

2015

**Automotive Simulation
World Congress**

Testing of Elastomers and Plastics in Support of Analysis

Kurt Miller, Axel Products, Inc.





Physical Testing Services

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Axel Products, Inc.

Provides testing services for engineers and analysts. The focus is on the characterization of nonlinear materials such as elastomers and plastics for users of ABAQUS, ANSYS, DIGIMAT, Marc, and Dyna.

Testing Services

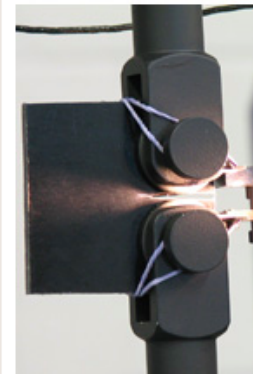
Related experiments, downloads and pricing by application.

- Elastomer (hyperelastic) Characterization
- Plastic Characterization
- Sponge Elastomer Characterization
- Vibration and Viscoelastic Experiments
- Thermal Properties Measurements
- High Strain Rate Experiments
- Medical Material Testing in Saline
- Friction Measurements
- Component Tests
- Durability and Crack Growth of Elastomers
- Fatigue and Crack Growth of Plastics
- Long Term Creep and Stress Relaxation Tests

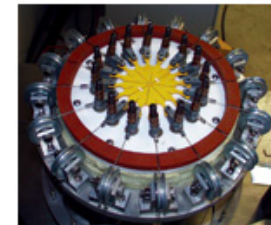
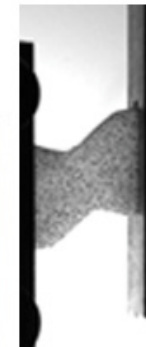
Technical Downloads

Popular downloads.

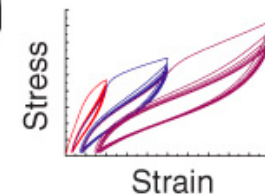
- Testing Elastomers for Hyperelastic Models (PDF)



Plastic



Rubber



Material Models

Training Courses

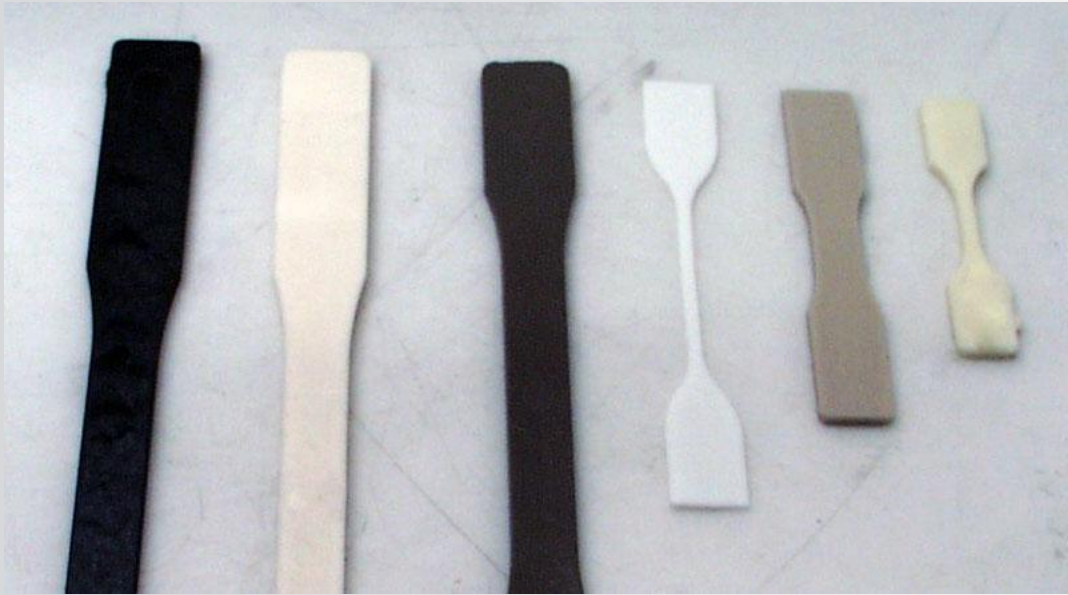
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We Measure Structural Properties

Stress – Strain–Time-Temperature



Elastic-plastic Models
Hyperelastic Models

What's New?

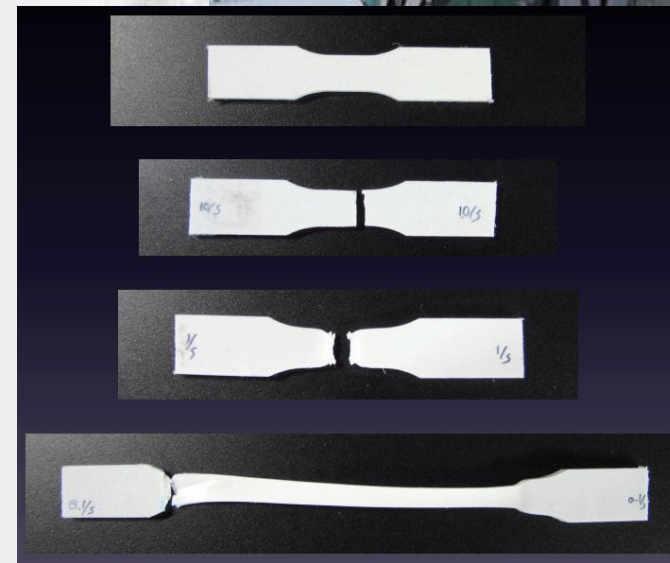
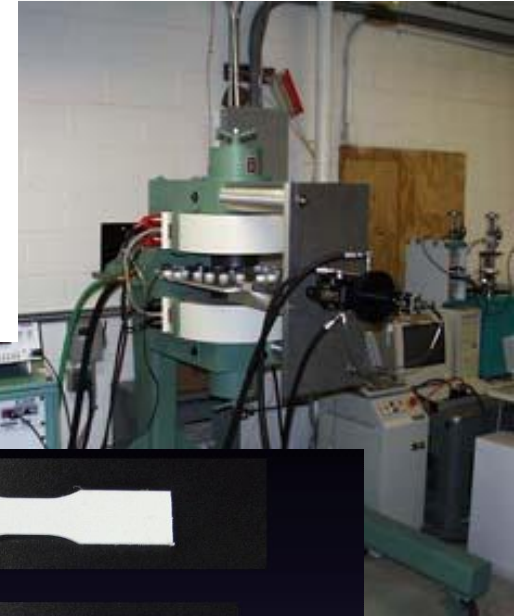
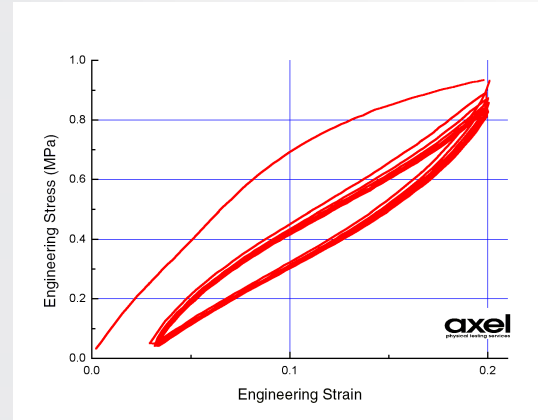
Combinations & Failure

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- Rubber + Softening
- Rubber + Viscoelasticity
- Plastic + Rate
- Rubber Set
- Plastic + Creep
- Rupture of Rubber
- Fatigue
- All things Hot and Cold
- Directional Properties
- Plastic-Rubber Stuff
- Plastic + Rate + Failure
- Plastic + Unload
- High Strain + Failure



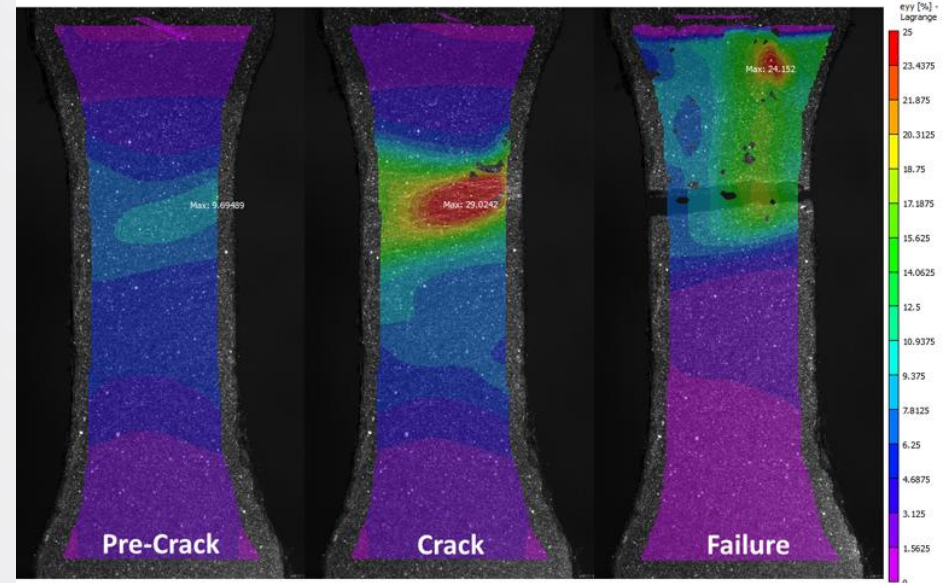
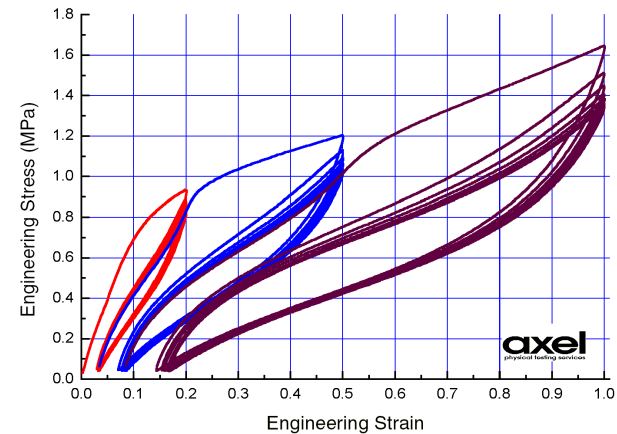
Strategy: Isolate Behaviors

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- Separate Elastic & Plastic
- Go to the Application Temperature
- Observe Failure
- Grow the Defect
- Go Very Slow
- Go Very Fast



You Can't Model Everything!

