Improving Simulation Quality with Reliable Materials Methods

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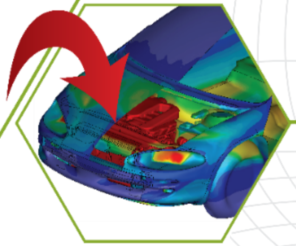


Outline

- Nature of the problem
- Sources of error
- Stepwise approach
- Documentation and Traceability
- Case studies

Why we need accurate simulations

- Early days- simulations were in ‘try-out’ phase
  - Use any available material data
  - Large commercial material databases with typical data
- CAE today- simulation-informed design
  - Relevant material data
  - Testing of actual material
    - composition
    - processing

Requirements for accurate simulation

- Simulations require accurate material representation
- Linear material models do not present a problem
- Non-linear models get complicated – quickly
  - Appropriate finite element
  - Right material model
  - Physical tests
  - Correct material parameter conversion
- Need to check that the simulation is working correctly

Physical tests- Systematic Method

- Look at the property requirement for the model
- Evaluate the physics
- Perform the most scientifically accurate measurement
- Apply measured values to material model

Pros and Cons

- Tests can yield data directly useable in material model
- Tests need to be scientifically accurate- not easy
- Tests attempt to obtain pure modes of deformation – not always successful
- Successful test data provides strong basis for material model
- No need for optimization
- Validation of simulation improves confidence

Physical tests- Empirical Method

- Perform a test with good boundary conditions that contains the behaviors of interest
- Simulate the test and use optimization to derive material parameters

Pros and Cons

- Test is easily performed
- Test can contain mixed modes of deformation
- Material parameter generation requires optimization
- Material parameters are ‘smeared’ across the general model surface
- Risk of localized optima
- Independent validation of simulation is important

Stepwise approach

- Select solver: finite element: material model
- Use Systematic method
- Obtain complete experimental data
  - – Real material
  - – Actual conditions (temperature, orientation, rate, environment)
- Capture correct physical properties*
- Correctly convert to material model parameters *
- Confirm simulation accuracy by validation *

* steps requiring some expertise

Need for documentation & traceability

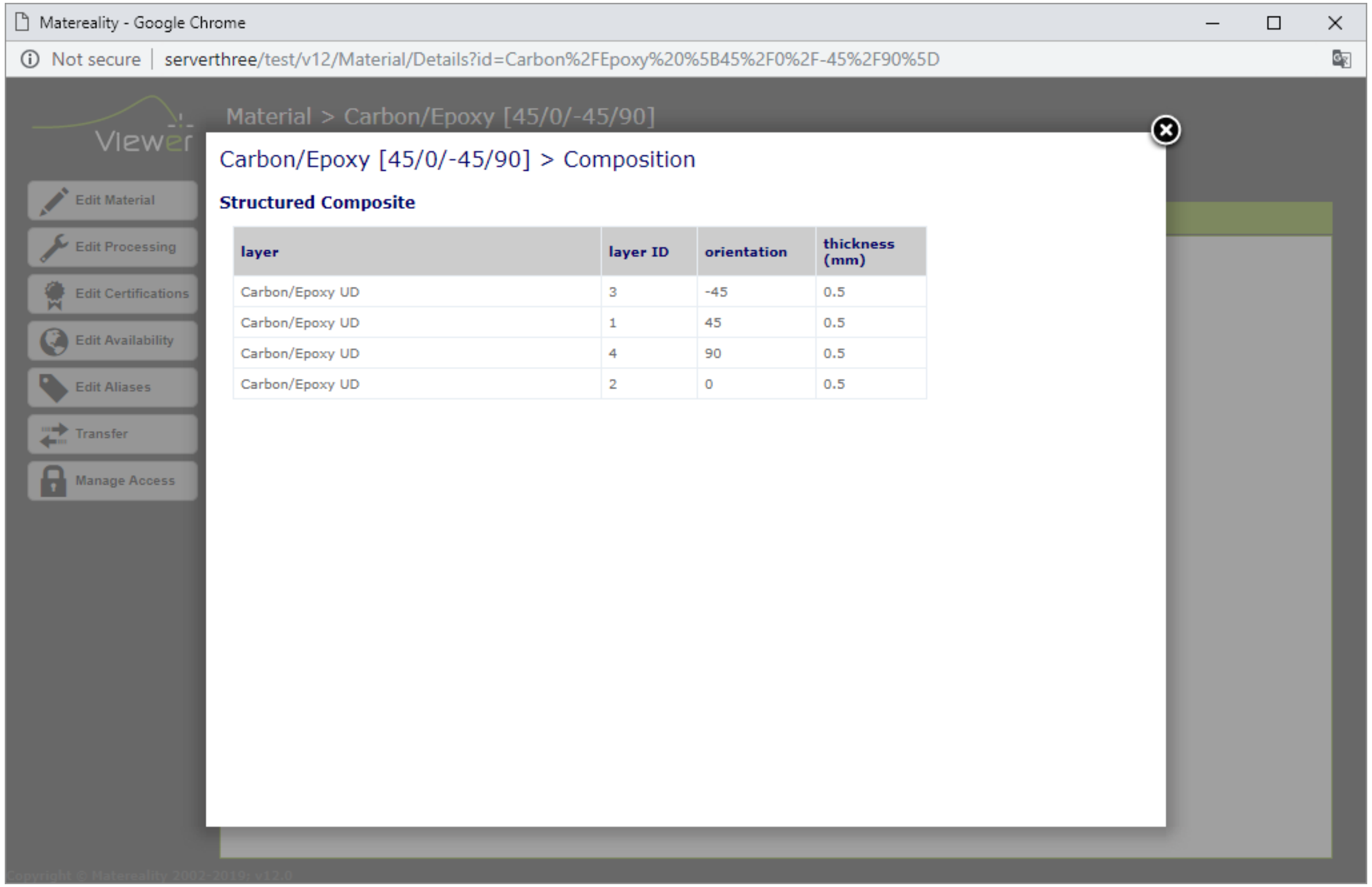
- Material properties depend on
  - Composition
  - Processing
  - Test conditions (temperature, rate, environment)
  - Test Lab – (instrument, technicians …)
- Data quality depends on
  - Replication
  - Statistical analysis / choice of representative value
- Material parameter conversion depends on
  - Conversion method & expertise of analyst

