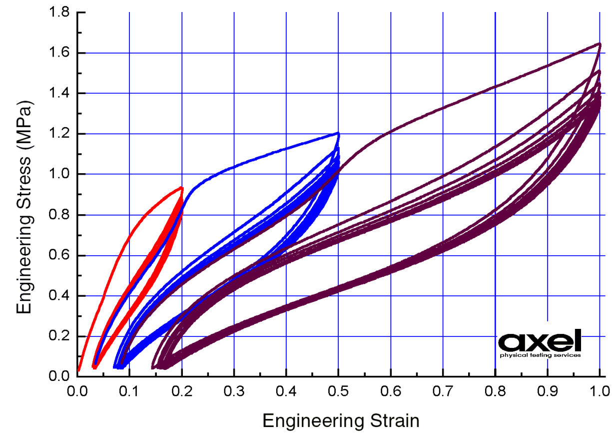
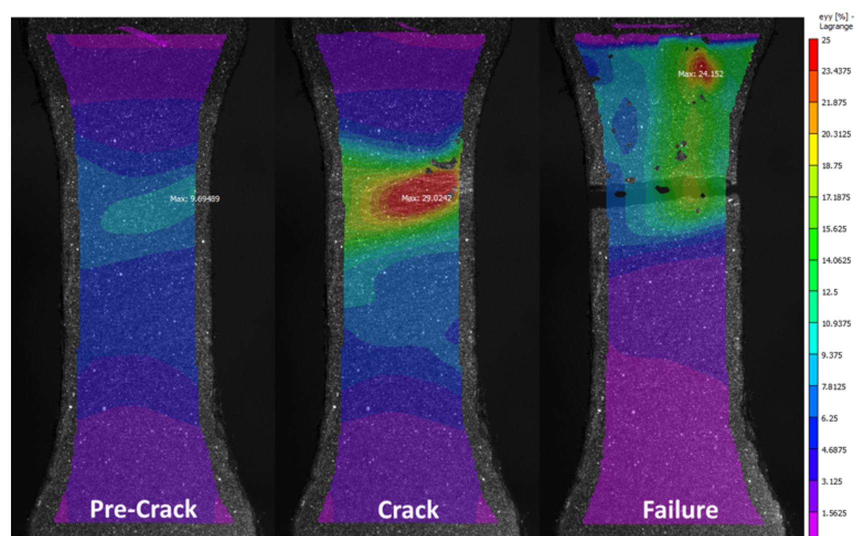
Testing Elastomers and Plastics for Marc Material Models

Presented by:

Kurt Miller

Axel Products, Inc.





axelproducts.com

axel
physical testing services

axel
physical testing services

Physical Testing Services

Home | Testing Services | Training Courses | Technical Downloads | About Axel | Contact Axel

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

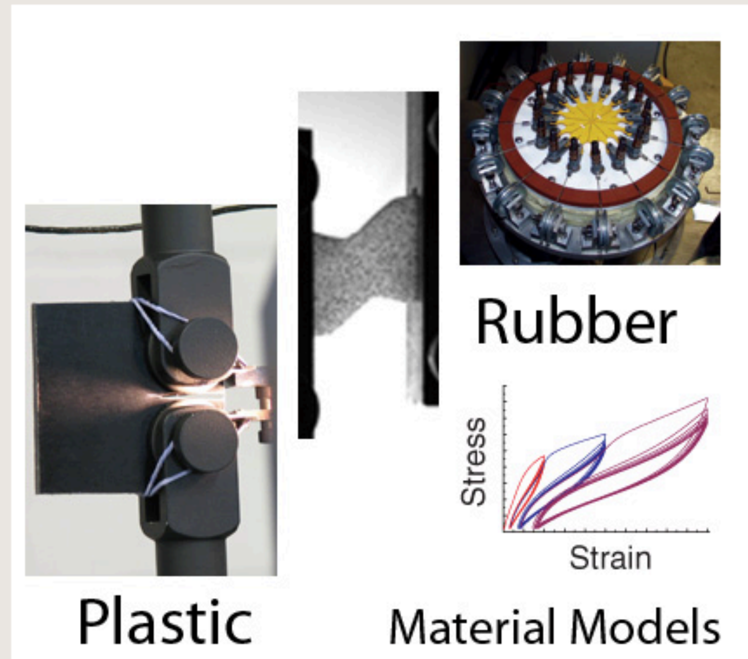
Related experiments, downloads and pricing by application.