Rubber

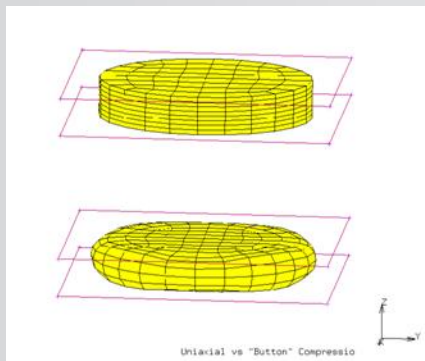
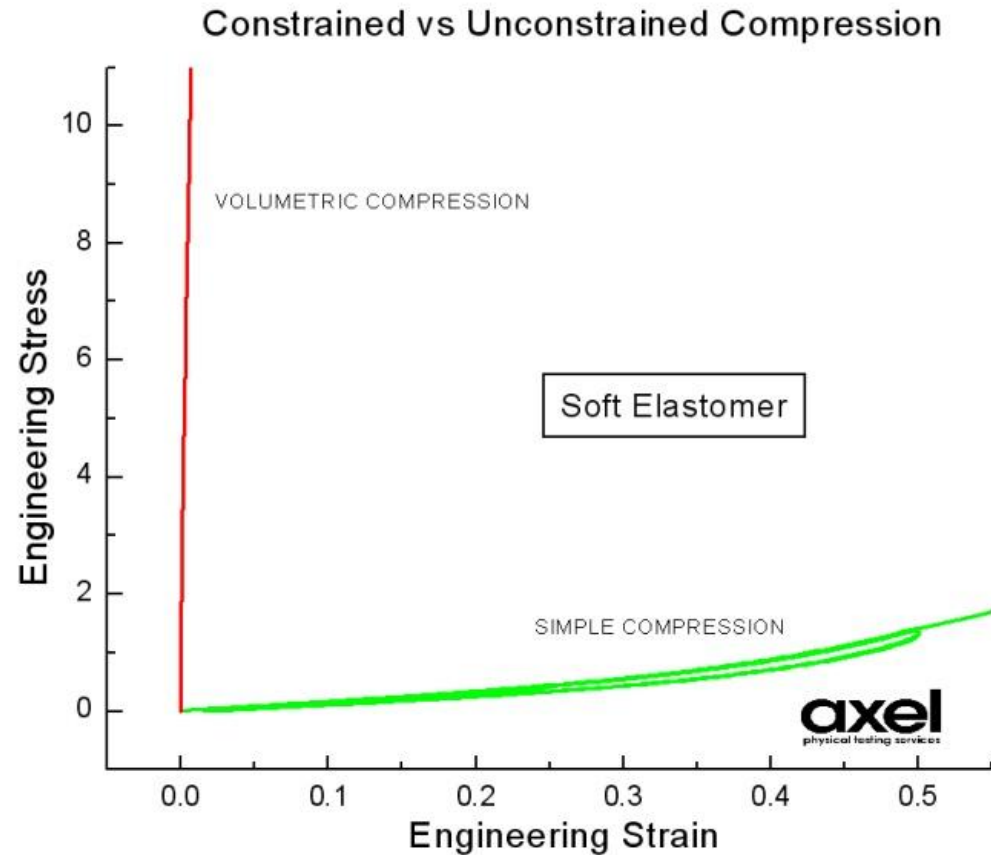
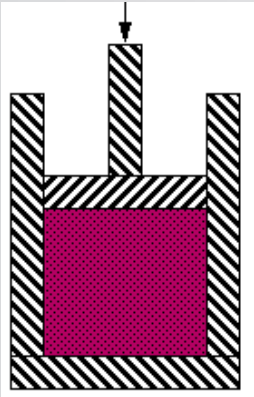
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What Does Incompressible Mean?

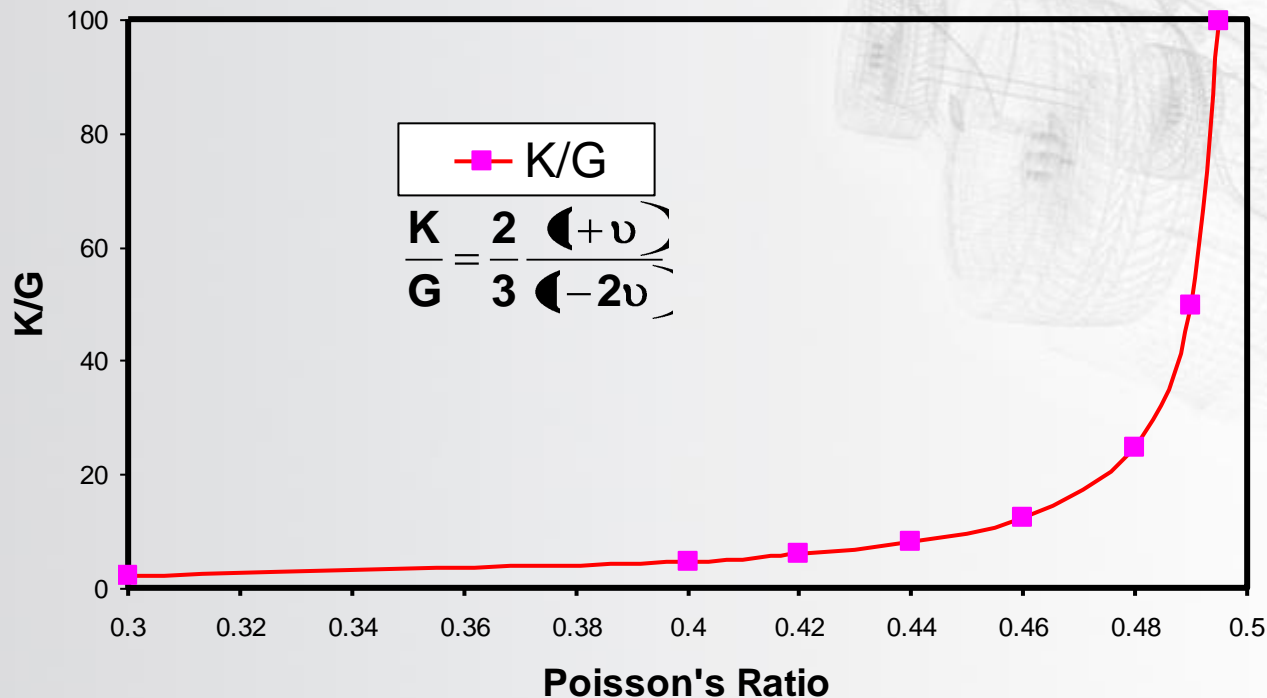


Volumetric Compression

Poisson's ratio approaching 0.5 means infinite bulk modulus, K

For elastomer materials, Poisson's ratio is difficult or impossible to measure accurately. For plastic materials, it is hard to measure VC accurately.

K/G Relationship to Poisson's Ratio



Incompressibility

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Not a spring and dashpot



Hyperelastic Models

- Material response is isotropic, isothermal, and elastic and is assumed fully or nearly incompressible.
- There are many hyperelastic models available in ANSYS which can cover wide varieties of elastomers used in Industries.

Available Hyperelastic models:

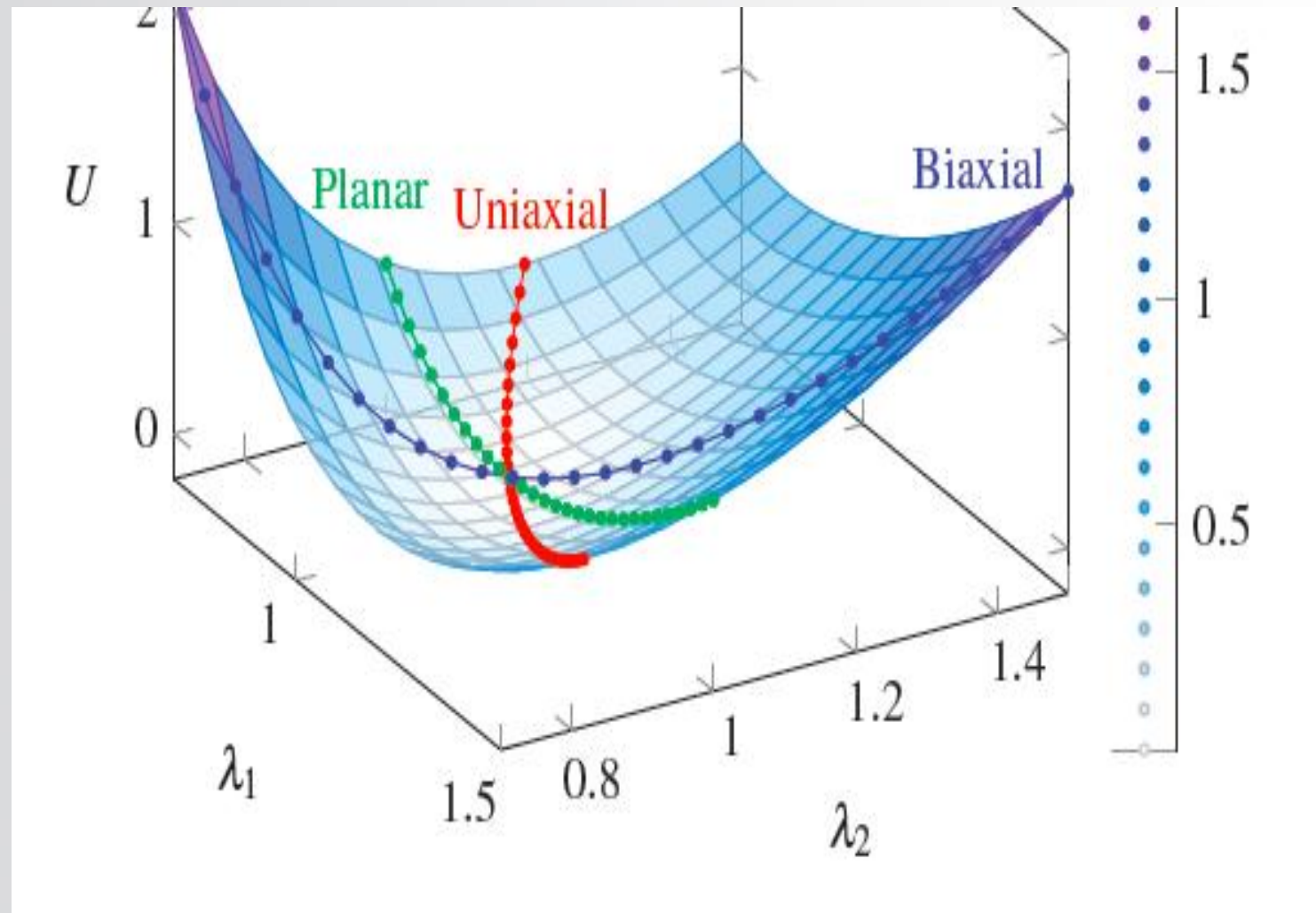
- Arruda-Boyce Hyperelastic Material
- Blatz-Ko Foam Hyperelastic Material
- Extended Tube Material
- Gent Hyperelastic Material
- Mooney-Rivlin Hyperelastic Material
- Neo-Hookean Hyperelastic Material
- Ogden Compressible Foam Hyperelastic Material
- Ogden Hyperelastic Material
- Polynomial Form Hyperelastic Material
- Response Function Hyperelastic Material
- Yeoh Hyperelastic Material

Hyperelastic

- ☒ Neo-Hookean
- ☒ Arruda-Boyce
- ☒ Gent
- ☒ Blatz-Ko
- ☒ Mooney-Rivlin 2 Parameter
- ☒ Mooney-Rivlin 3 Parameter
- ☒ Mooney-Rivlin 5 Parameter
- ☒ Mooney-Rivlin 9 Parameter
- ☒ Polynomial 1st Order
- ☒ Polynomial 2nd Order
- ☒ Polynomial 3rd Order
- ☒ Yeoh 1st Order
- ☒ Yeoh 2nd Order
- ☒ Yeoh 3rd Order
- ☒ Ogden 1st Order
- ☒ Ogden 2nd Order
- ☒ Ogden 3rd Order
- ☒ Response Function
- ☒ Ogden Foam 1st Order
- ☒ Ogden Foam 2nd Order
- ☒ Ogden Foam 3rd Order
- ☒ Extended Tube
- ☒ Mullins Effect

Specialized Hyperelastic models:

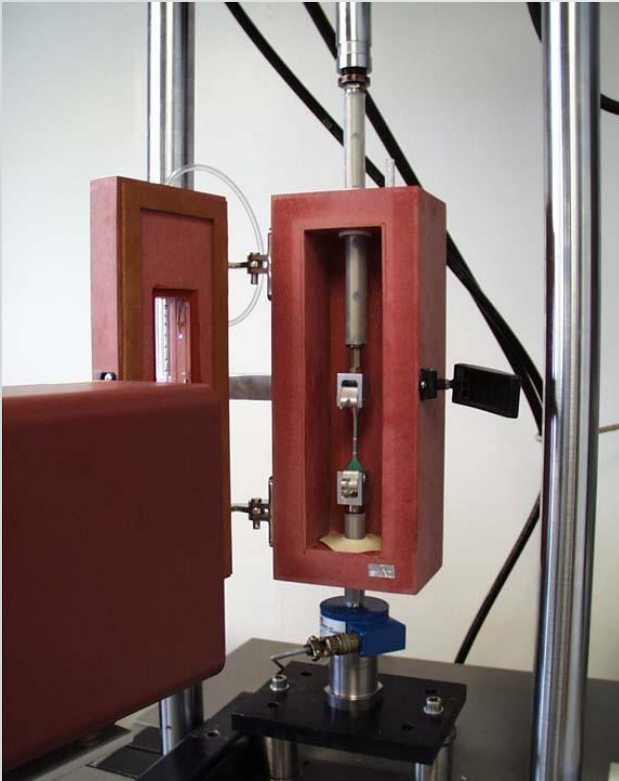
- Anisotropic Hyperelastic Material
- Bergstrom-Boyce Material
- Mullins effect
- User-Defined Hyperelastic Material



