THE ROLE OF MATERIALS IN SIMULATION-DRIVEN PRODUCT DEVELOPMENT

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DatapointLabs TestPaks matereality knowmats picsci

expert material testing | CAE material parameters | CAE Validation | software & infrastructure for materials | materials knowledge | electronic lab notebooks

About Us

DatapointLabs

EST 1995

ISO 17025 Quality

technical center for materials

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software for materials

TestPaks

testing for simulation

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electronic lab notebooks

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materials in simulation

Nature of the problem

- Materials are intrinsic to products
  - (a physical product cannot exist without a material)
- Simulations require proper material representation
  - (getting the physics right)
- Some simulations use simple data
  - Linear analysis (metals), NVH …
- Some simulations use complex data
  - Non-linear analysis (plastics)
  - Dynamic situations (drop, crash, impact)
  - Post-yield behavior (metals, plastics)
  - Hyperelasticity (rubber, foams)
  - Time based behavior (creep, stress relaxation, visco-elasticity)

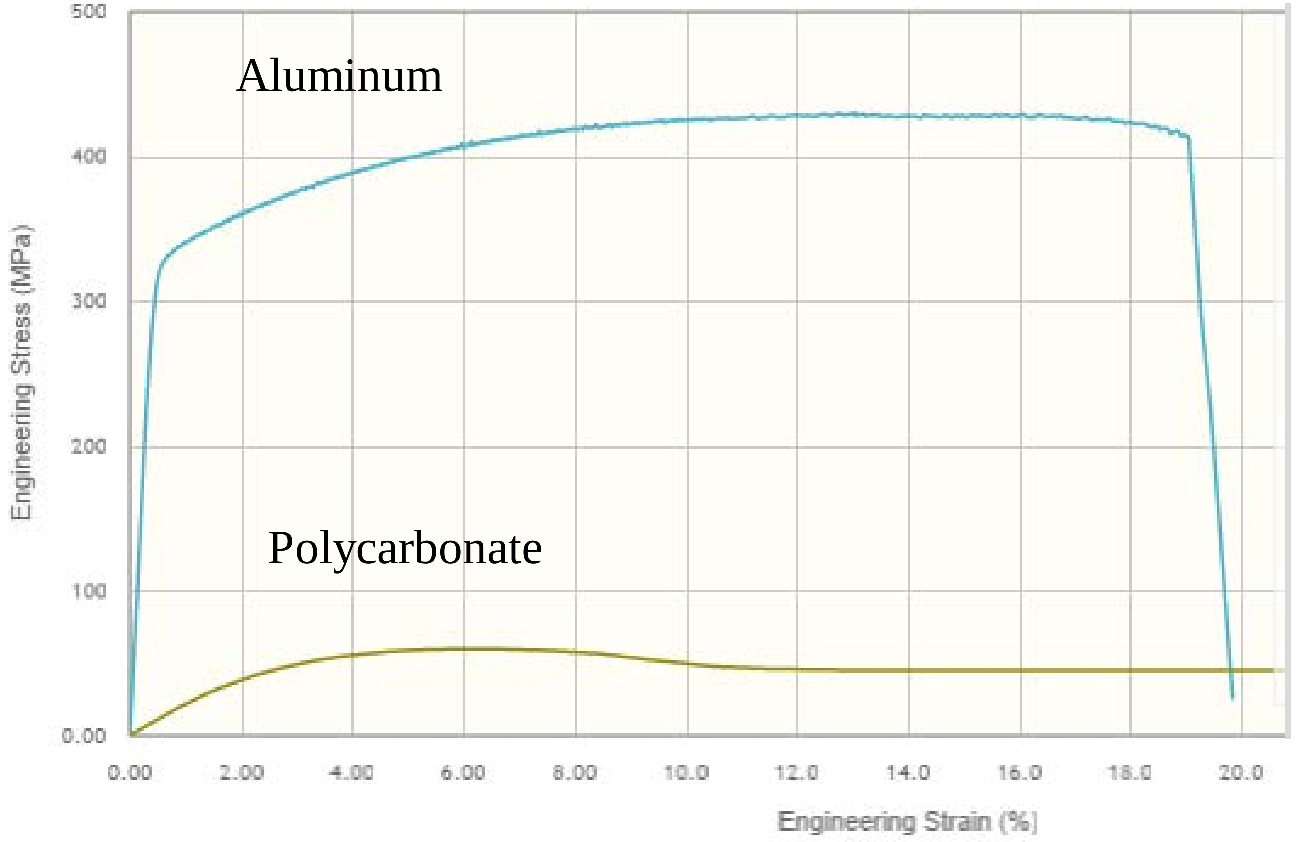
Solution Outline

- Correctly identify your materials and situations
- Simple cases
  - Use database data if available
- For complex cases
  - Obtain correct representative data
    - Material supplier
    - Test lab (internal or external)
  - Make a good material model
- Check for simulation accuracy (Validation)
- Store data for consistent use
  - All users
  - All solvers