Using Digitalization Software

- Capture all the details about
  - the material :
    - composition, processing, availability
  - experimental tests
    - all tests, parameters, variables, source
  - material parameter conversion
    - source material data, conversion process, documentation
    - target solver, material model, unit system
  - validation of simulation
    - Model tuning

Digitalization software- composition

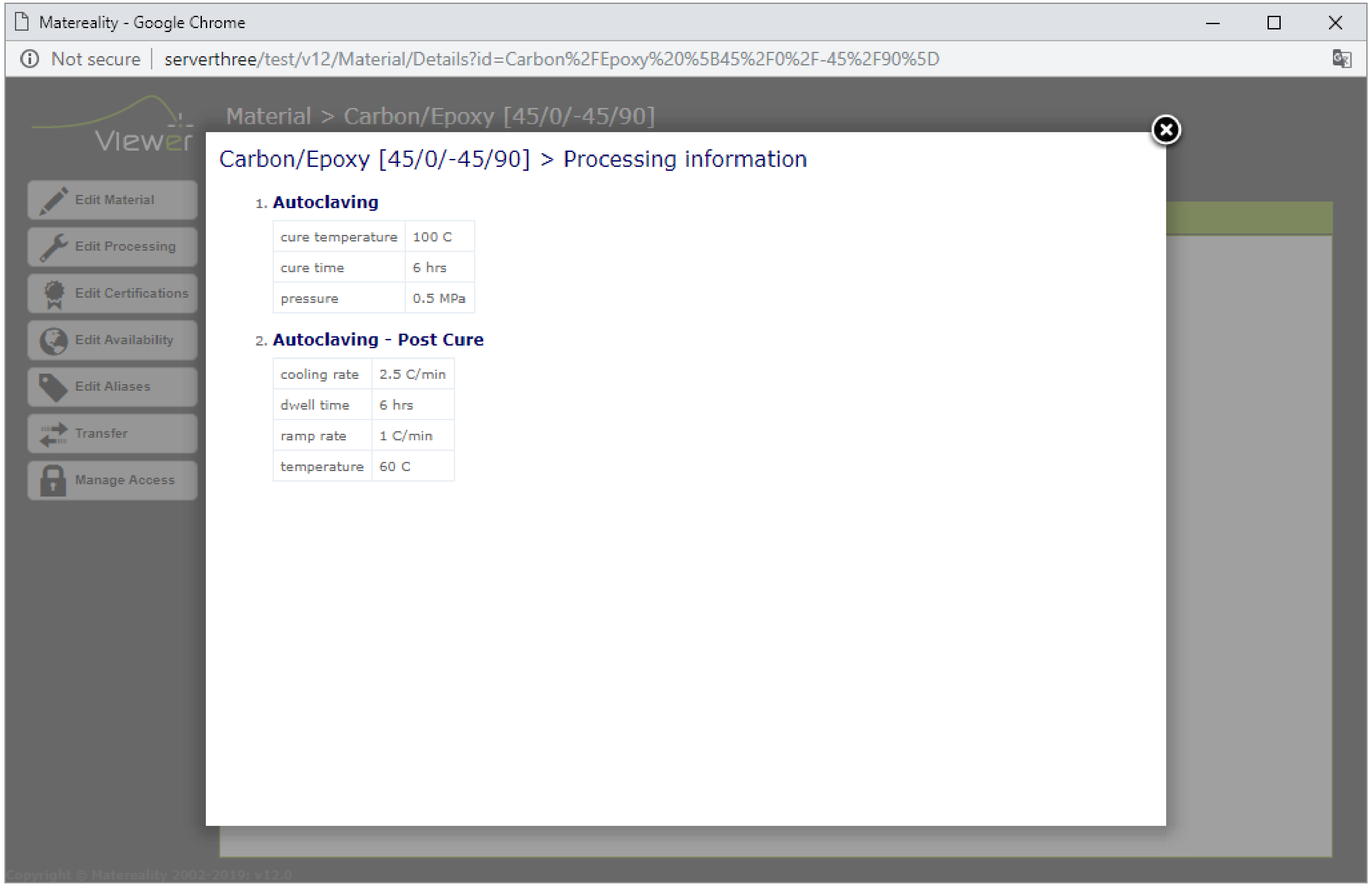
Store detailed compositional information about a composite layup



layer	layer ID	orientation	thickness (mm)
Carbon/Epoxy UD	3	-45	0.5
Carbon/Epoxy UD	1	45	0.5
Carbon/Epoxy UD	4	90	0.5
Carbon/Epoxy UD	2	0	0.5