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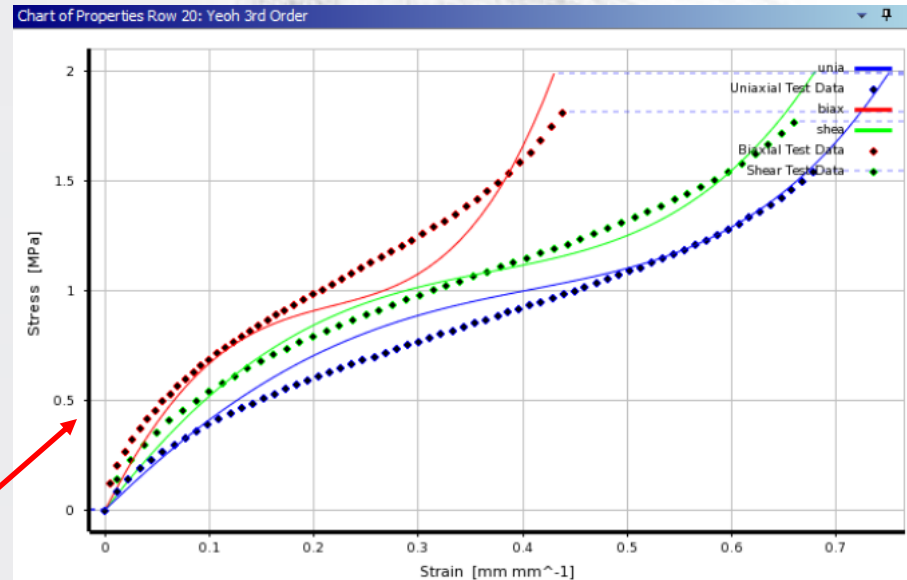
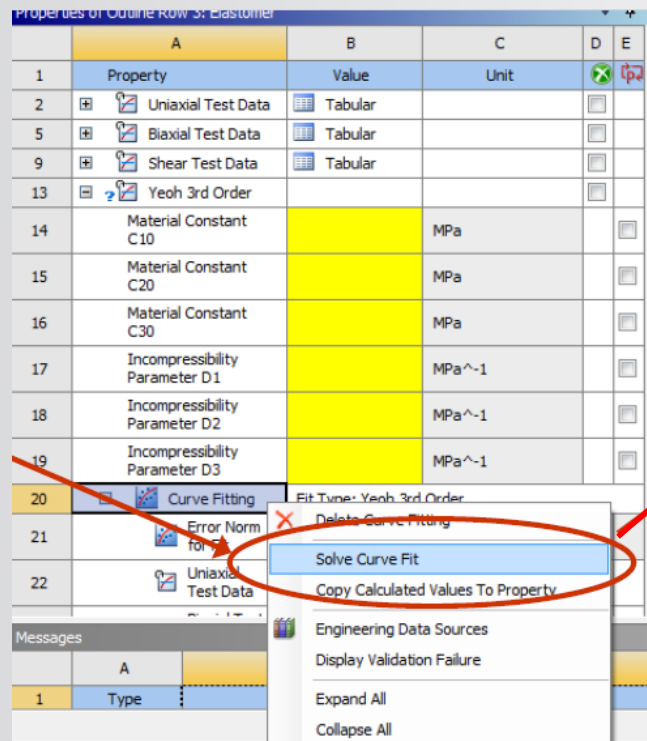
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Hyperelastic Models

Curve Fitting feature

- Material curve fitting allows you to derive coefficients from experimental data that you provide for your material.
- With this capability, you compare experimental data versus program-calculated data for different nonlinear models and determine the best material model to use.
- ANSYS provides curve-fitting, based on experimental data, for all of the available hyperelastic models. Any of the hyperelasticity models in ANSYS can be used.



Loading Conditions

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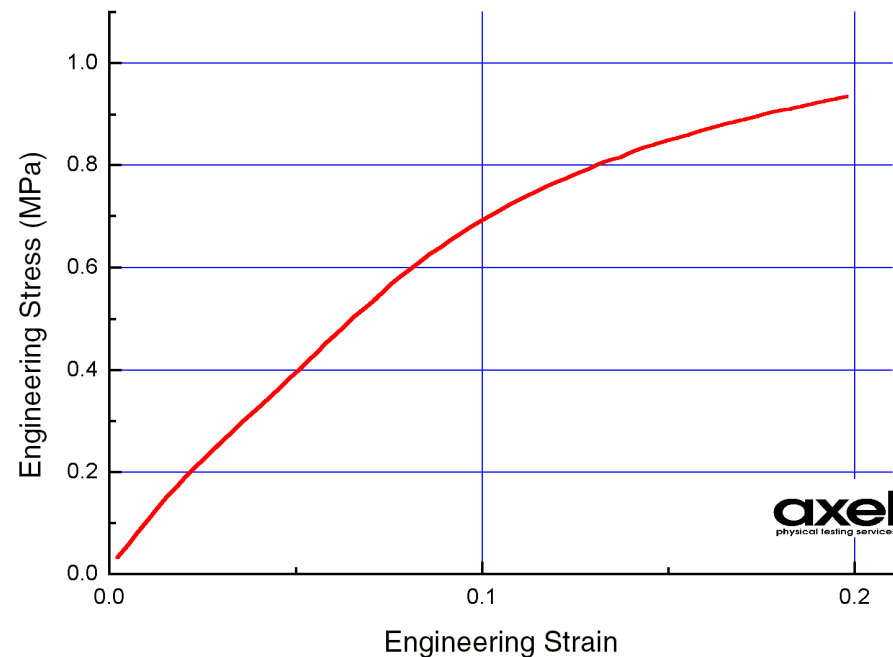
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- Some common Elastomers exhibit dramatic strain amplitude and cycling effects at moderate strain levels

Conclusions:

1. Test to realistic strain levels
2. Use application specific loadings to generate material data
3. Need to load and unload to separate elastic from plastic



Loading Conditions

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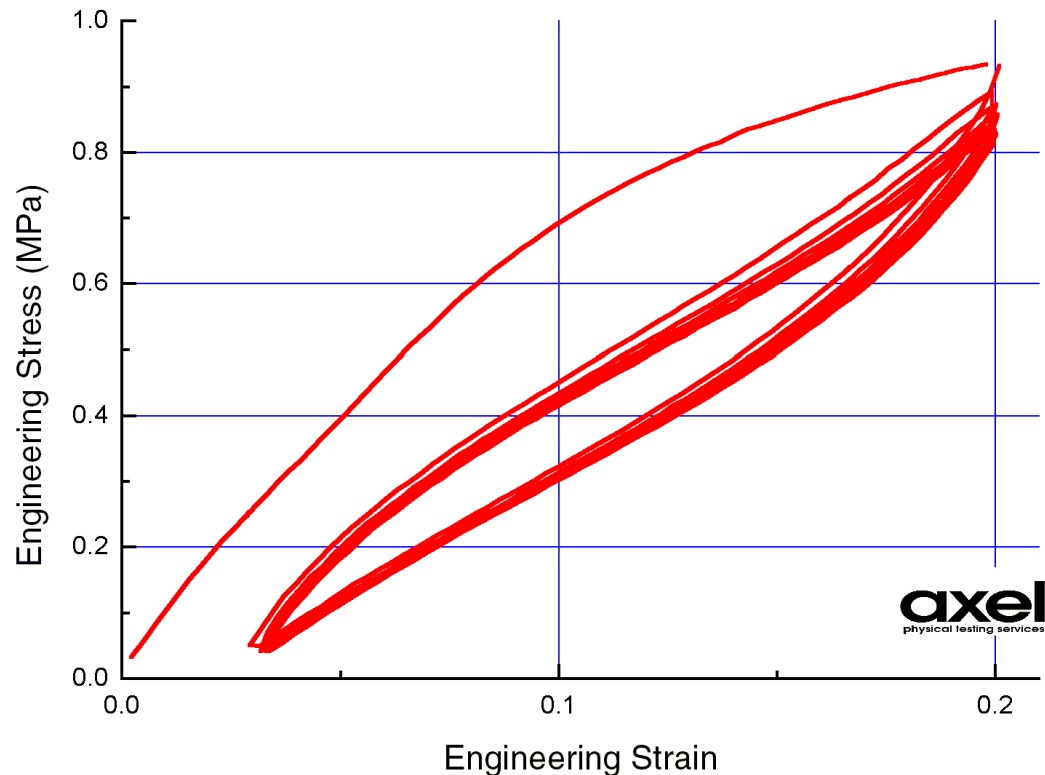
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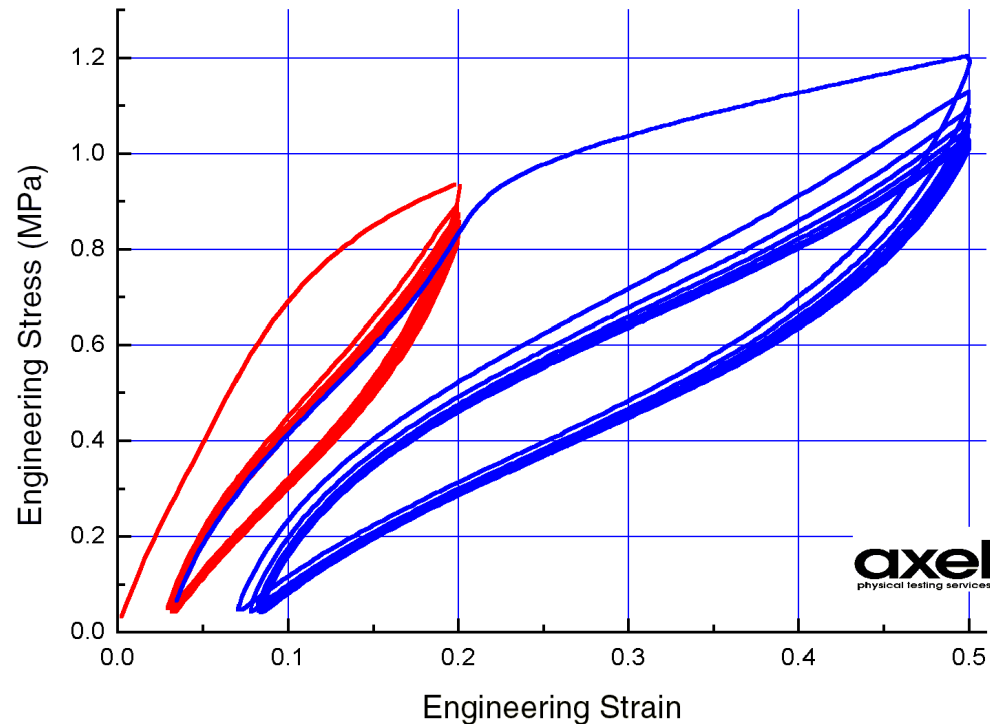


Loading Conditions

- Some common Elastomers exhibit dramatic strain amplitude and cycling effects at moderate strain levels