What is Representative data

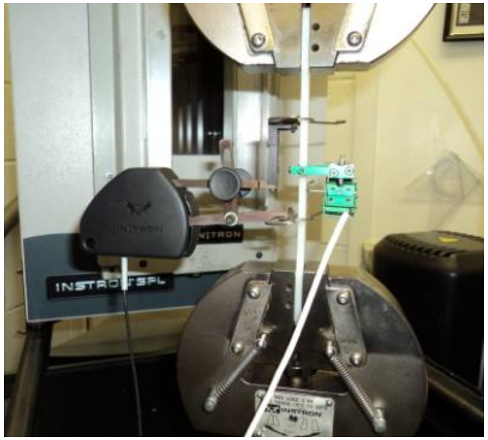
- Actual material used in your product
- Represents real-life situation
  - Temperature
  - Rate-dependent
  - Product environment
  - Processing method

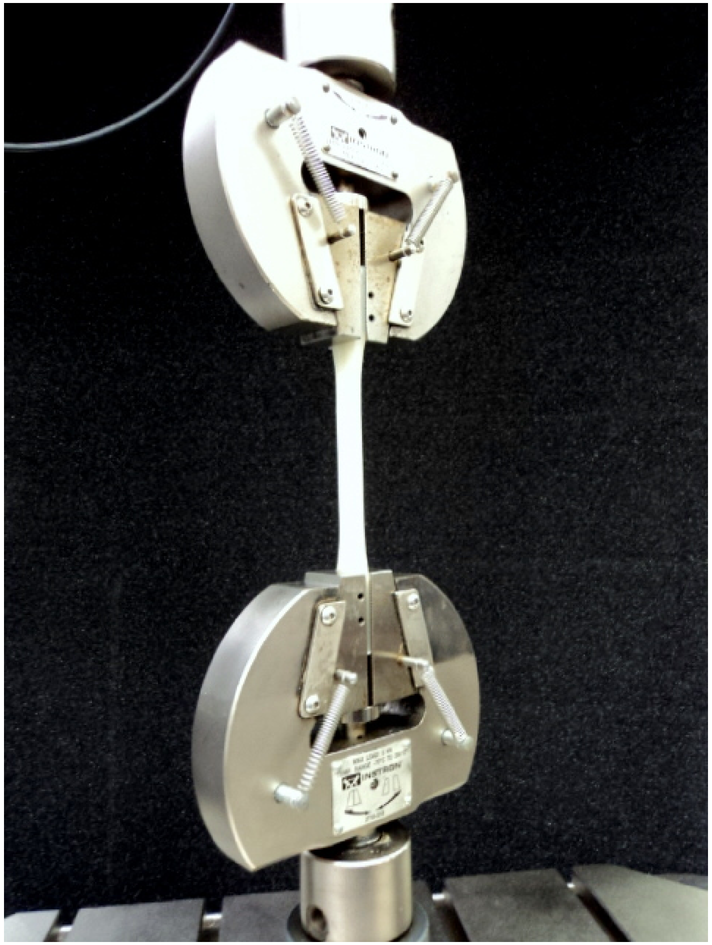
Defining non-linear behavior



Measuring stress-strain

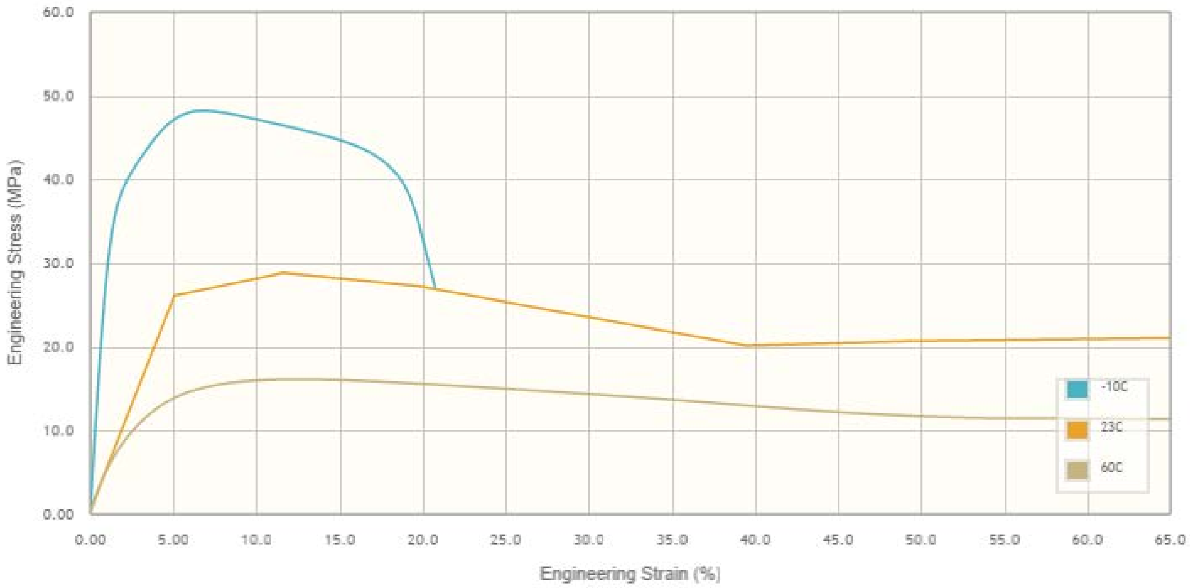
- Universal Testing M/c
- Extensometry for strain
- Stress-strain data
  - Modulus, Poisson's ratio
  - Stress v. plastic strain