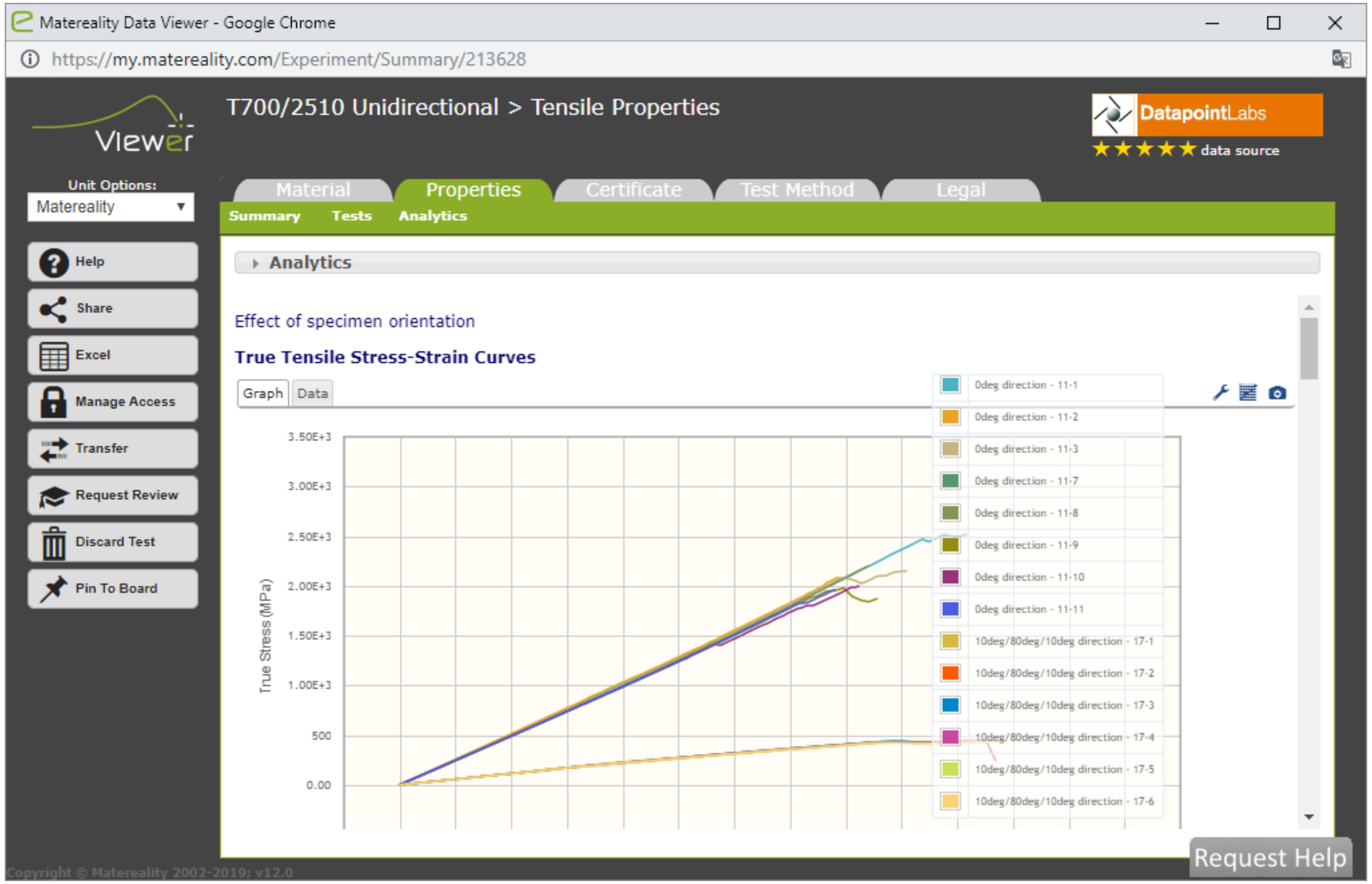
Digitalization software- processing

- **Processing can affect material properties**
- **Processing can involve multiple steps**
- **Store detailed information about processing**