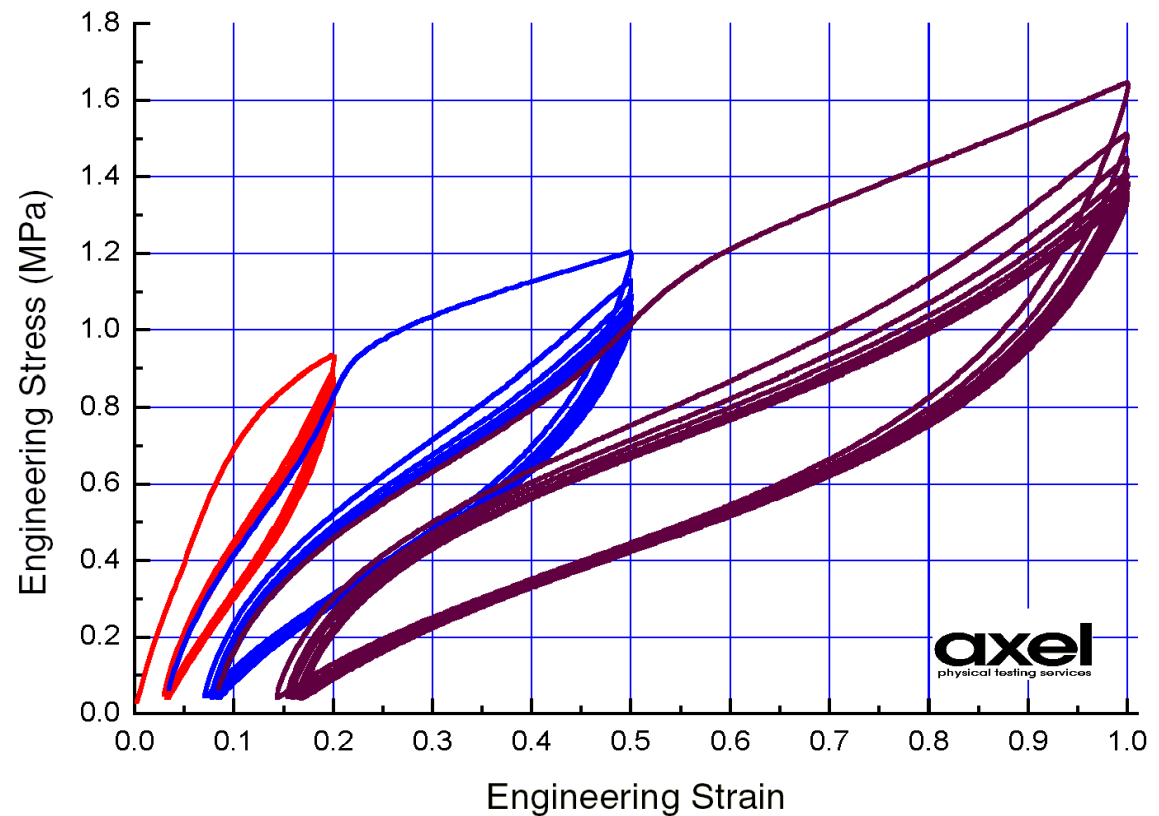
Conclusions:

1. Test to realistic strain levels
2. Use application specific loadings to generate material data
3. Need to load and unload to separate elastic from plastic



Loading Conditions

- Single Loading
- Softening
- Load vs Unload
- Amplitude Effect
- Set

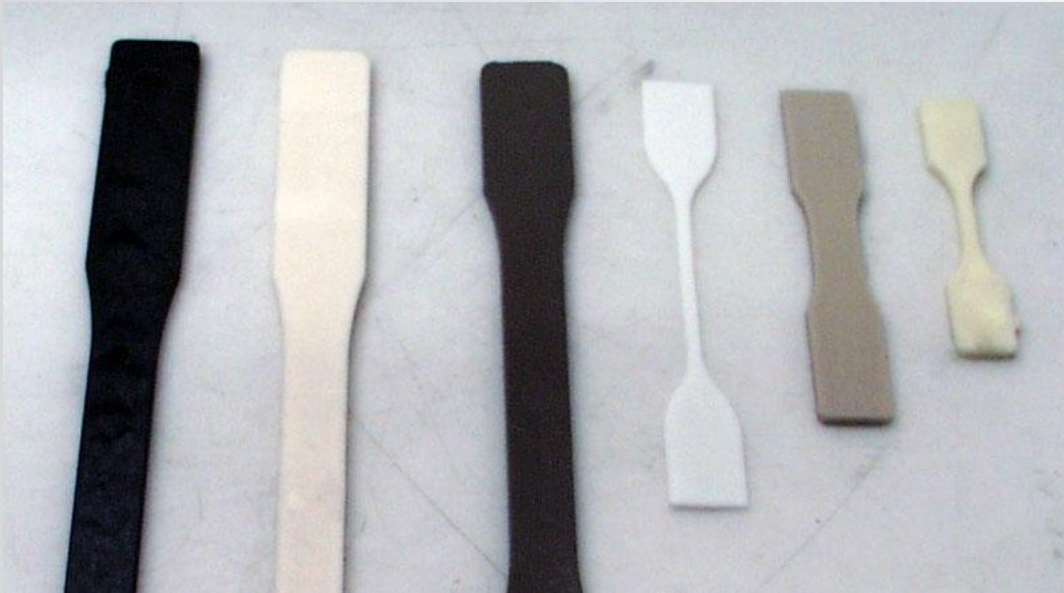


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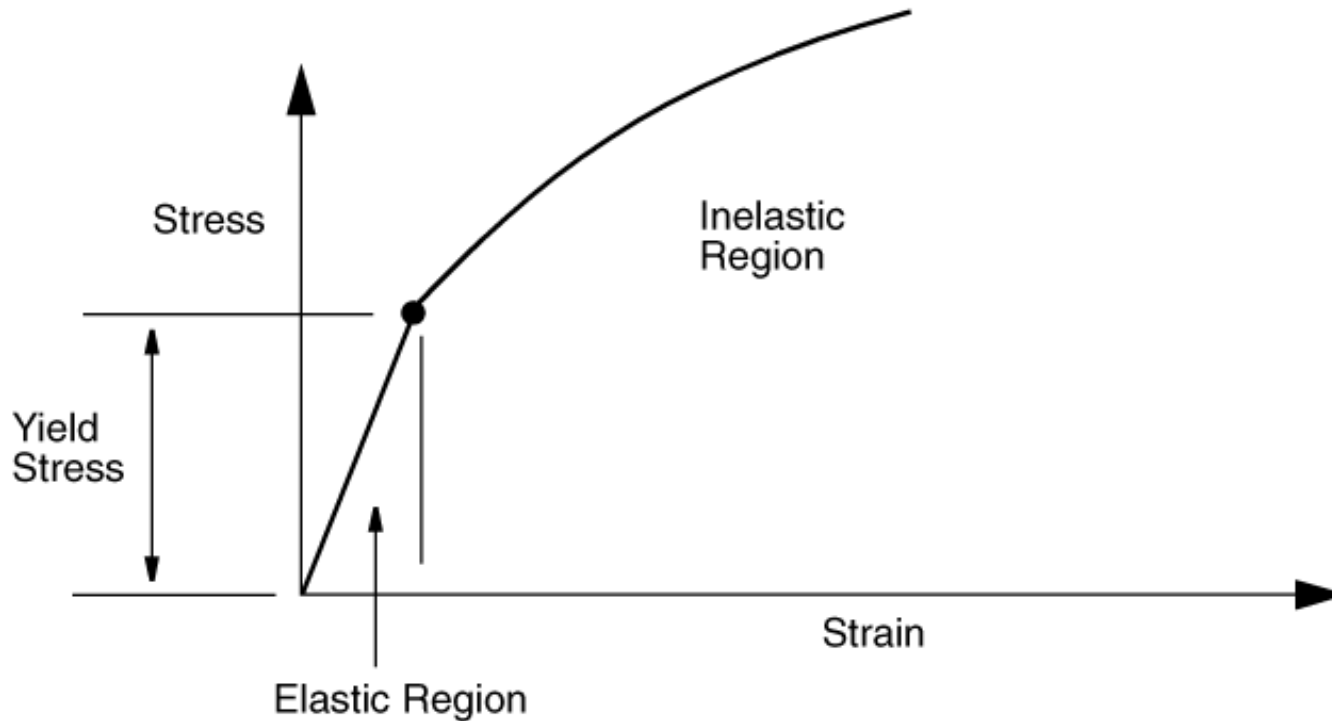
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Structural Properties



Structural Properties



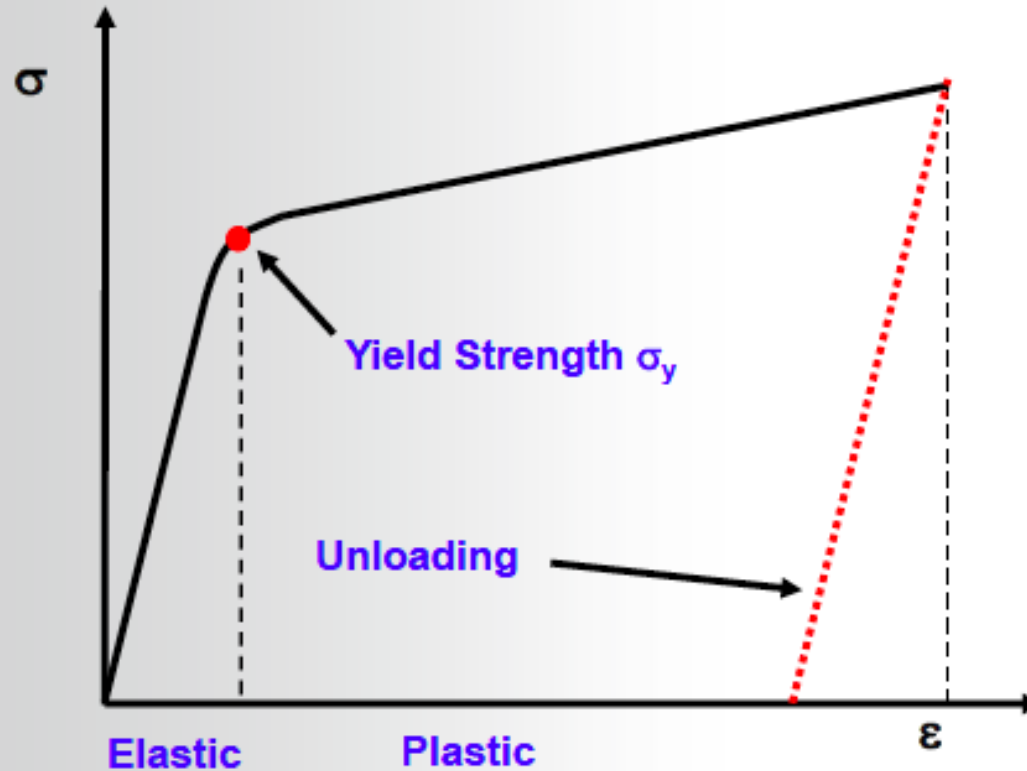
Note: Stress and strain are total quantities.

Structural Properties (small deformation plasticity)