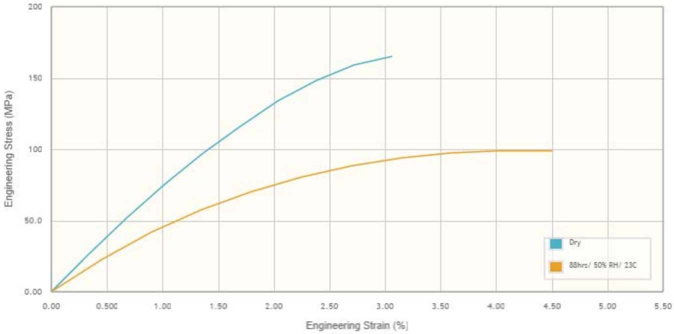
Test temperature

- Properties are temperature dependent
- Solution
  - Test over product temperature range
  - Focus on worst case scenario
  - Watch for low temperature ductile-brittle transitions



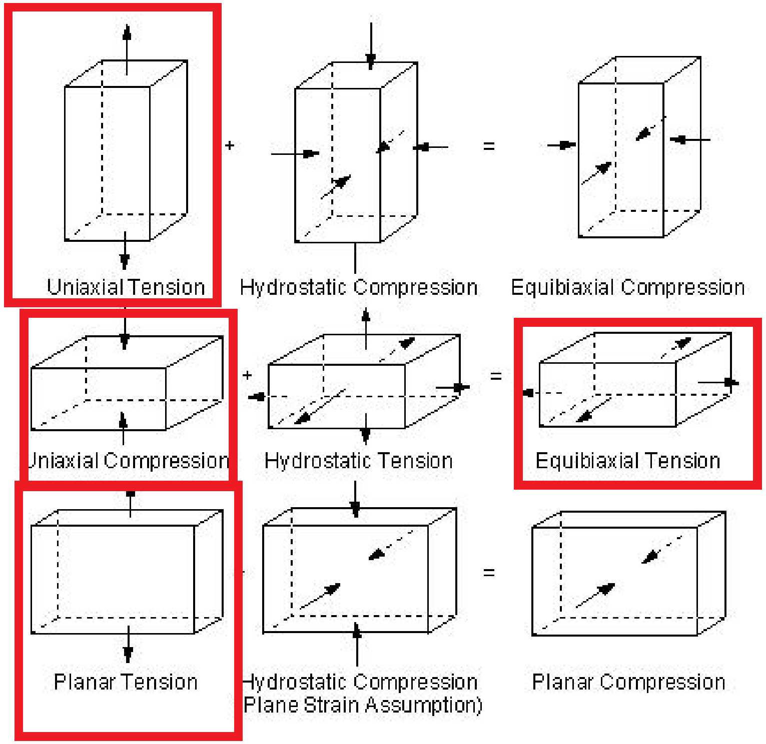
Environmental conditioning

- Properties change with environmental exposure
  - More severe with some polymers
- Solution
  - Determine product use environment
  - Expose specimens to analogous environment
    - Heat aging
    - Moisture conditioning, weathering
    - Fluid exposure
    - *In-vivo*
  - Test at time intervals after exposure -> equilibrium

