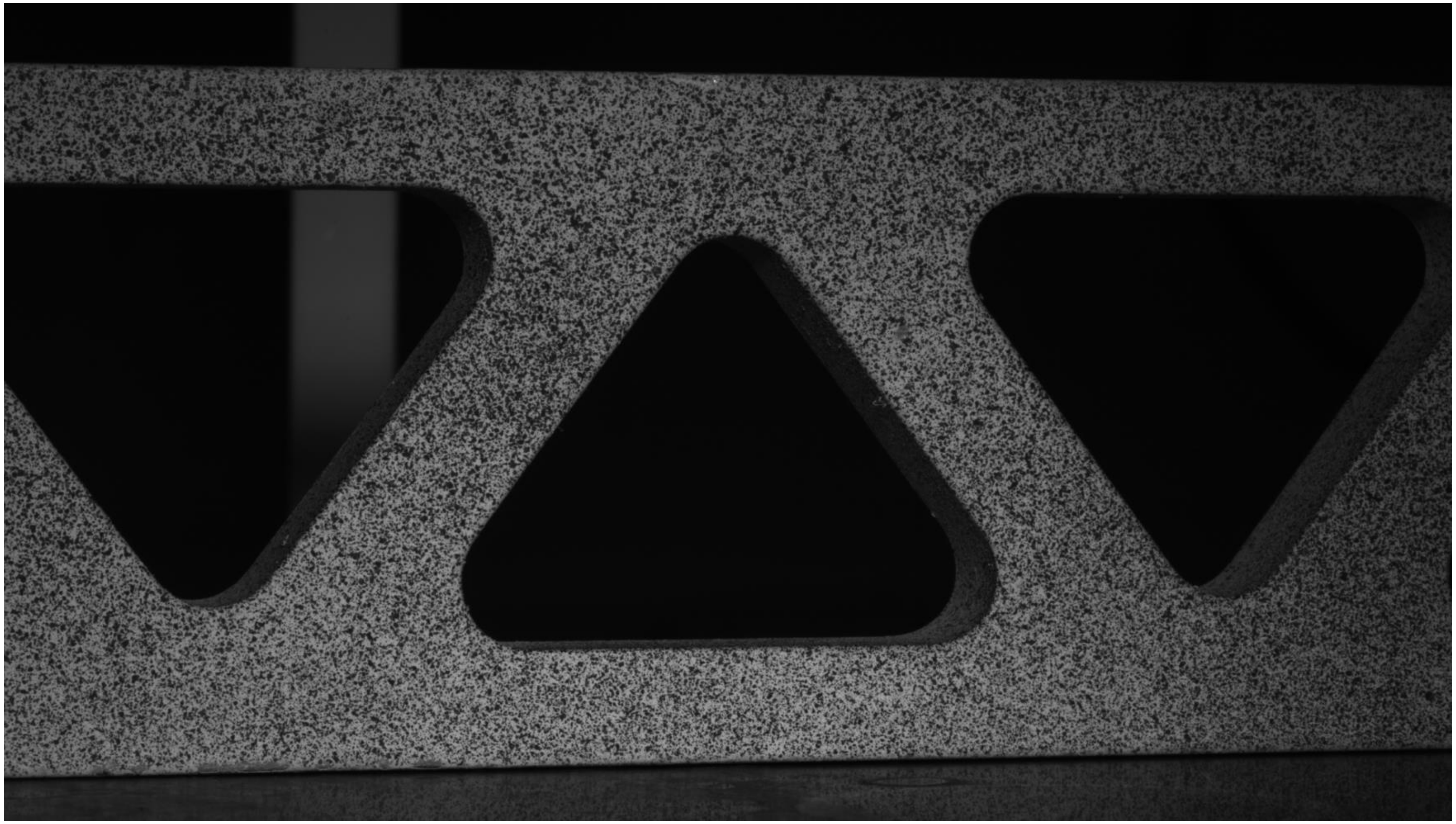
Percent Differences

	Simulation vs. Theory	DIC vs. Theory	DIC vs. Simulation
Upper gauge	.887 %	18.1 %	16.1 %
Lower gauge	1.12 %	2.8 %	3.81 %