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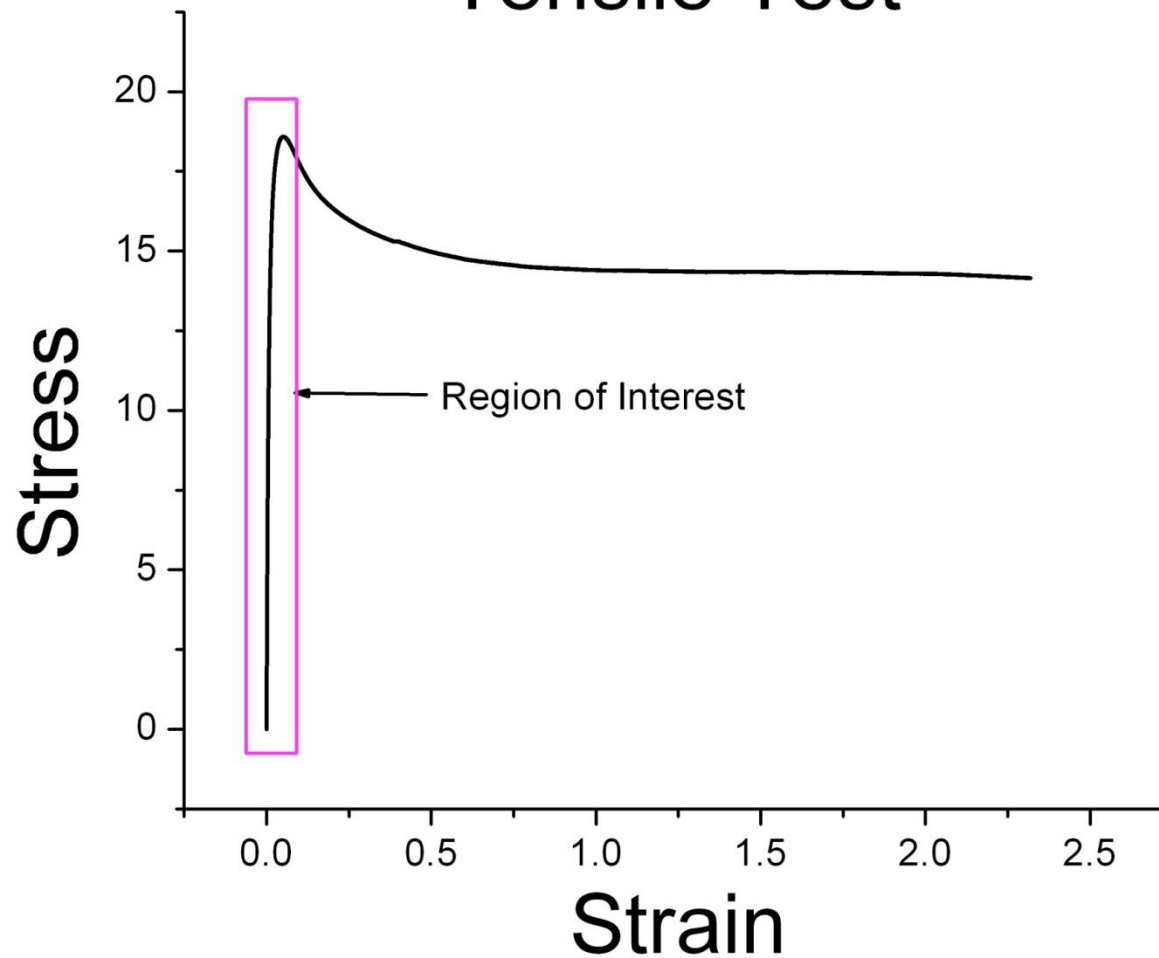
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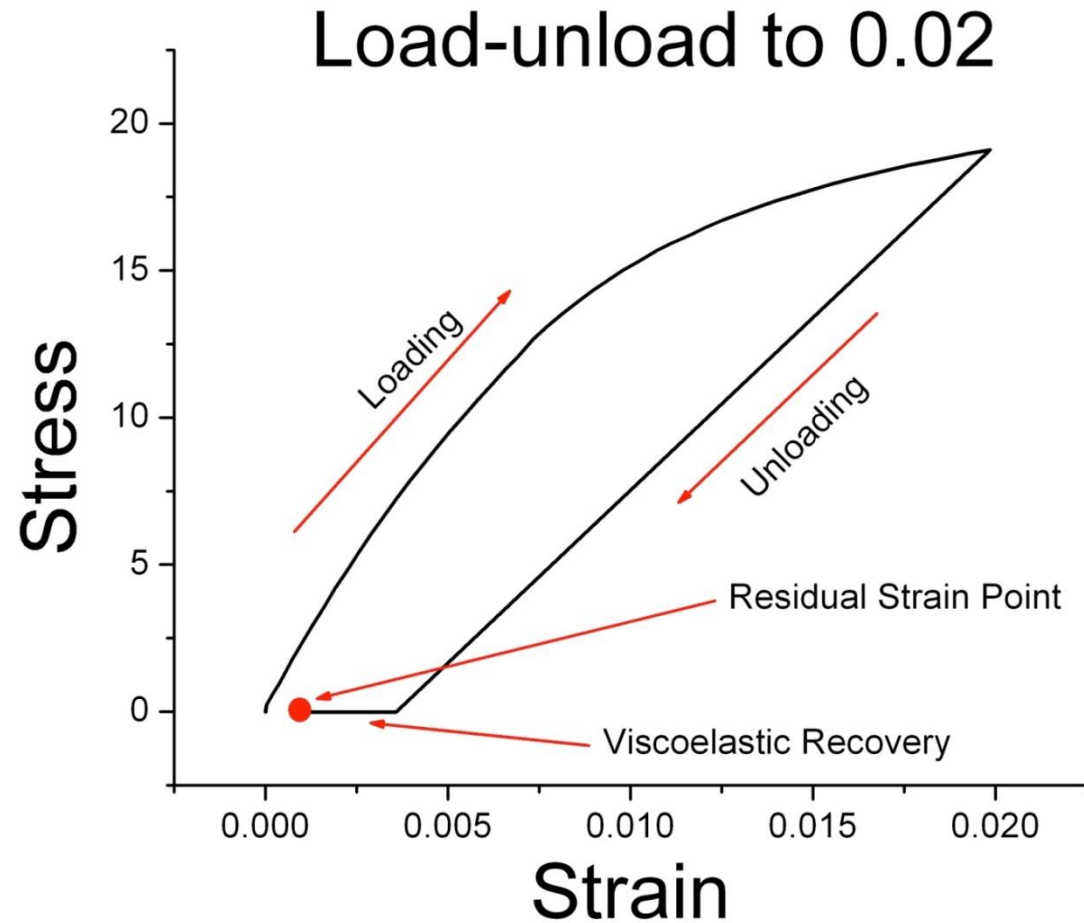
Plastic

Tensile Test



Plastic

- Modulus is Unclear
- Yield is Unclear
- Load = Unload?
- Set

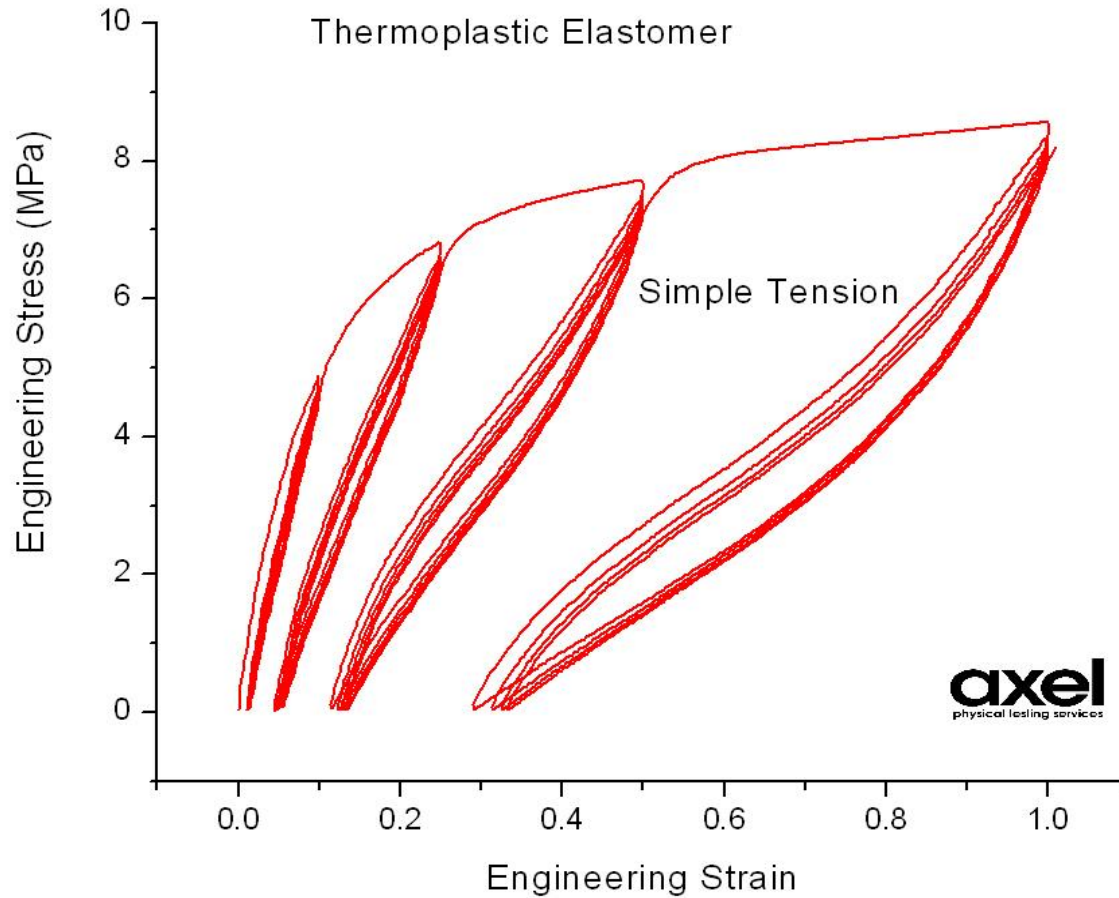


Thermoplastic Elastomers

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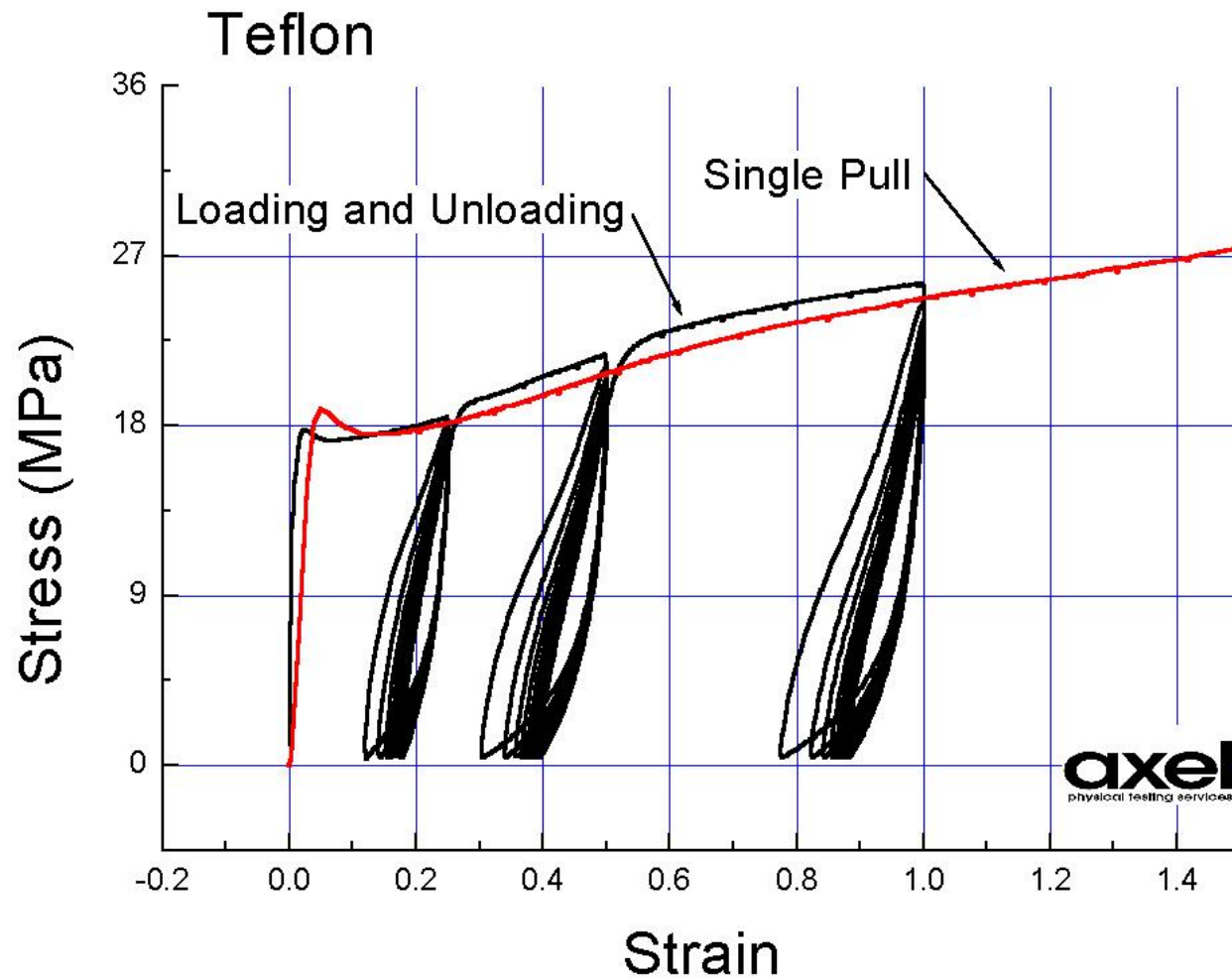