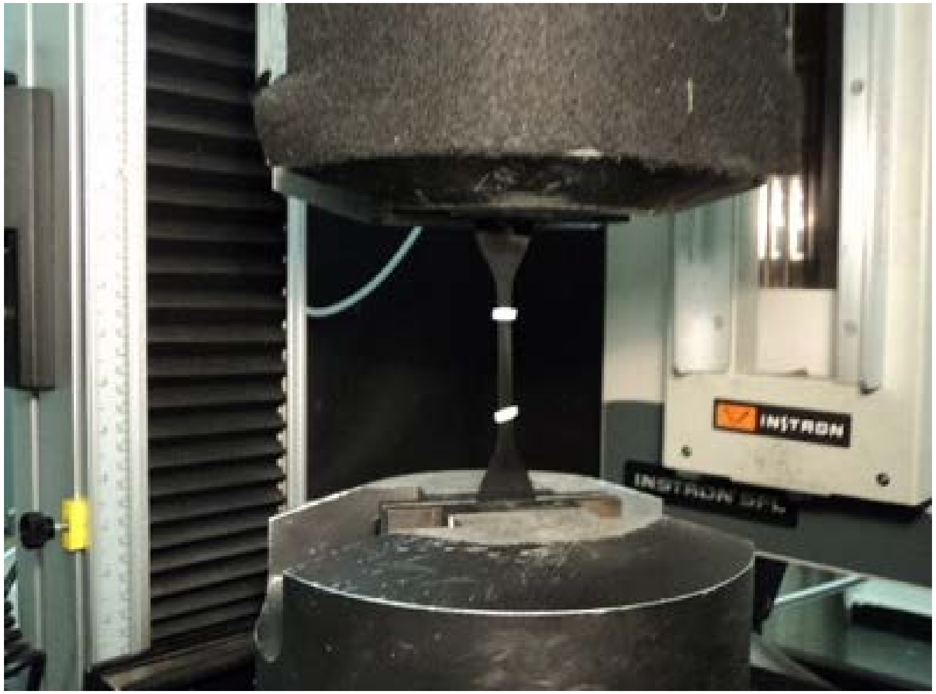


Hyperelastic Testing

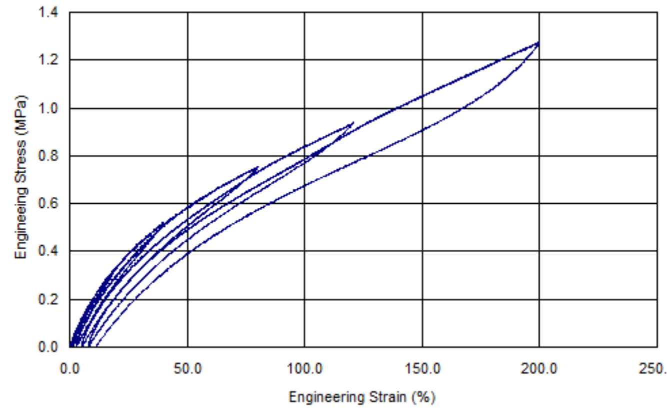
- Multiple modes of deformation to define material models
  - Uniaxial Tension
  - Uniaxial Compression
  - Planar Shear
  - Biaxial Tension
  - Volumetric Compression