- 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)



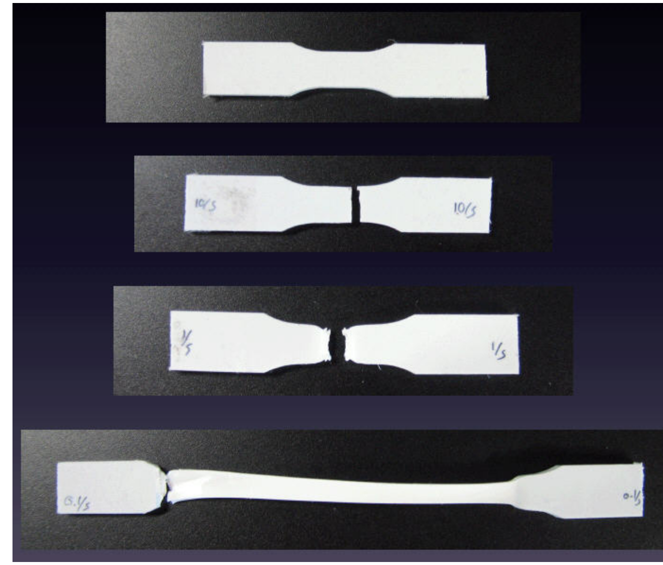
Training Courses

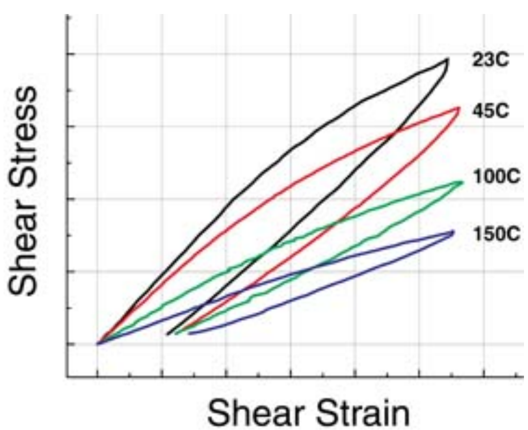
We Measure Structural Properties

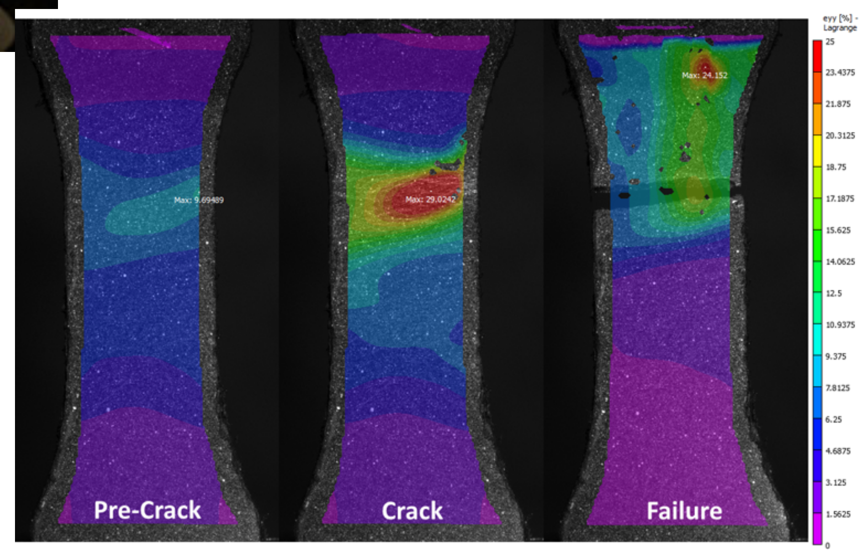
Stress – Strain–Time-Temperature

Test Combinations

- Softening
- Viscoelasticity
- Vibrations
- Rate, Set
- Set, Creep
- Fatigue
- All things Hot and Cold
- Directional
- Plastic + Unload

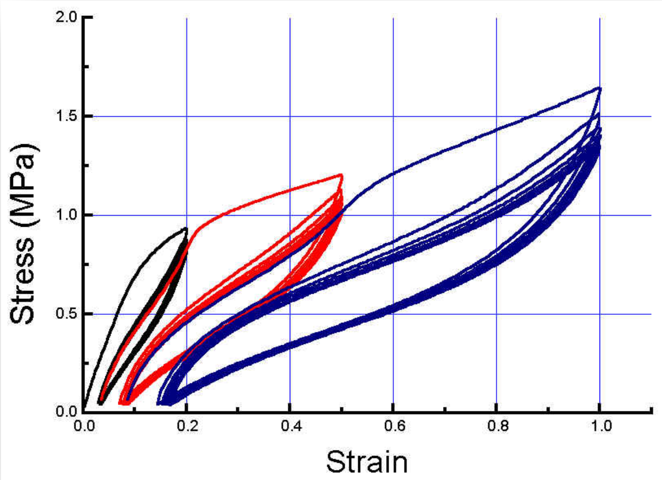






Nonlinear Elasticity with Permanent Set

- Parallel Rheological Framework - Behavior Supported
- Nonlinear Elasticity
- Viscoelastic
- Plasticity
- Damage