Teflon

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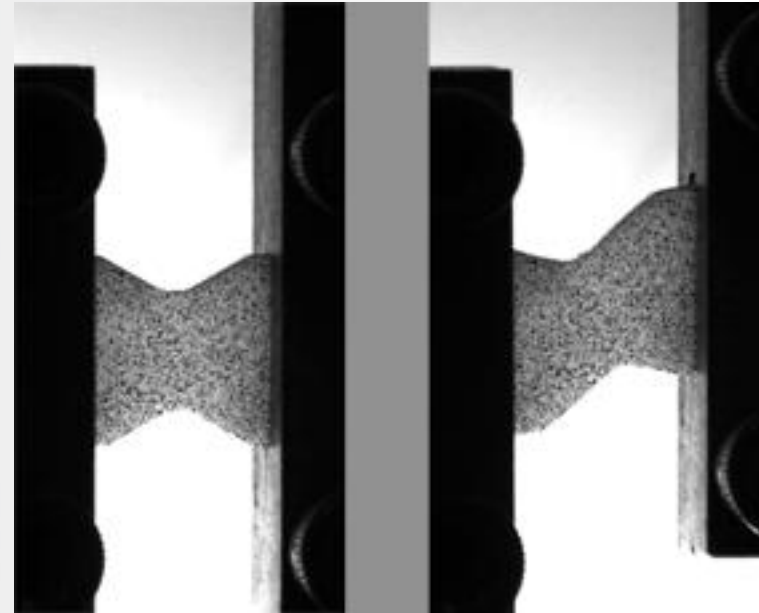
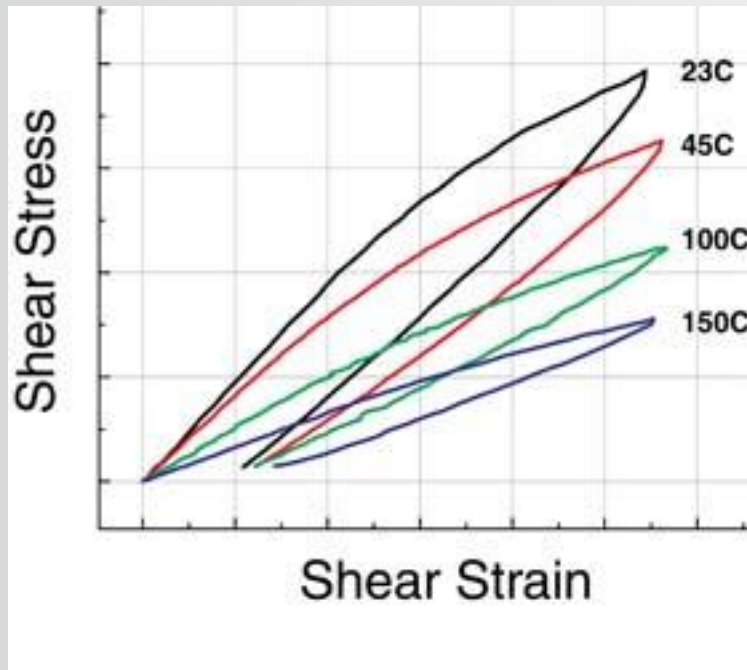
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Simple Shear

1. Additional Strain State
2. Using DIC Strain Measuring

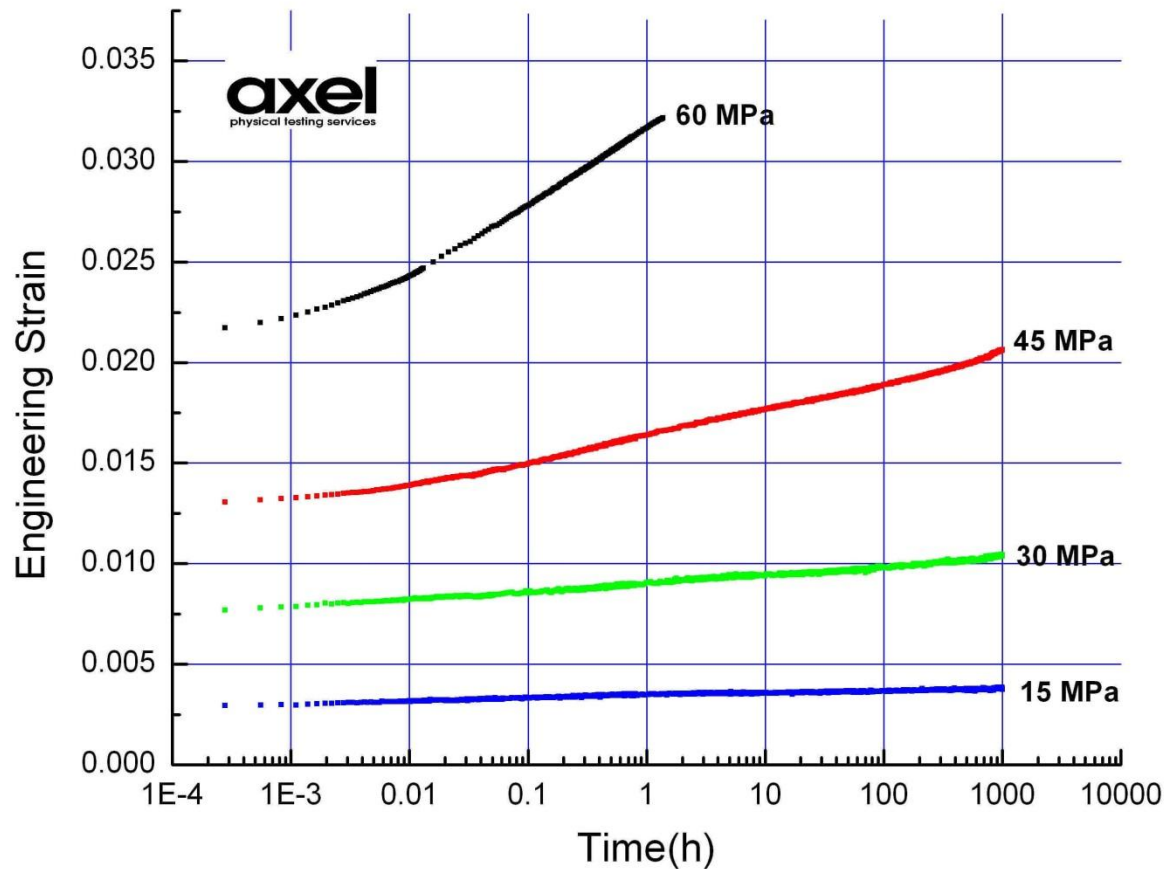


Long Term Creep

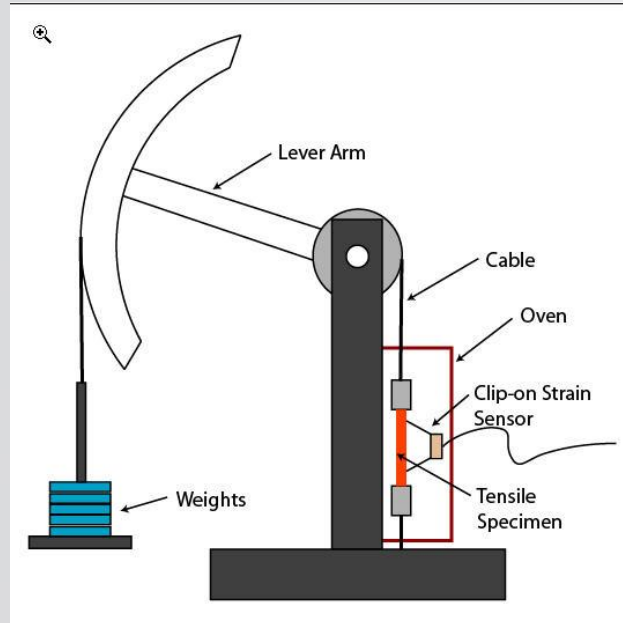
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Plastic



- Long Term Creep Experiments

- ➔ Often Required for Metal Replacement Applications
- ➔ Structural Applications May Require a Range of Stress Levels and Temperatures

Summary of rate-dependent plasticity models in ANSYS:

	CREEP	RATE ¹	ANAND ⁴
Behavior	Strain rate- or time-dependent		
	Isotropic or anisotropic creep (see HILL below)	Isotropic or anisotropic viscoplasticity (see HILL below)	Isotropic
Yield Surface	No explicitly defined yield surface	Includes yield surface	No explicitly defined yield surface. However, includes evolution equation.
Combination with rate-independent plasticity	Possible to combine with plasticity, which is decoupled with creep strains	Rate-independent plasticity model is required. Inelastic strains are coupled	No additional rate-independent plasticity allowed. Inelastic strains are coupled
	BISO, MISO, NLISO, BKIN, HILL	BISO, MISO, NLISO, HILL	None
Strain Rates	Suitable for small strain rates	Suitable for large strain rates	Suitable for small strain rates
Time scale	Long periods, creep and plasticity have different time scales	Short periods, usually for impact-type problems	Short/medium periods
Temperature Effects	Temperature effects included as part of equation (or material constants can be temperature-dependent) ²	Can input temperature-dependent material constants, but equations do not consider temp effects directly	Anand's equation considers temperature effects directly. No need to input temperature-dependent material constants
Supported Element Types³	Implicit - core and 18x Explicit - core and misc	Core and 18x	VISCO106-108

¹ "RATE" includes Peirce and Perzyna models.

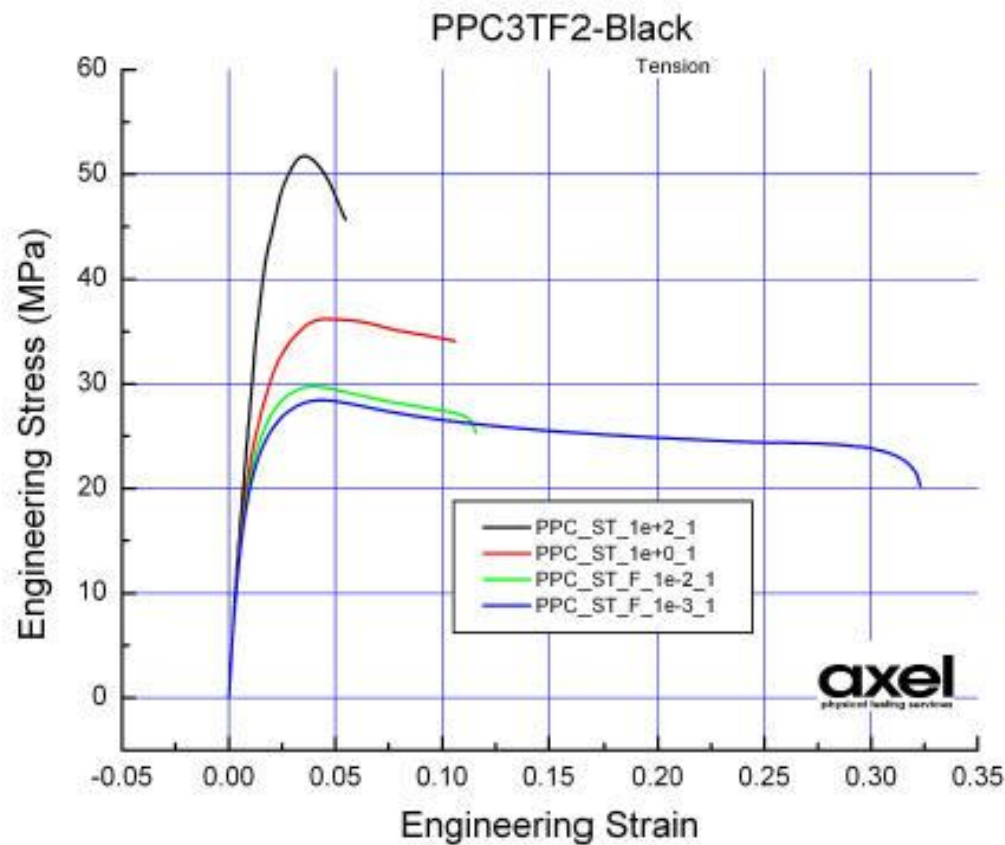
² Temperature-dependent material constants available for implicit creep