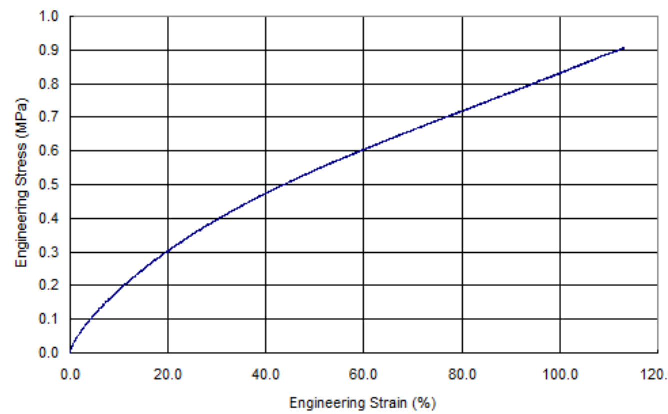
Tensile Test



Cyclic Stress-Strain Data

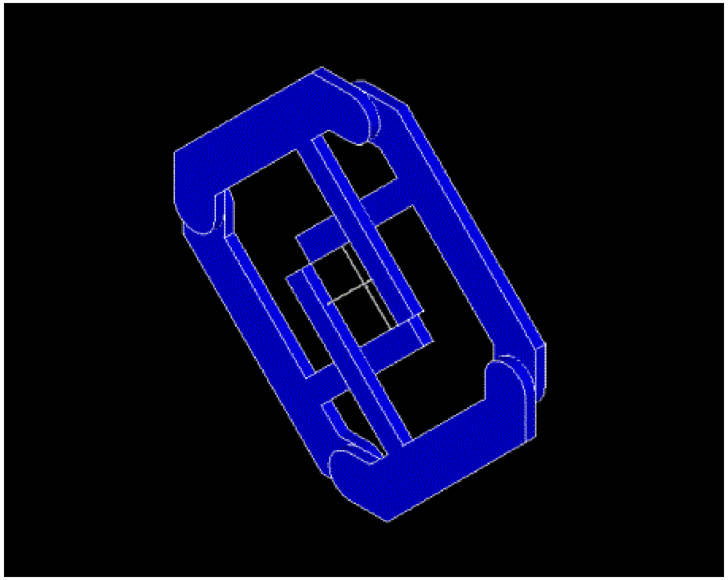


Post-Cycling Stress-Strain Curve



Biaxial tension test

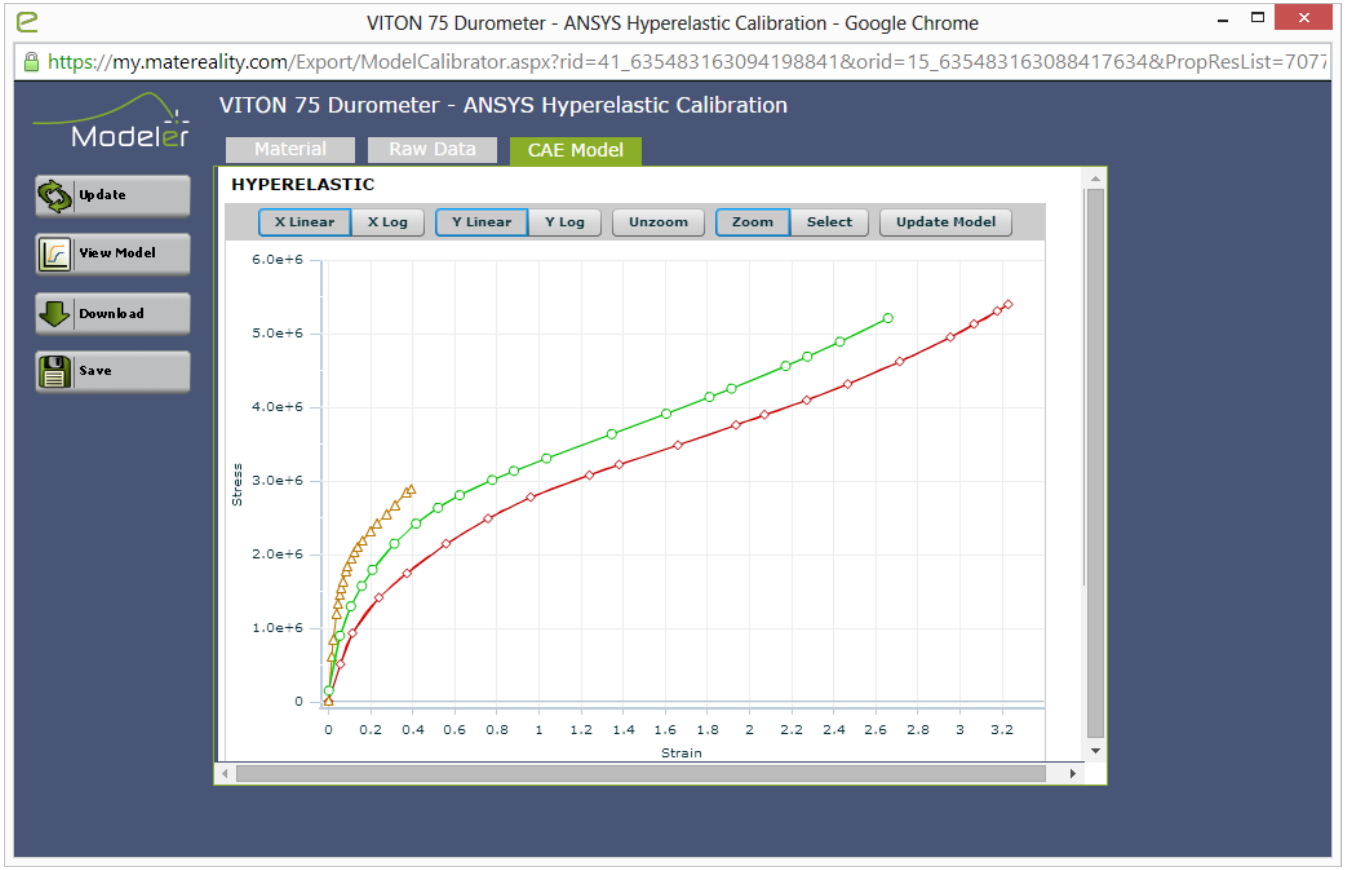
- Stretch in x & y plane
- Thinning in z-plane
- Suitable for thin specimens



Planar tension

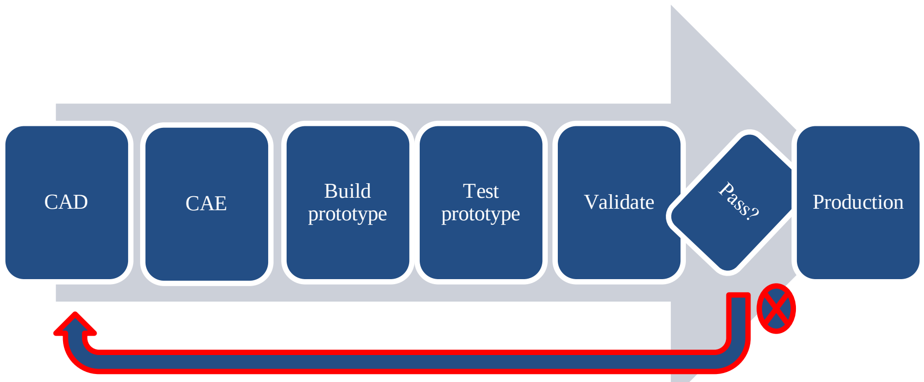
- Shear deformation
- Large width to length ratio minimizes contraction in width direction
- Non-contact extensometry to eliminate edge effects