Digitalization software- material data

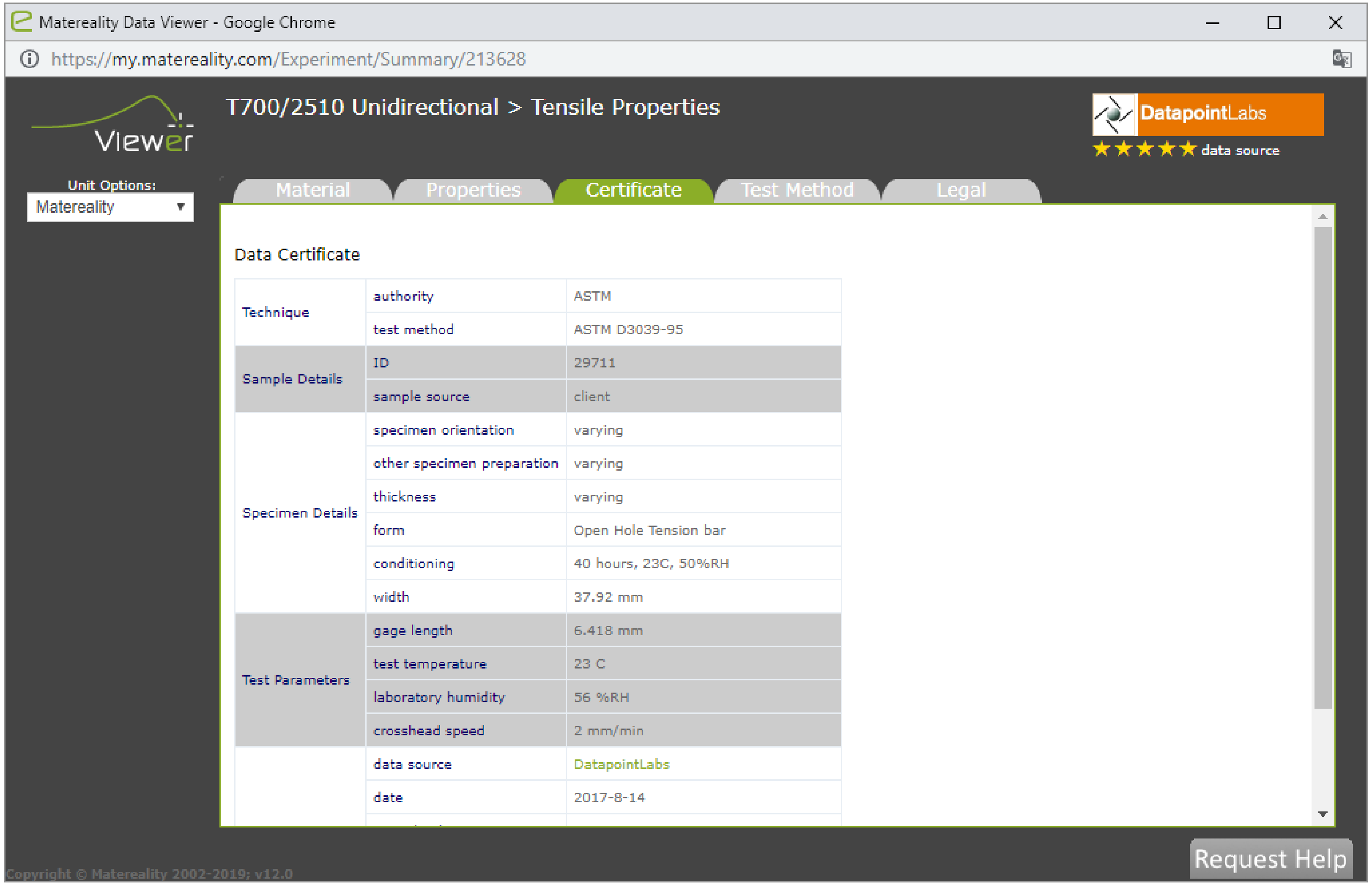
- **Capture data for each replicate from the physical test**
- **Capture variation in properties with orientation, rate, temperature or other parameters**



Digitalization software- traceability

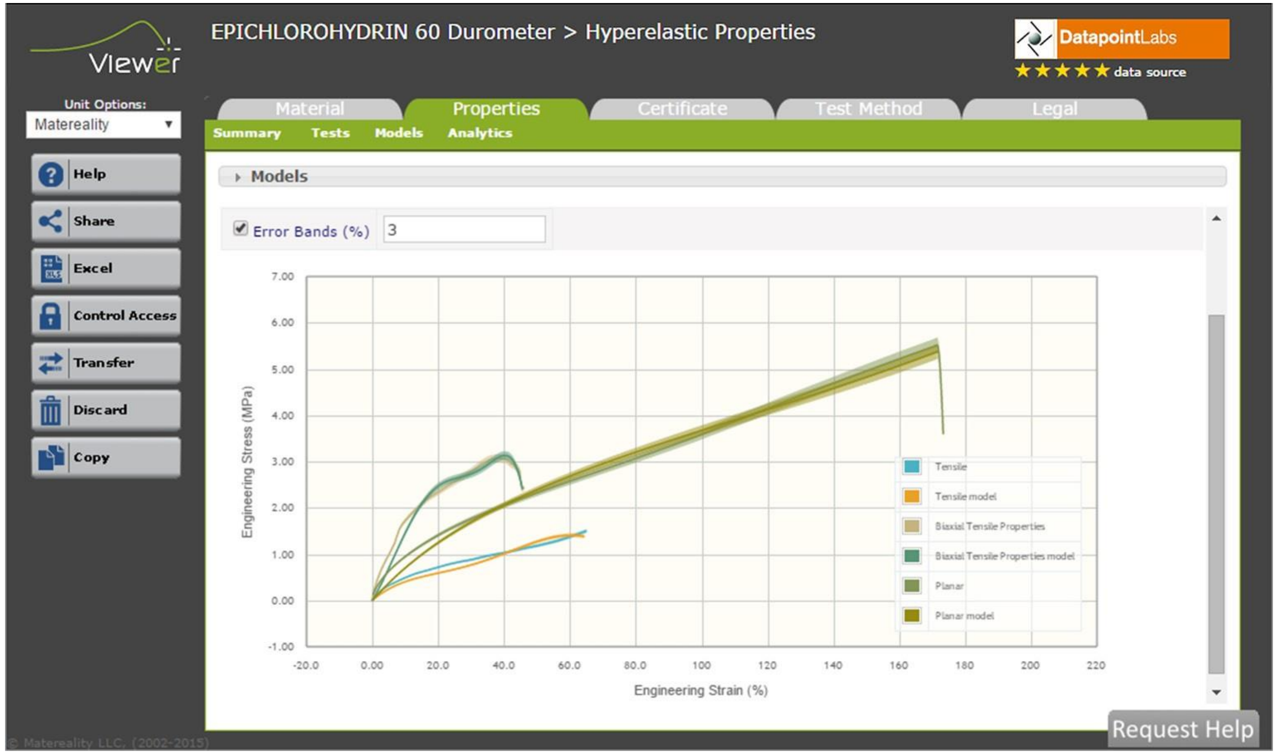
- Capture details of the physical test
- Sample information
- Test parameters
- Test lab and technician

Satisfy the ISO 17025 data reporting requirement



Material Parameter Conversion

- Models often do not use data as measured
  - Conversion calculations are needed
  - Equations must be fit to data
  - Created files and process used are stored