³ Core Elements = PLANE42, SOLID45, PLANE82, SOLID92, SOLID95

18x Elements = LINK180, SHELL181, PLANE182-183, SOLID185-187, BEAM188-189, SOLSH190, SHELL208-209

⁴ Anand's Model is discussed in Appendix A

Plastic Rates

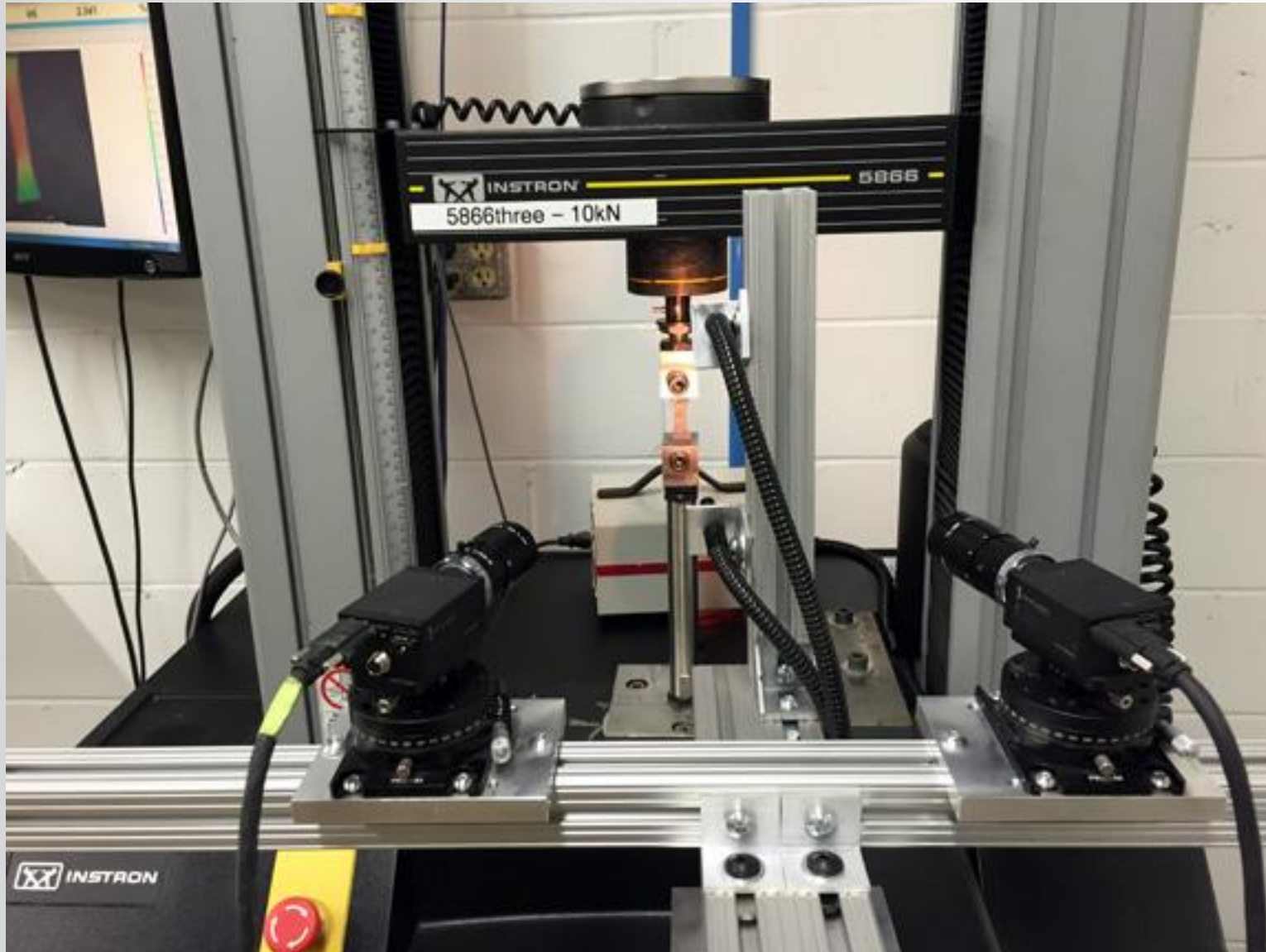


Structural Properties

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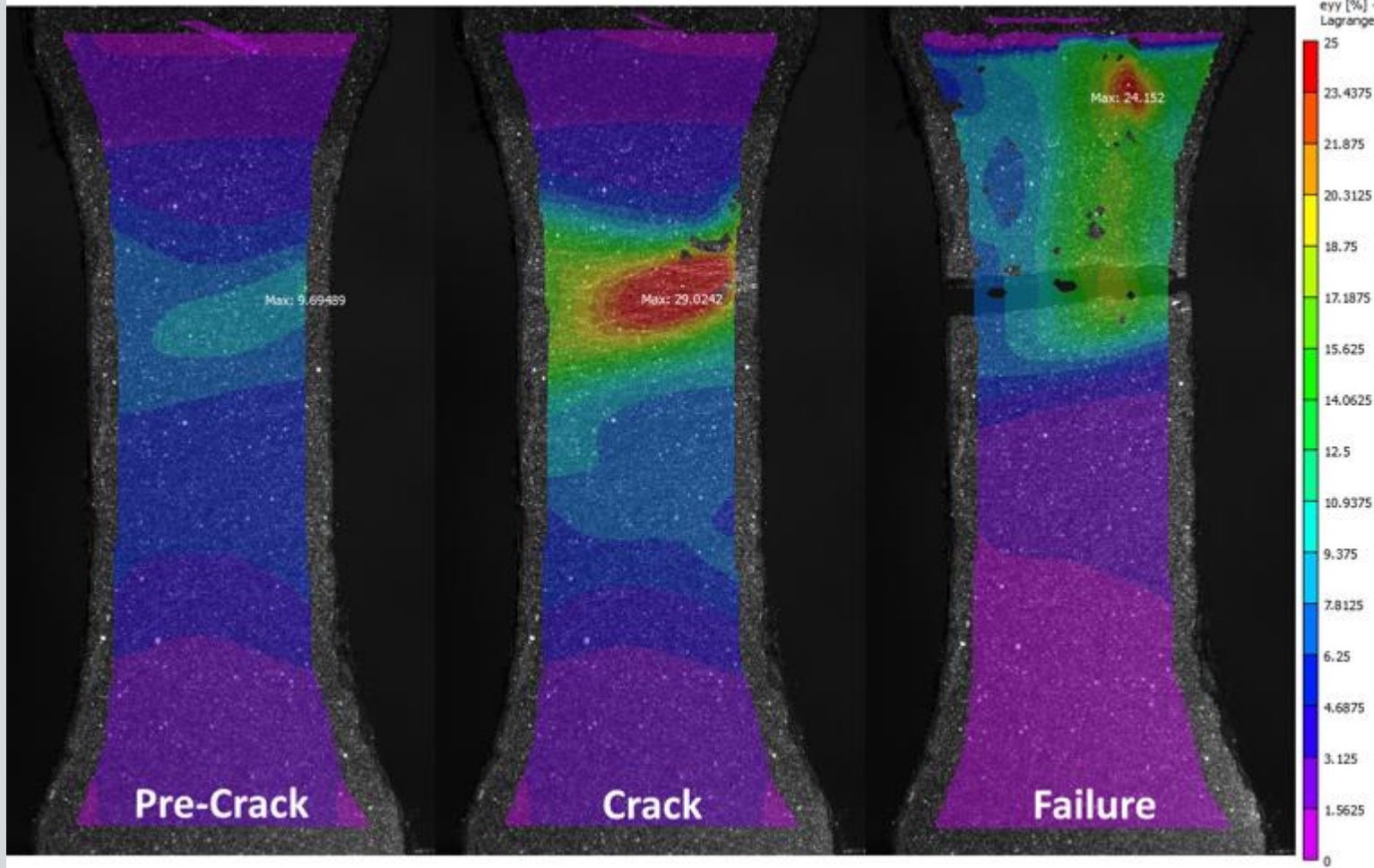


Structural Properties

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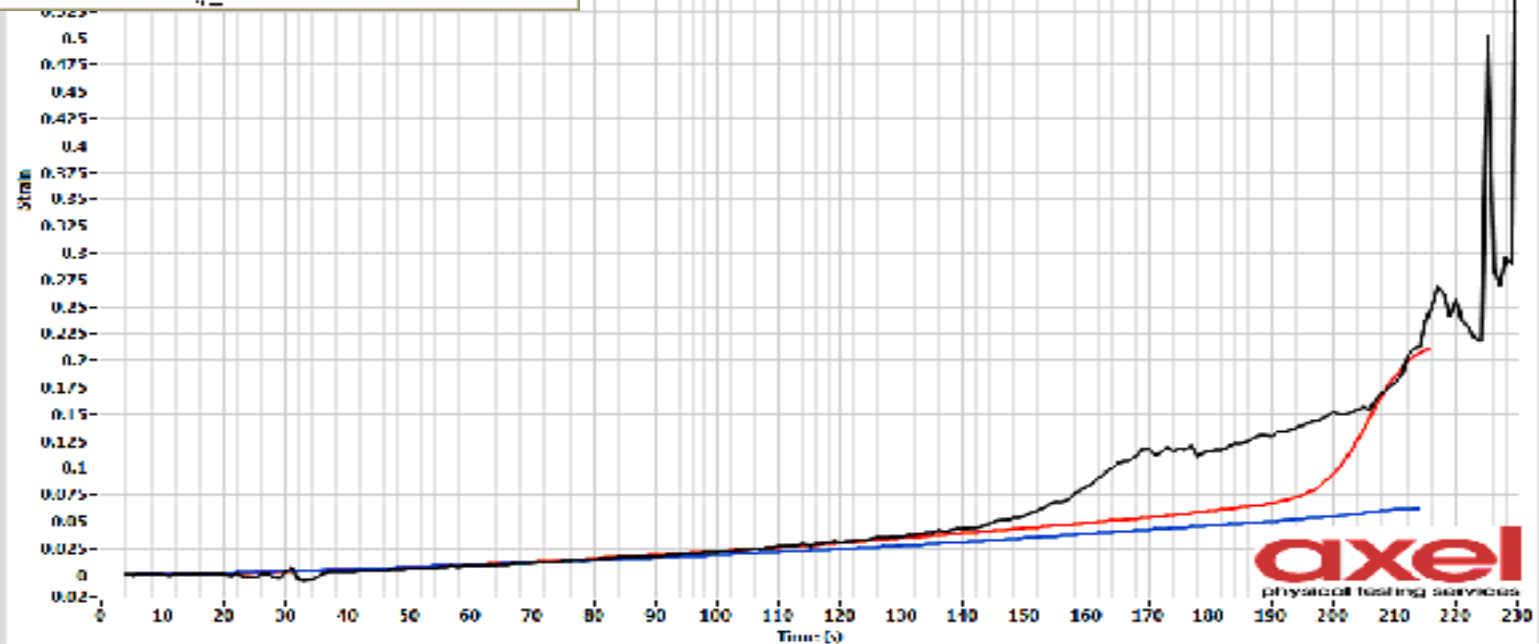
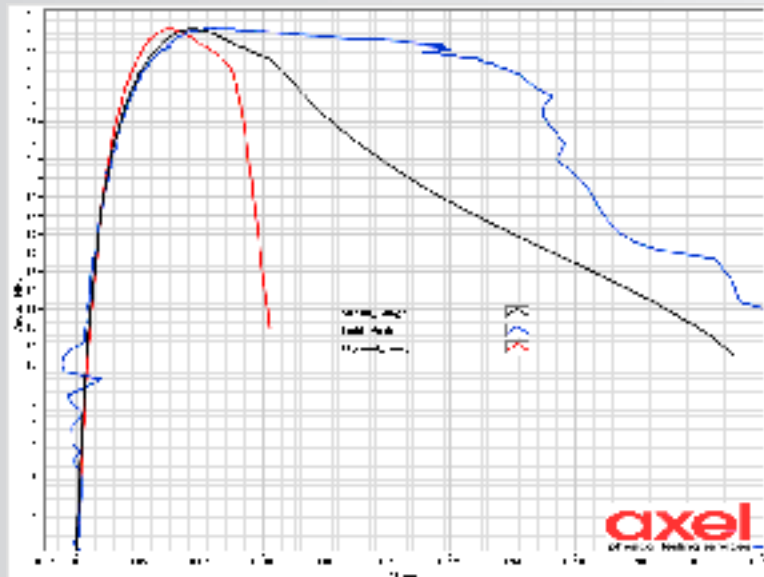