Rubber Modeling



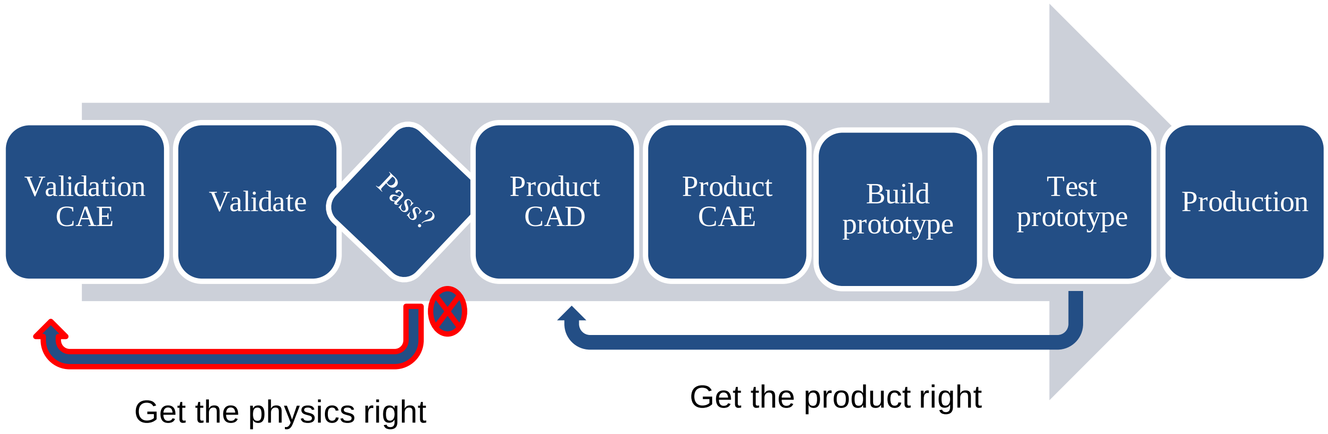
Validation

- Conventional process with actual prototype



Get the physics and product right

Mid-stage validation

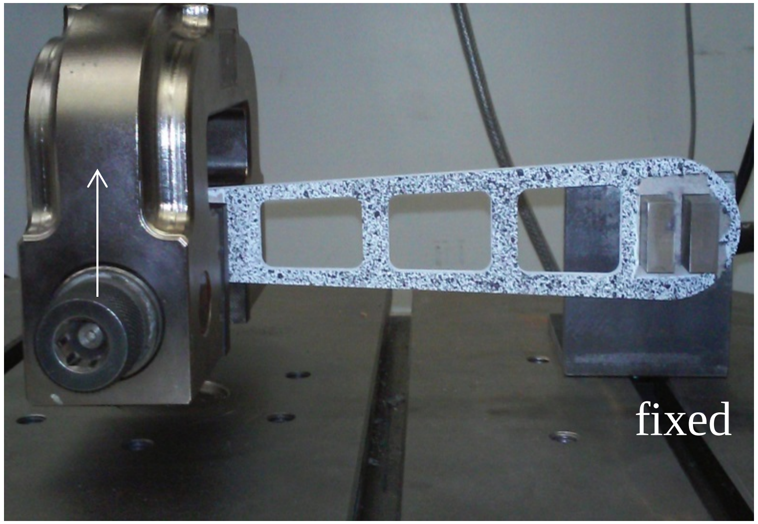


Mid-stage validation features

- Standardized geometry
  - Geometry is complex, easily made, not like real-life part
- Complex load case
  - Mixed mode, accurately reproduced in simulation
- Material model
  - Correct model, actual material, environment, exposure
- Accuracy measures
  - Force-displacement &/or DIC

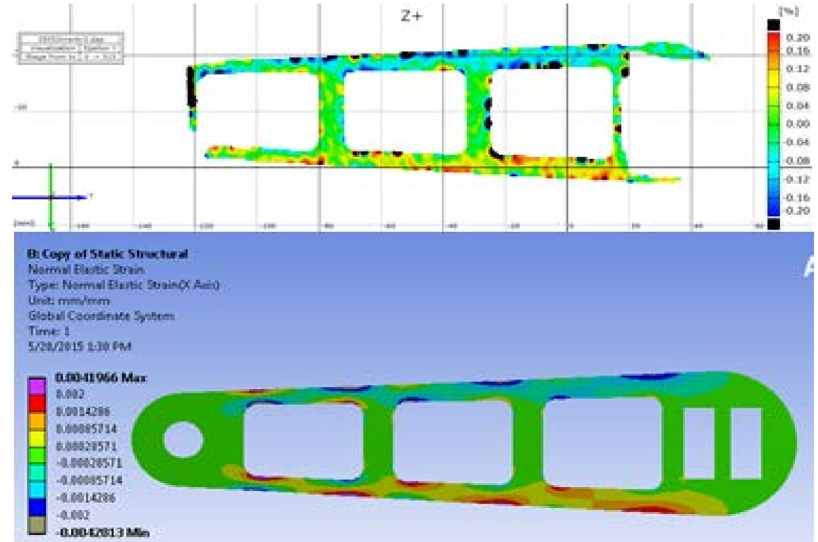
Case Study-1 3D printed bike crank

- Direct metal laser sintering
- Part features
  - No slip at fixed end
  - Rotation at load end
  - DIC for surface strain measurement
  - Tapered geometry to force failure in camera-viewable region