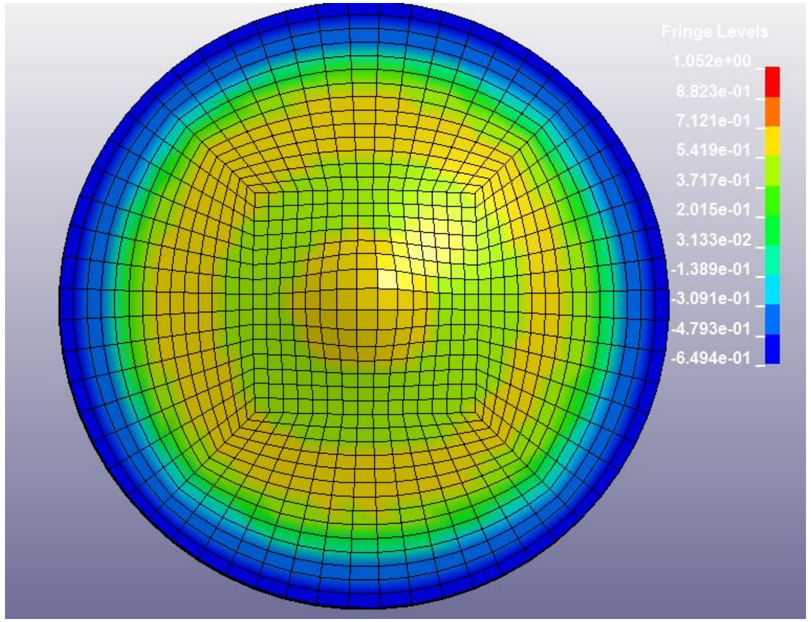
When to use simulation-driven conversion

- Scientifically measure all possible parameters
- Utilize simulation only for the unmeasurable

  e.g. Stress triaxiality at failure

  - Falling dart is a biaxial experiment
  - Measured biaxial fail strain for ABS is 1.8

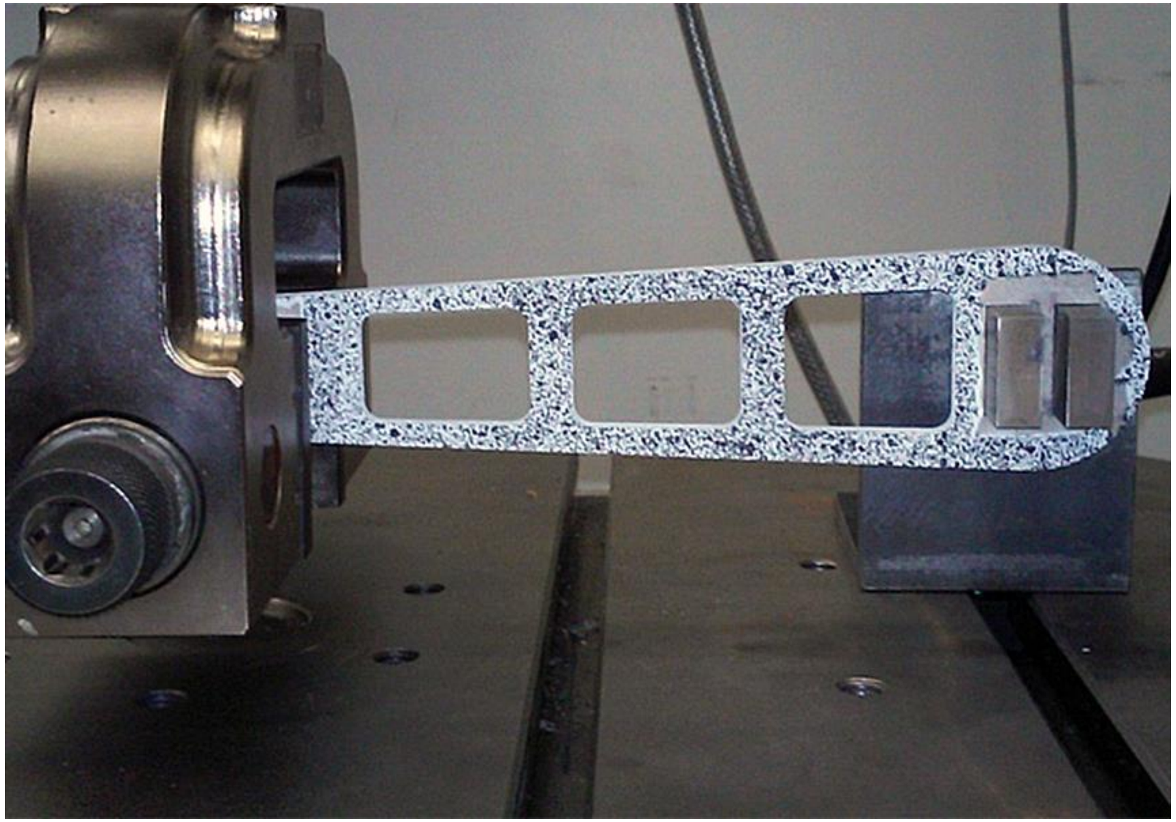
  (Ericssen Cupping experiment combined with DIC, with advice from Dr. H. Gese.)