Structural Properties

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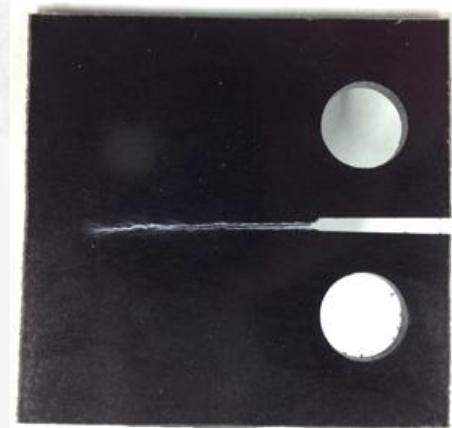
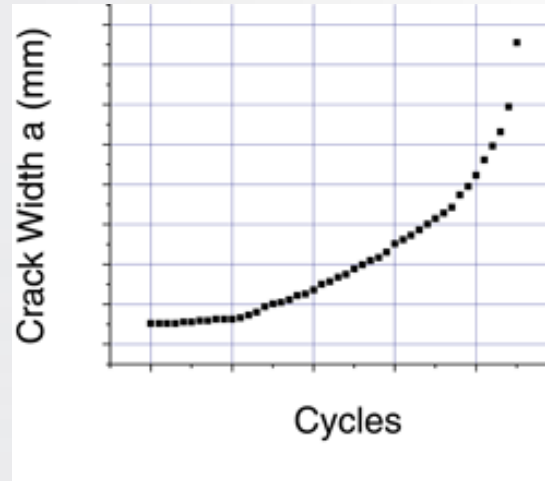


Fracture in Plastic

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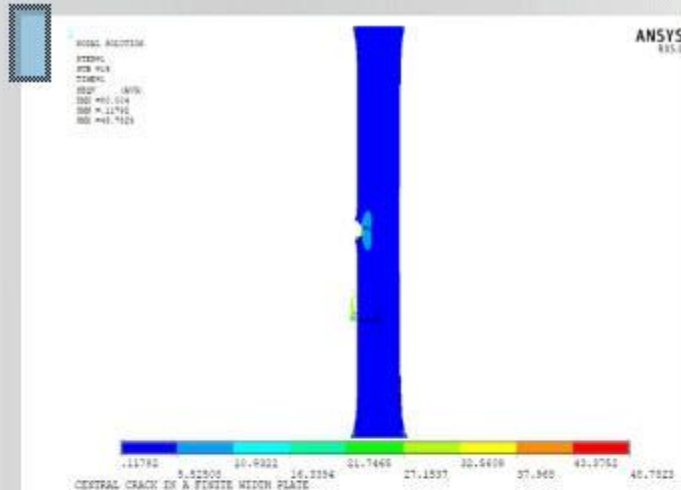


Fracture in Rubber

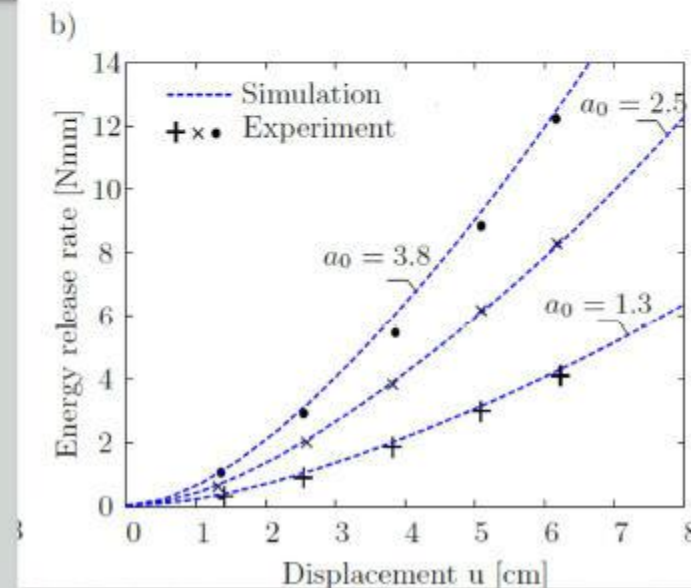
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Material forces can be seen as the driving forces acting on any kind of inhomogeneity, including crack tips.



Calculations are performed similar to regular fracture parameters with a special option for material forces.

Minimum Requirement for Crack Growth

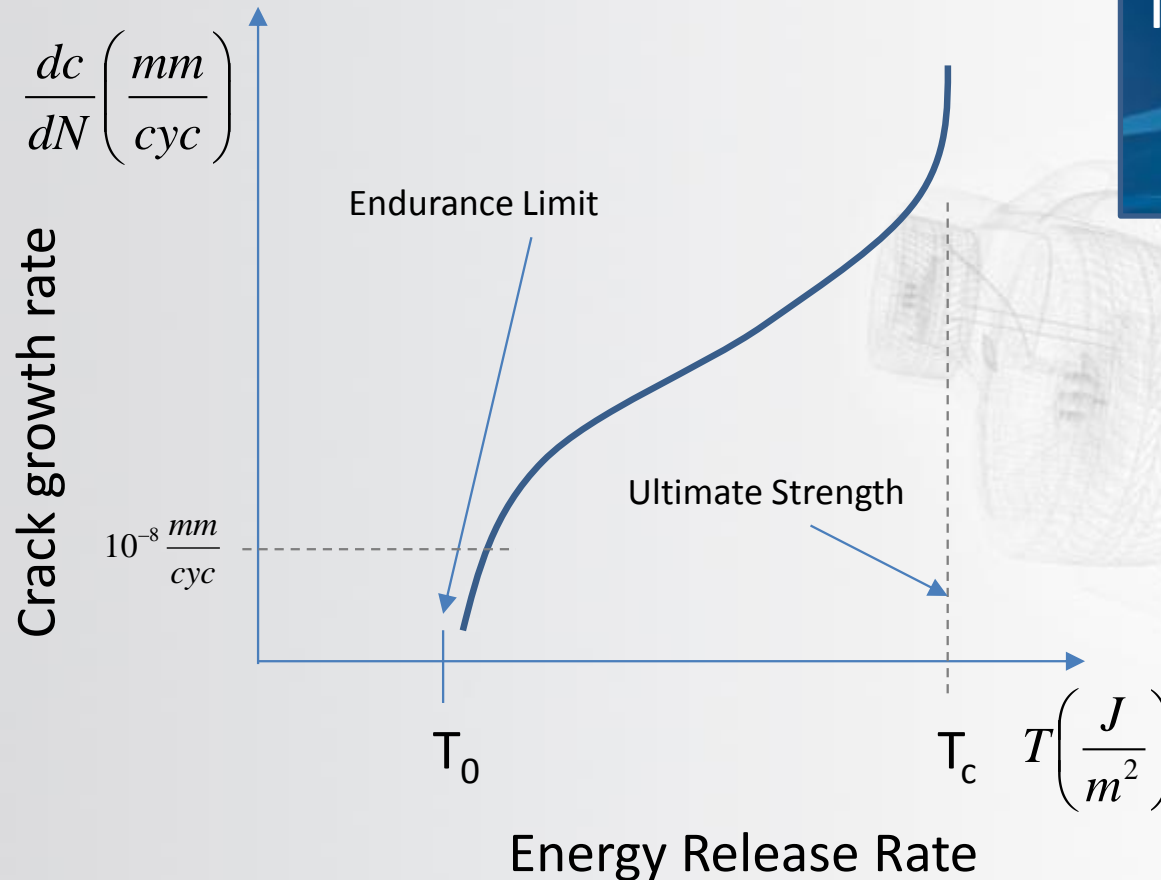
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Fatigue Property Mapping

Know Your Material



Intrinsic Strength Option
(>10⁶ cycles)
Quantify endurance limit

Endurica CL

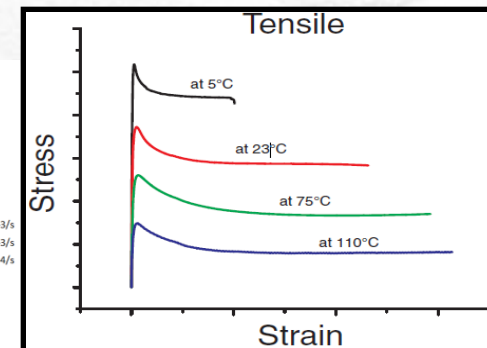
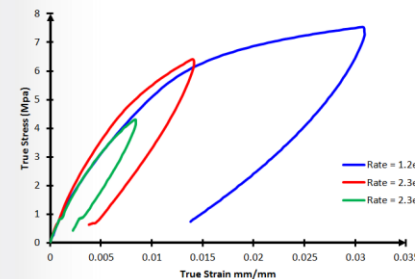
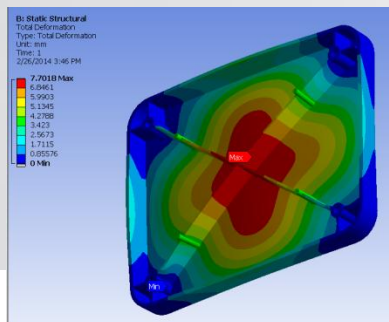
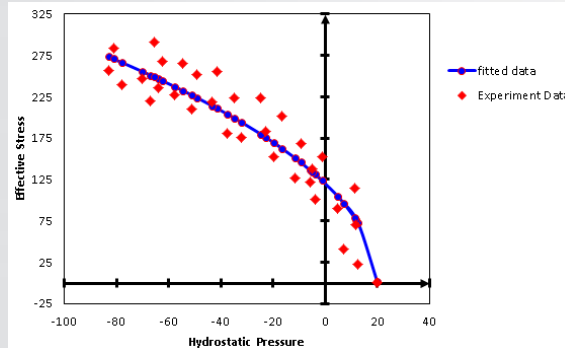
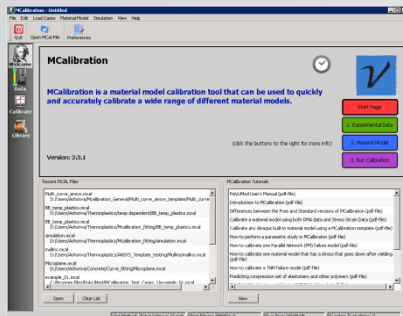
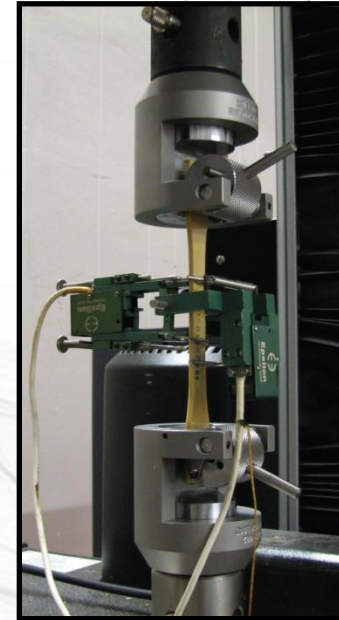
Fatigue Analysis Software

ANSYS Experimental Structural Plastic Training at Axel Products

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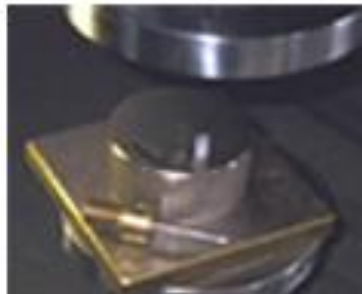
n

• ANSYS teams with Axel Product, Inc. (www.axelproducts.com) to offer this course that covers material testing, material modeling and finite element analysis of structural plastics such as Polyethylene (PE), Polypropylene (PP), Polyvinyl chloride (PVC) etc.



ANSYS Experimental Elastomers Training at Axel Products

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ANSYS

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Lecture 2

Hyperelasticity

14.0 Release

Fluid Dynamics

Structural Mechanics

Electromagnetics

Systems and Multiphysics

ANSYS Mechanical Experimental Elastomers

ANSYS

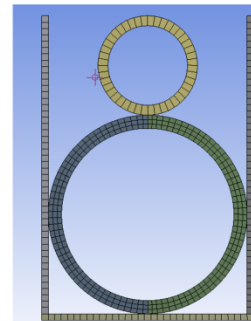
Workshop 6 – Axisymmetric Ring

Goal

- Run a viscoelastic analysis of an axisymmetric hyperelastic ring.
- Become familiar with performing viscoelastic curve-fitting.

Model Description

- 2D plane axisymmetric model
- Frictional contact between the rings
- Frictional contact between the bottom ring and side walls



Thank You for Listening.

- Kurt

- kurt@axelproducts.com