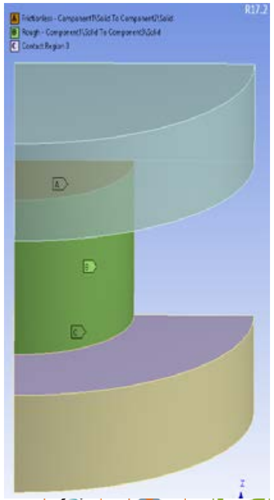
Linear analysis validation

- Quantitative and spatial match
  - Strain locations are correct
  - Strain levels are correct

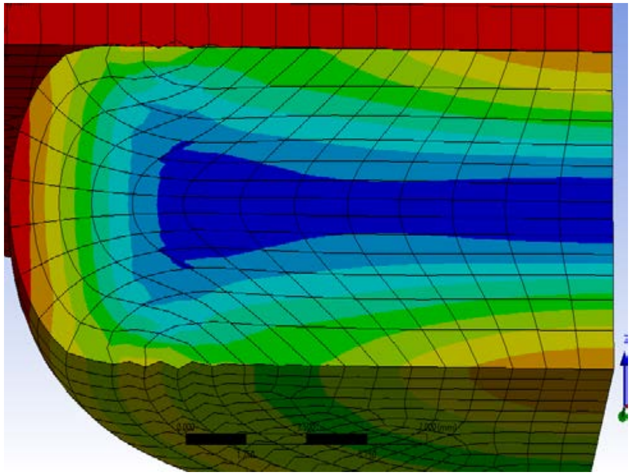


Case Study-2 rubber hyperelasticity

- Part features
  - “standardized” compression test
  - Both faces slipping (closed loop case)
  - Top face fixed (open loop)
  - Top and bottom faces fixed (open loop)
- Simulate and compare to experiment
- Quantify simulation accuracy