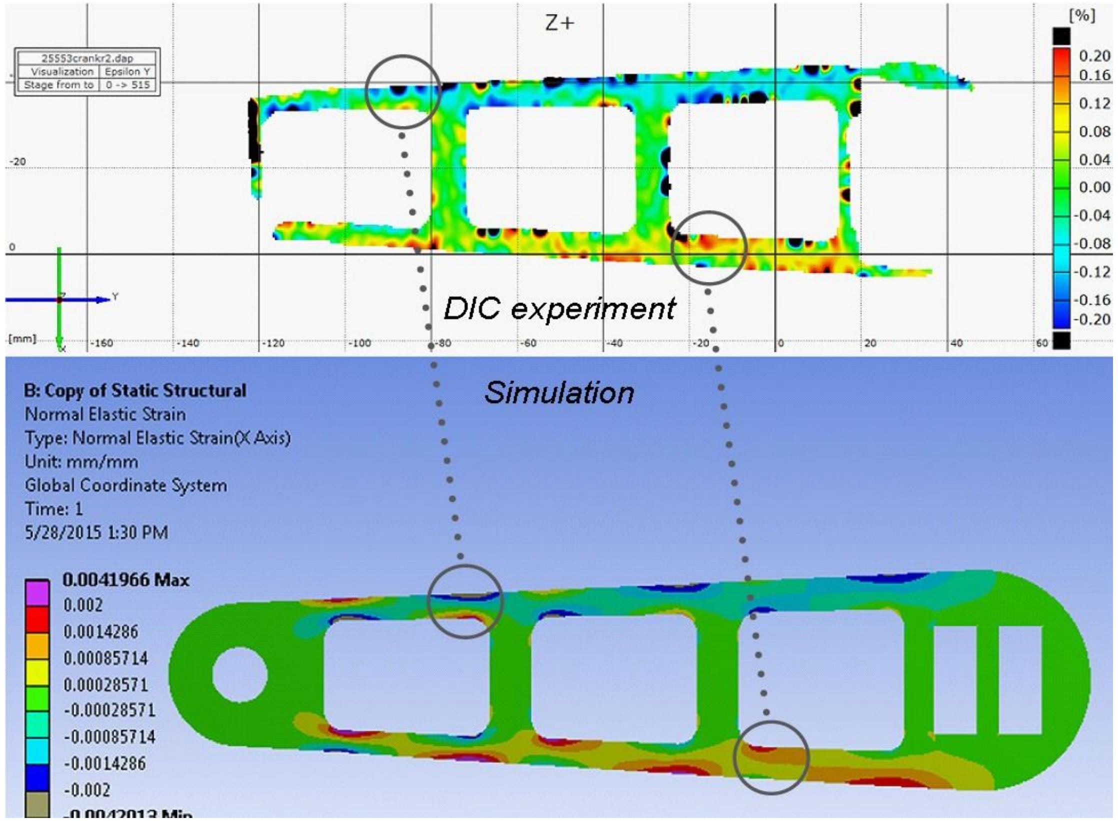


Validation of Simulation

- Use target solver, element type, material model
- Use experiment that can be accurately simulated
  - Standardized case, relevant load case
    - Falling dart test for impact
    - Ribbed plate test for elasto-plasticity of polymers
    - Open hole tension for composites
    - Compressive squeeze test for rubber
  - Quantitatively compare simulation to test