This Slide is Borrowed from MSC

Amplitude Dependent Harmonic Models

- Phenomenological models
  - Thixotropic (Lion)
    - Process dependent relaxation times (viscosities)
  - Triboelastic
    - Cyclic plasticity
  - Direct
    - Kraus/Ulmer
  - Combined thixotropic and triboelastic
- General models
  - Tabular
  - User defined

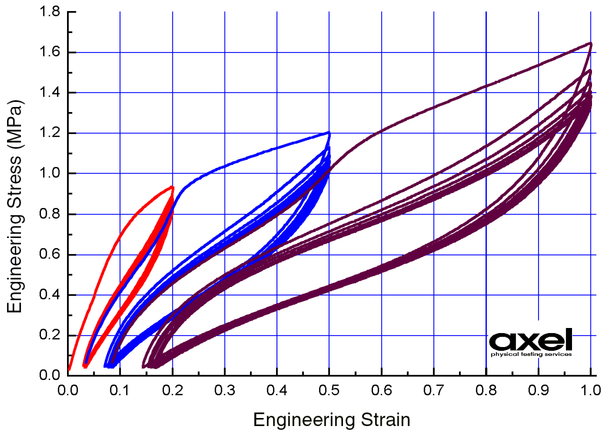
This Slide is Borrowed from MSC

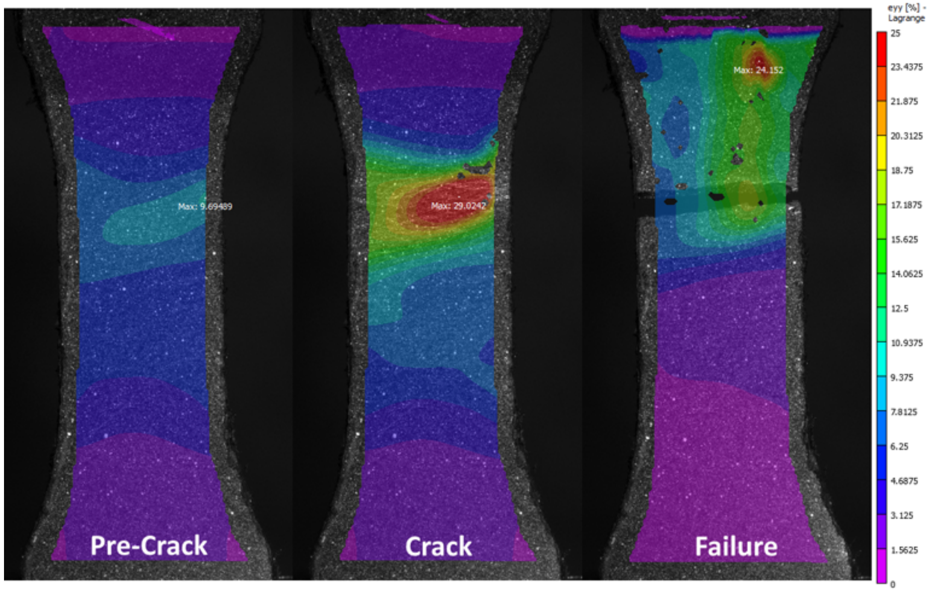
A General Strategy

1. Understand the loading conditions of the part
2. Understand the general behavior of the materials involved
3. Select the significant material behaviors
4. Use existing or develop material models to describe the behavior
5. Verify the performance of the material model