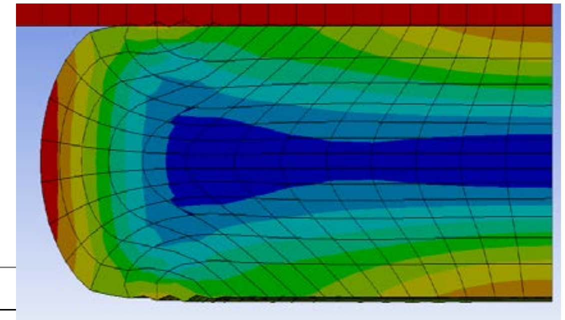


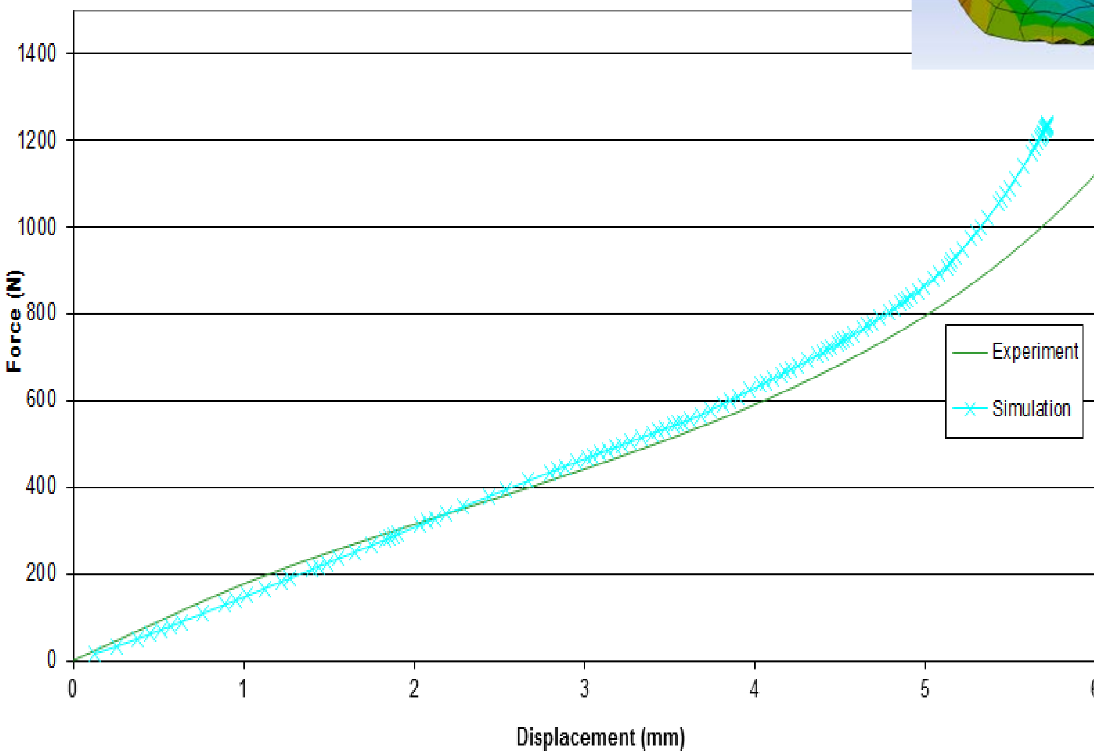
Simulation complexities



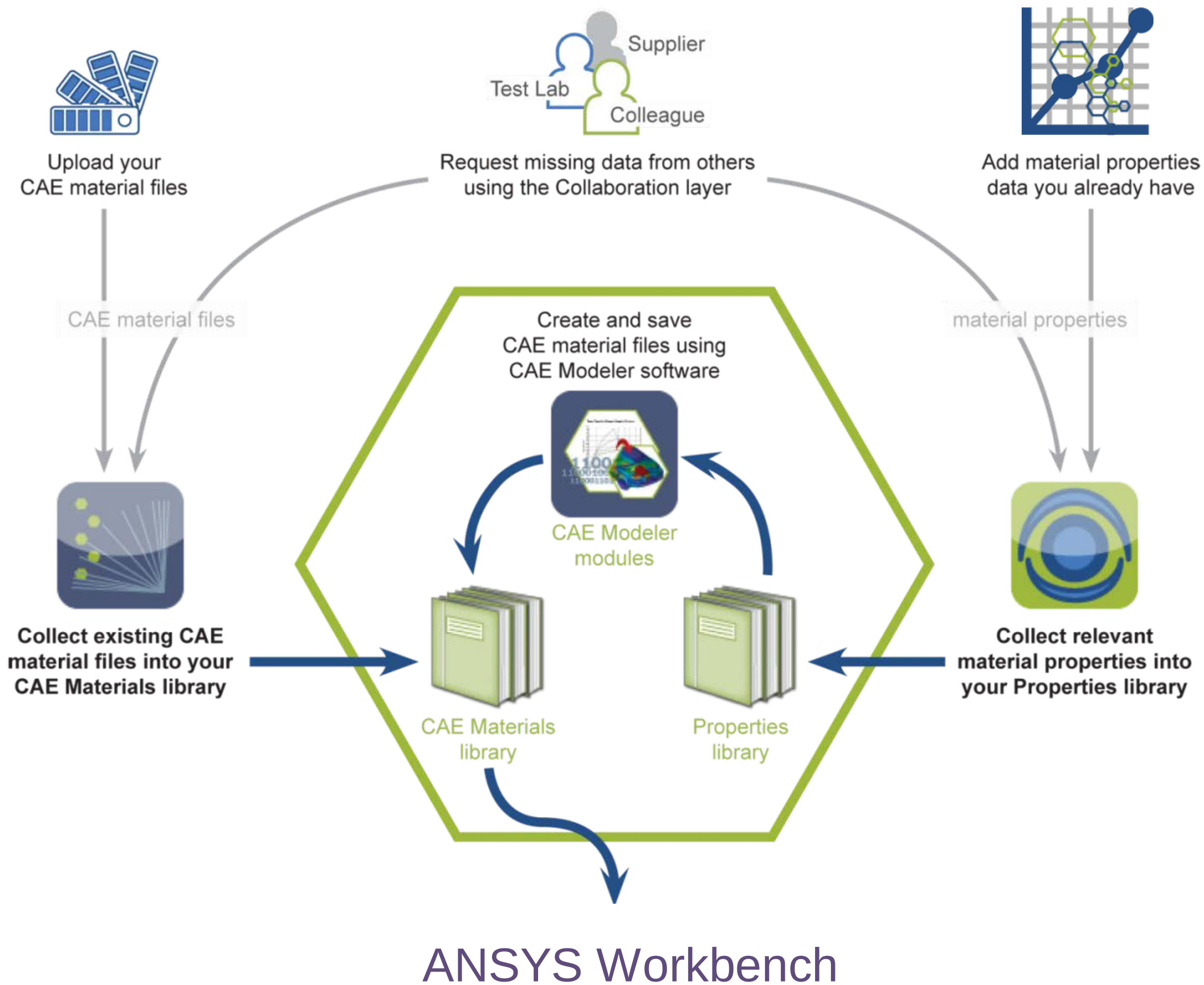
- Choice of material model
  - Mooney-Rivlin
  - Ogden
- Contact
  - Fixed boundary has roll over which is addressed with the rough contact
  - The corner element and nearby mesh are distorted

Validation: simulation v. ANSYS





Materials & CAE Material files Workflow



Reference

- NAFEMS book
- Determination and Use of Material Properties for Finite Element Analysis
- *By Hubert Lobo and Brian Croop. NAFEMS, 2016. 90 pp.*
- **Available from NAFEMS.org**

- **Advanced topics at http://knowmats.com/**