Additively manufactured lattice structure



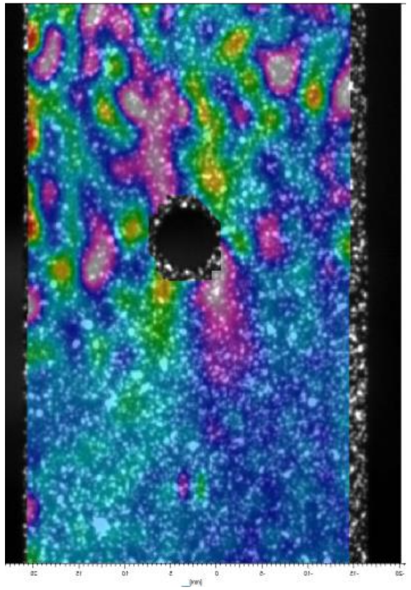


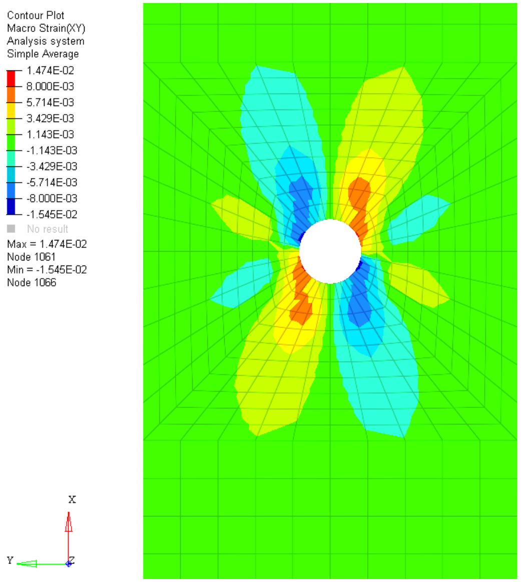
Composites- Open Hole Tension DIC

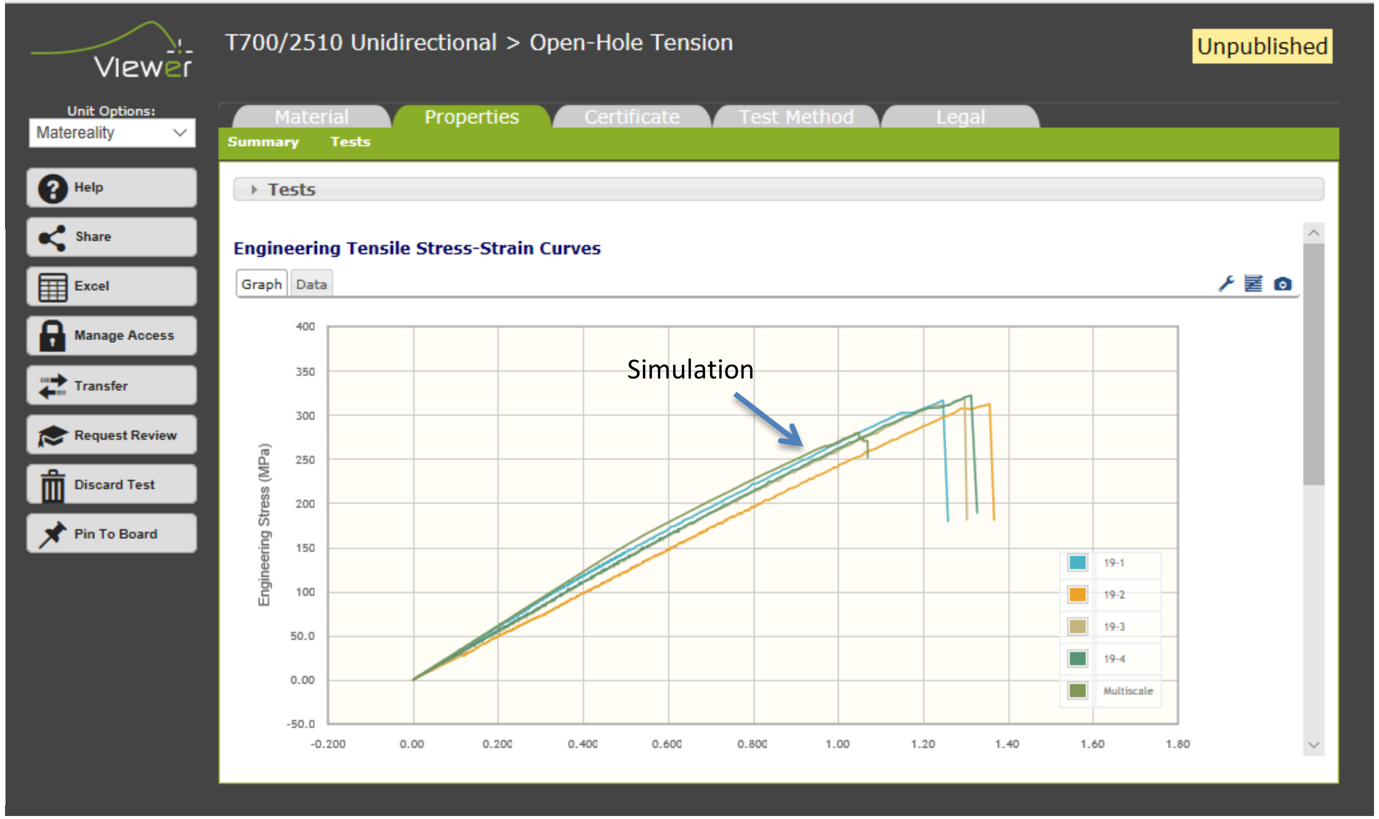
Confirm that the simulation can predict complex case

- Complex layup- [-45/02/45/90/45/02/-45/0]s
- Complex test - Open hole tension ASTM D5766

Experimental strains by digital image correlation (DIC)