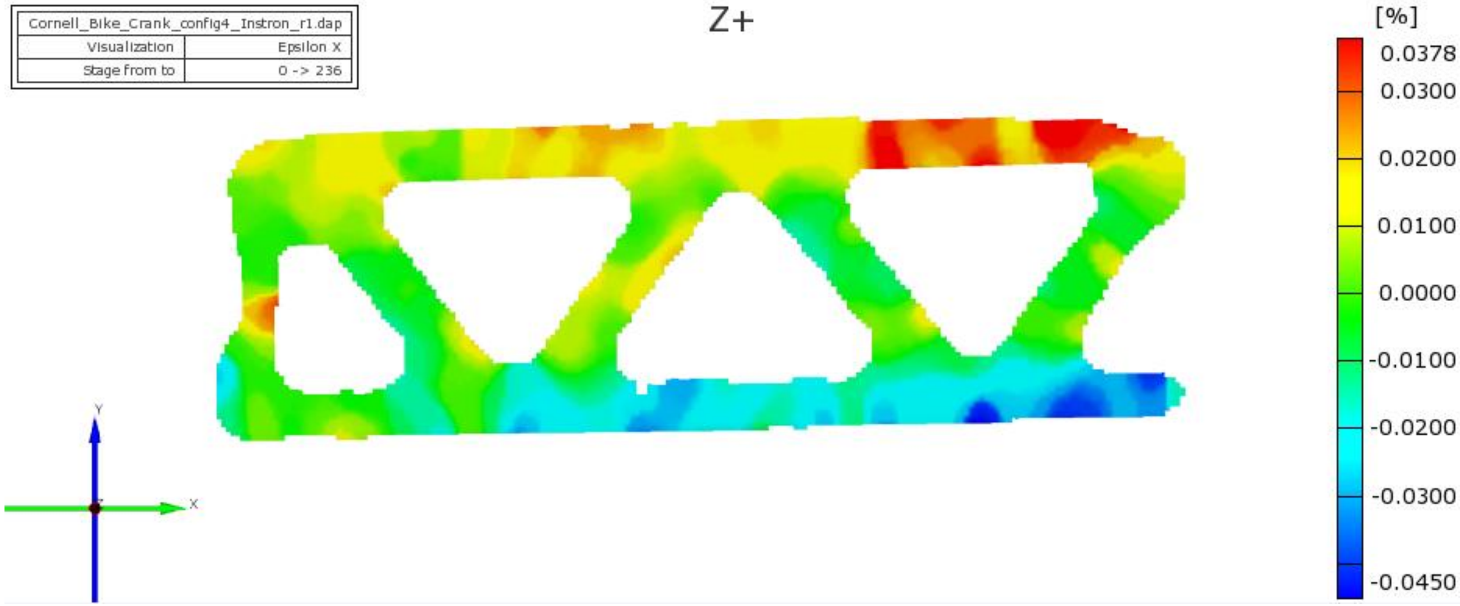
More Complex Geometry

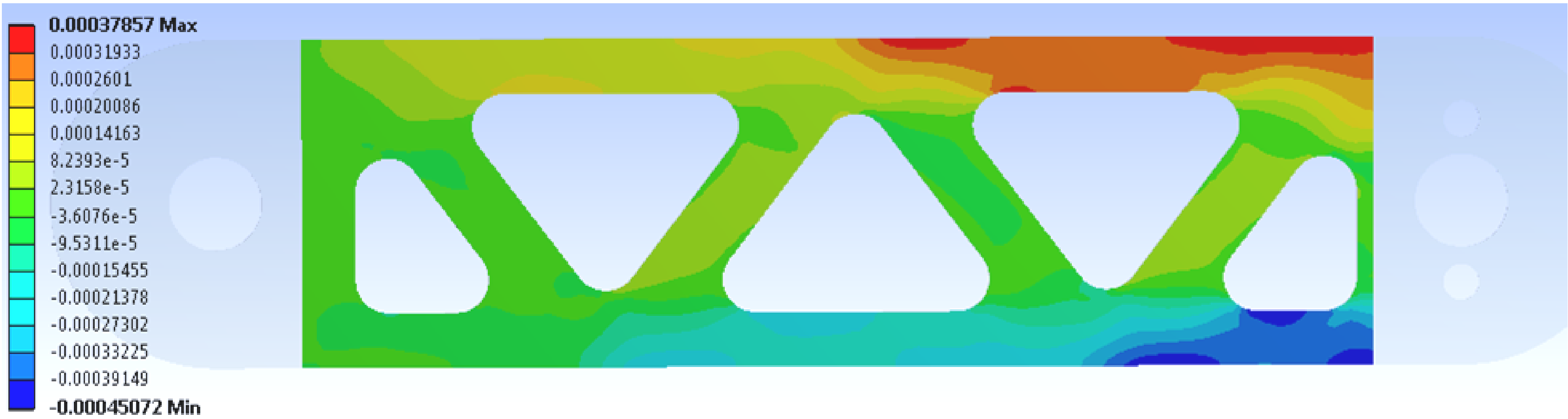


Speckle Pattern

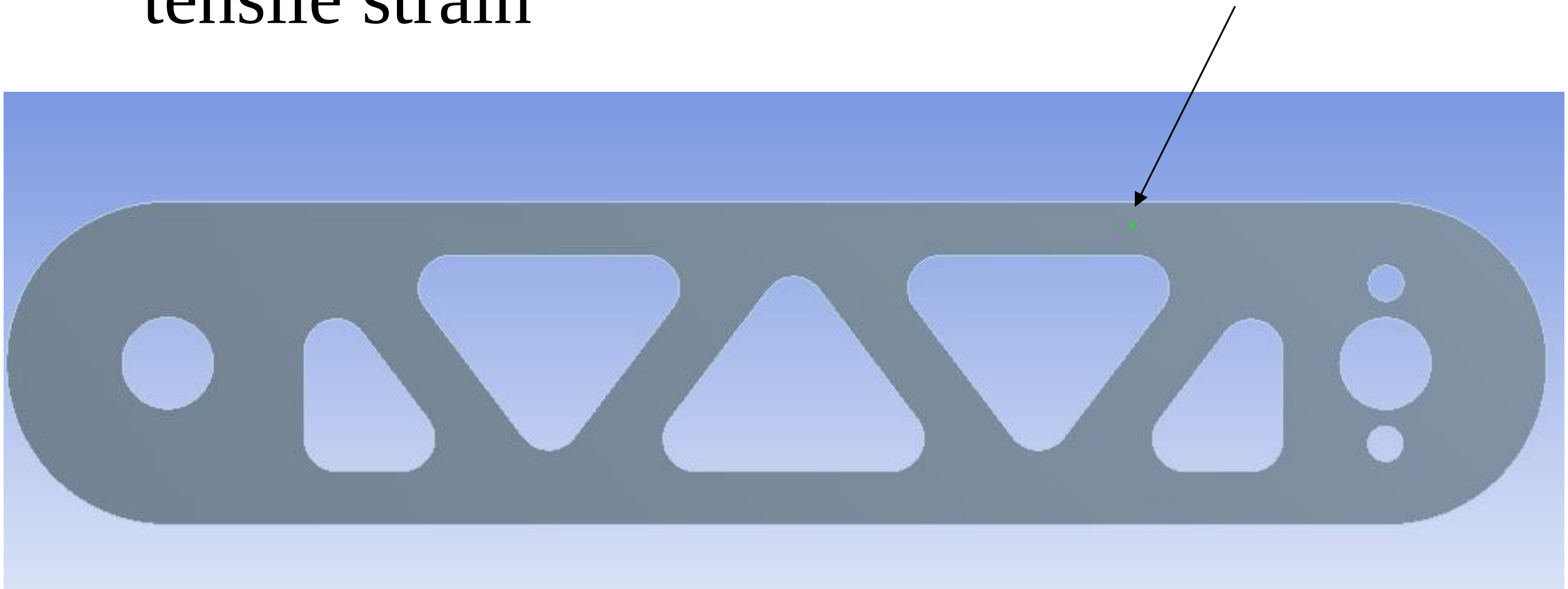


Compare DIC and ANSYS





- Strain gauge placed on an area of high tensile strain



Truss Theory

- Beam treated as a truss with a 100 pound force applied at one end, and fixed supports on the members at the opposite end
- The magnitude and direction of the force in each member was determined, and from this the stress and strain at the position of the strain gauge were calculated