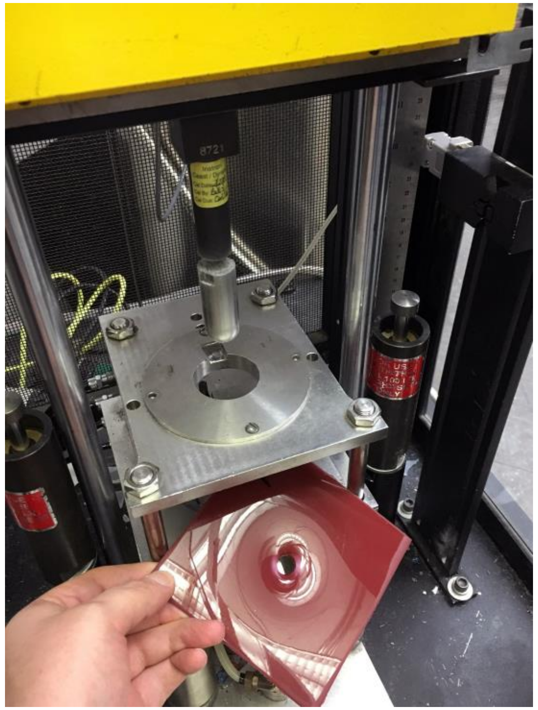


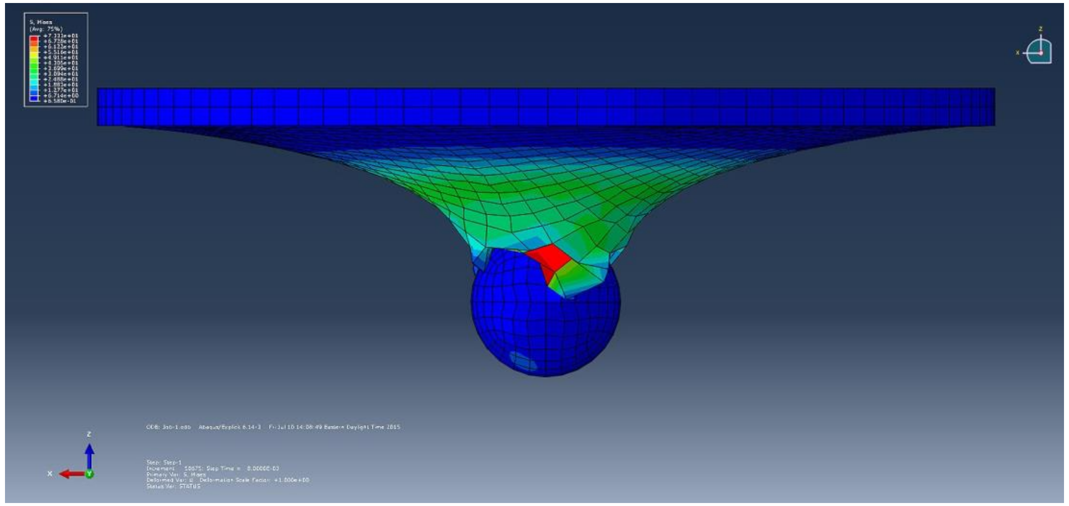




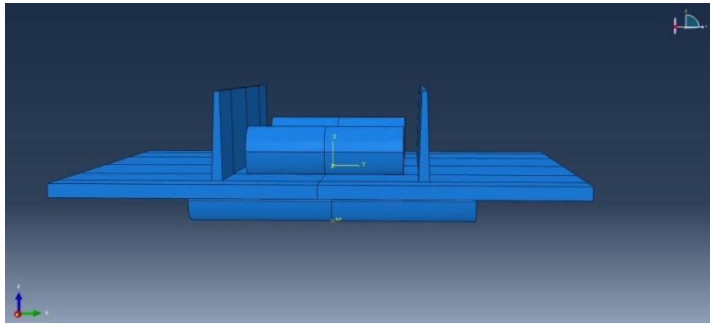
Simulations courtesy: J. Wollschlager, Altair

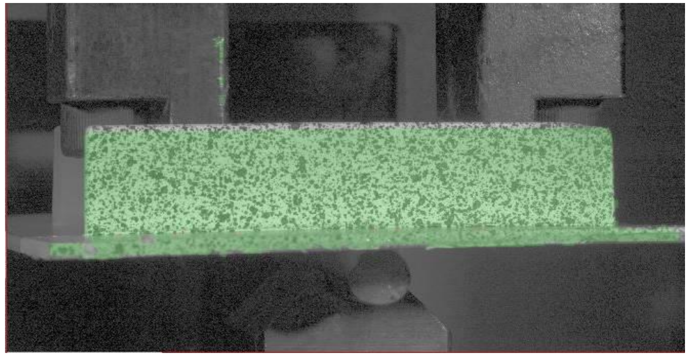
Plastic- Impact phenomena

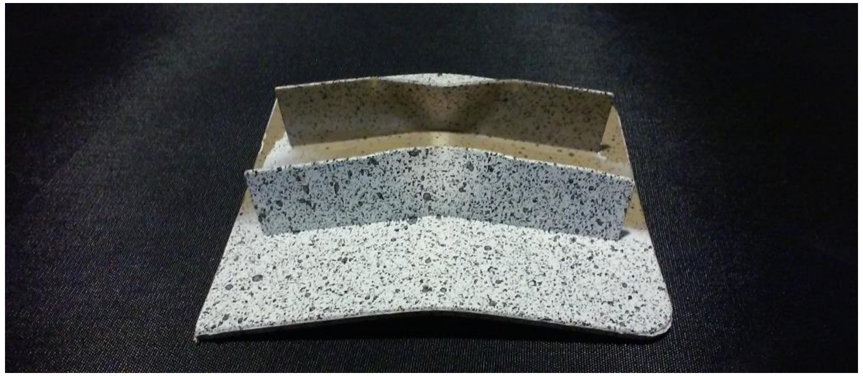




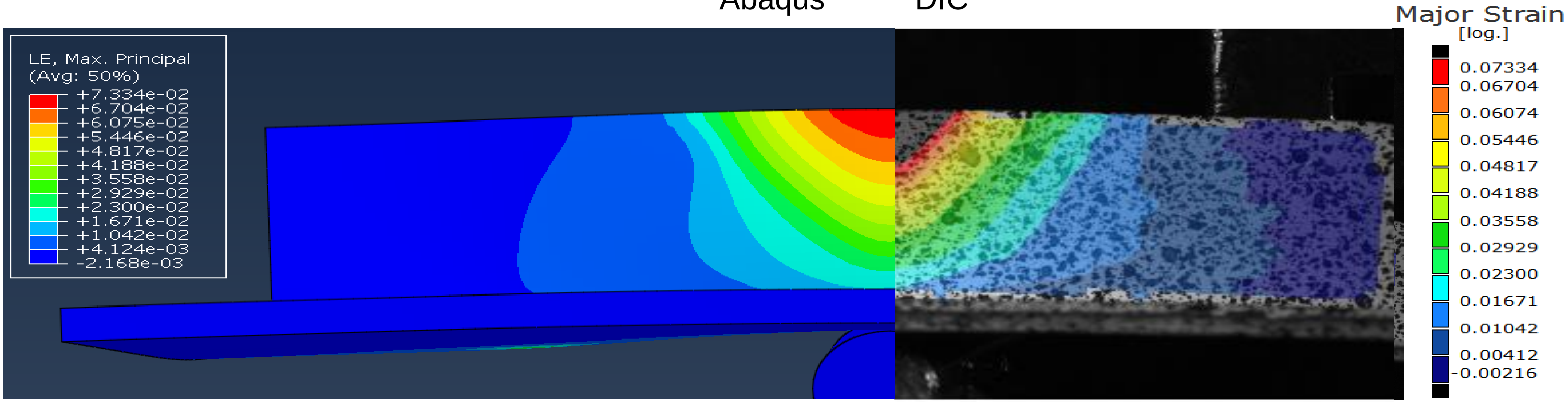
Plastic- DIC strain field validation







Abaqus DIC



Conclusions

- A systematic approach yields a robust basis for simulation
- Material parameter conversion process should be consistently followed
- Digitalization is important to capture diverse data and maintain traceability
- Validate simulation using robust & relevant test case before real life application