Numeric Comparison

Simulation, DIC, and Theoretical ε_x Values

	Simulation	DIC	Theory
Gauge X-strain (με)	292	270	262

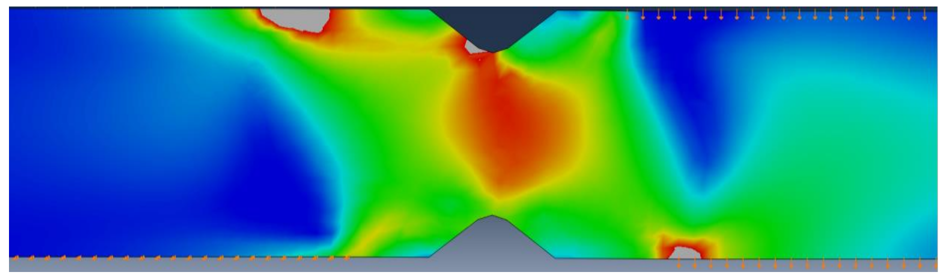
Percent Differences

Simulation vs.Theory	DIC vs. Theory	DIC vs. Simulation
11.5 %	2.96 %	8.15 %

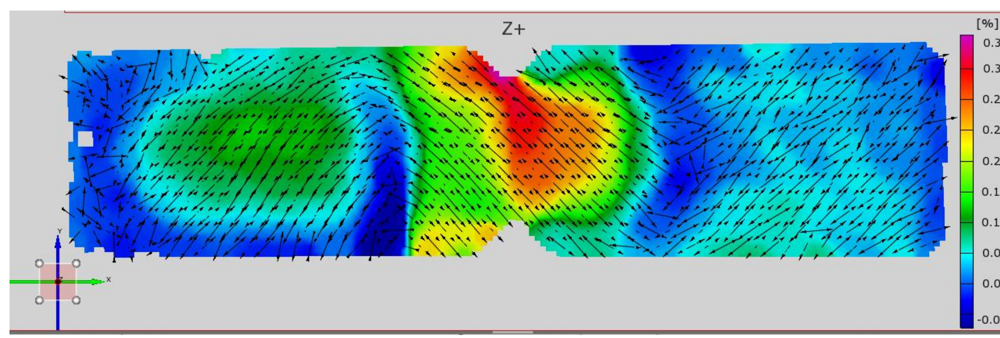
Extension of DIC Validation

Complex material model validation and calibration

Perform simulation of test, verify boundary conditions

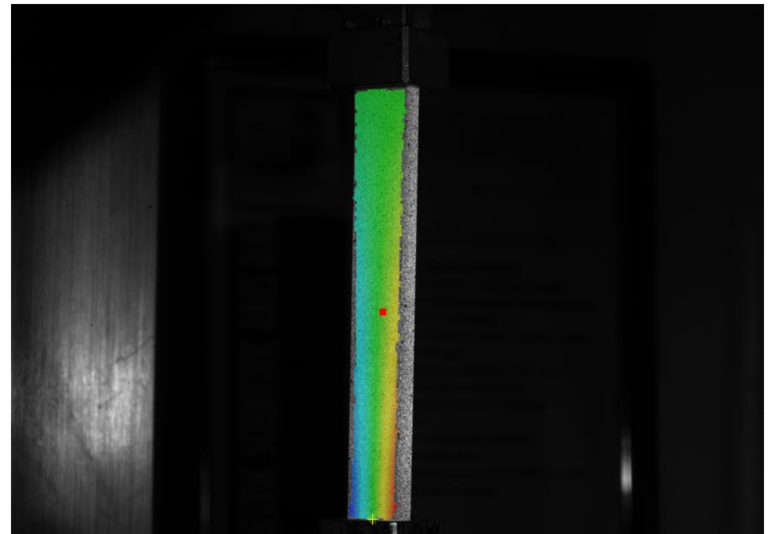


Calculate actual strains during the testing using DIC software

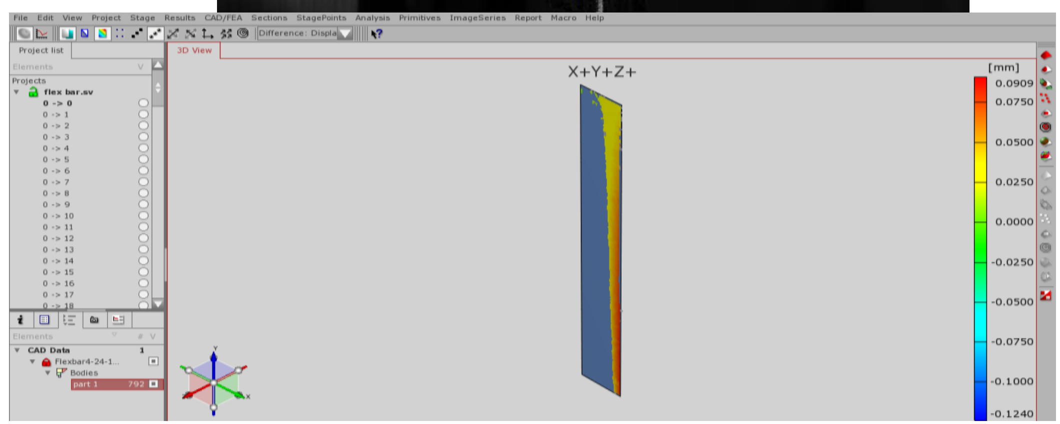


Evaluate Multi-Mode Deformation

Tension with torsion load

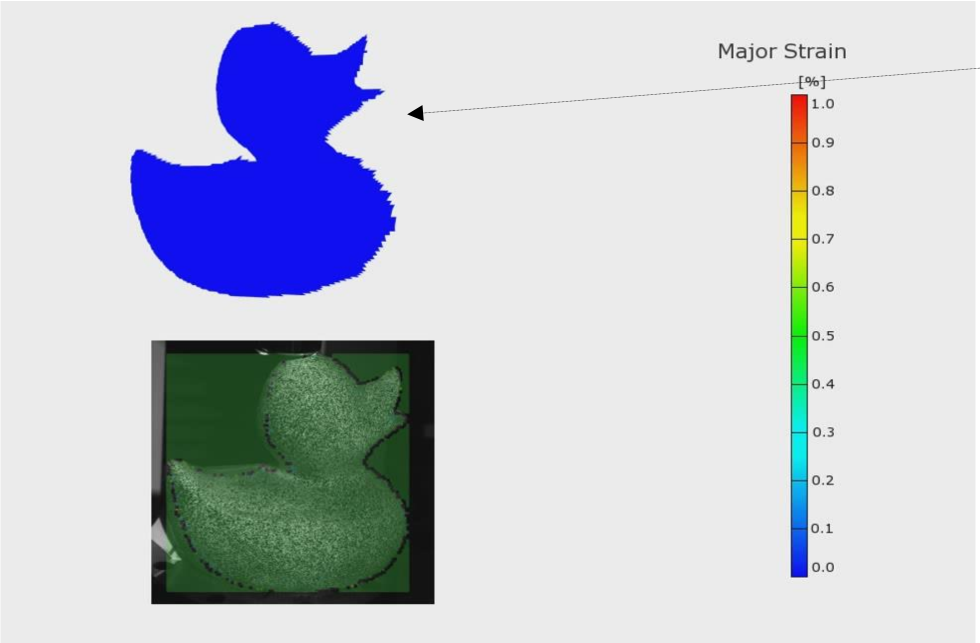


Compute deviation between measured strains and simulated strains.



Component Measurement (Define Boundary Conditions)

- The material model can now be applied to the component simulation
- The DIC can now be used to refine boundary conditions of the actual test



Live mapped strain field

Conclusions

- DIC provides full field validation of simulation data rather than single-point spot checks
- Ability to pinpoint problem areas in beam analysis
- Provides better understanding of localized strain behavior at any location
- Eliminates error associated with strain gauge placement
- Less likely to miss strain “hot spots” that can arise with complex loadings or geometries

Acknowledgments

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