Isolate Behaviors

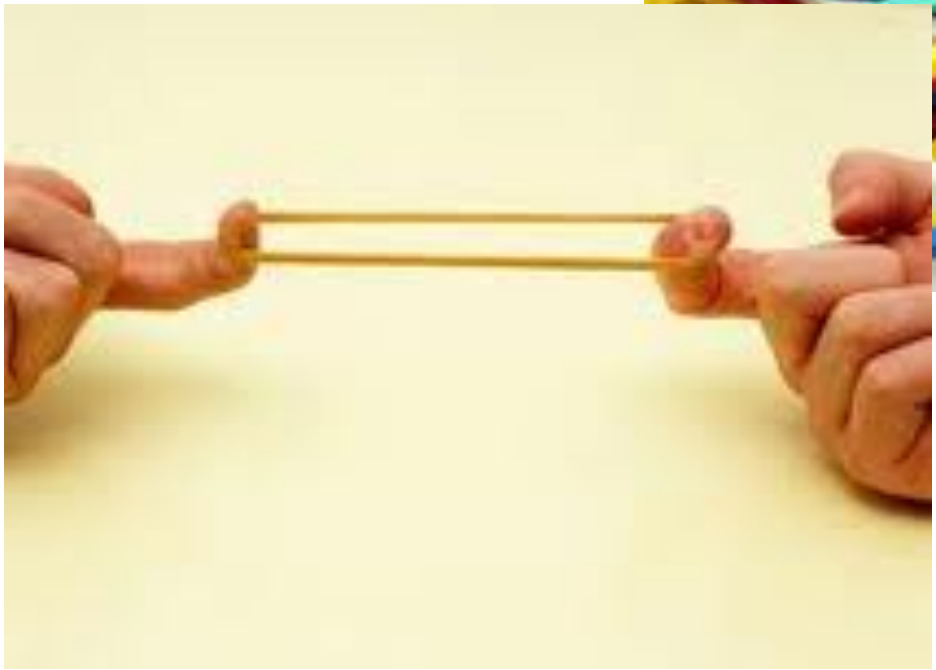
- Separate Elastic & Plastic
- Go to the Application Temperature
- Observe Failure
- Grow the Defect
- Go Very Slow
- Go Very Fast





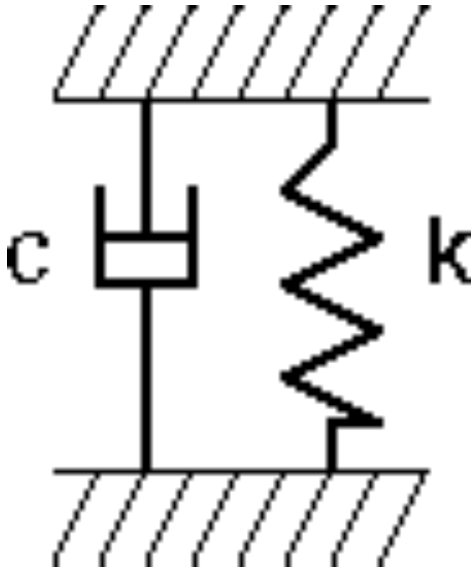
You Can't Model Everything!

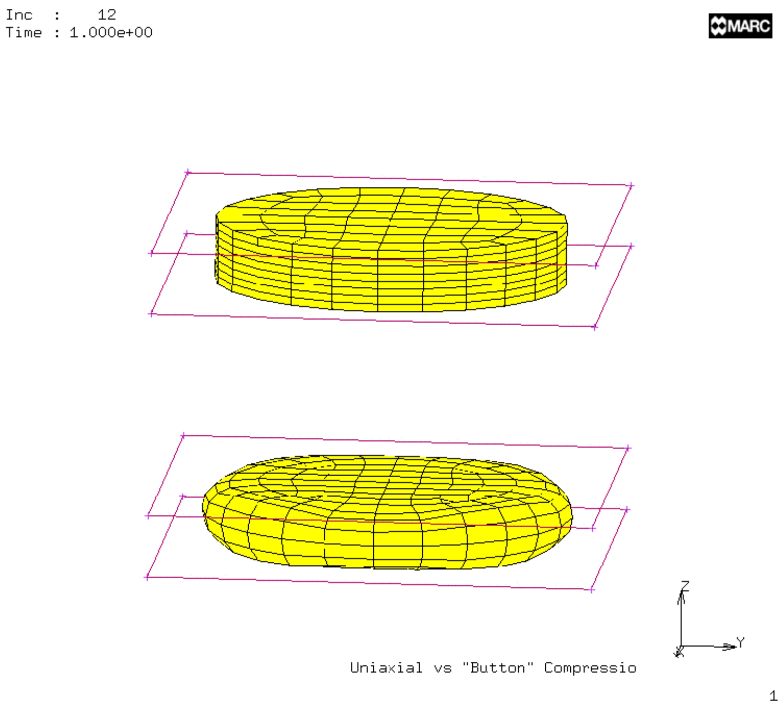
Rubber Bands



Rubber

A Spring and a Dashpot?

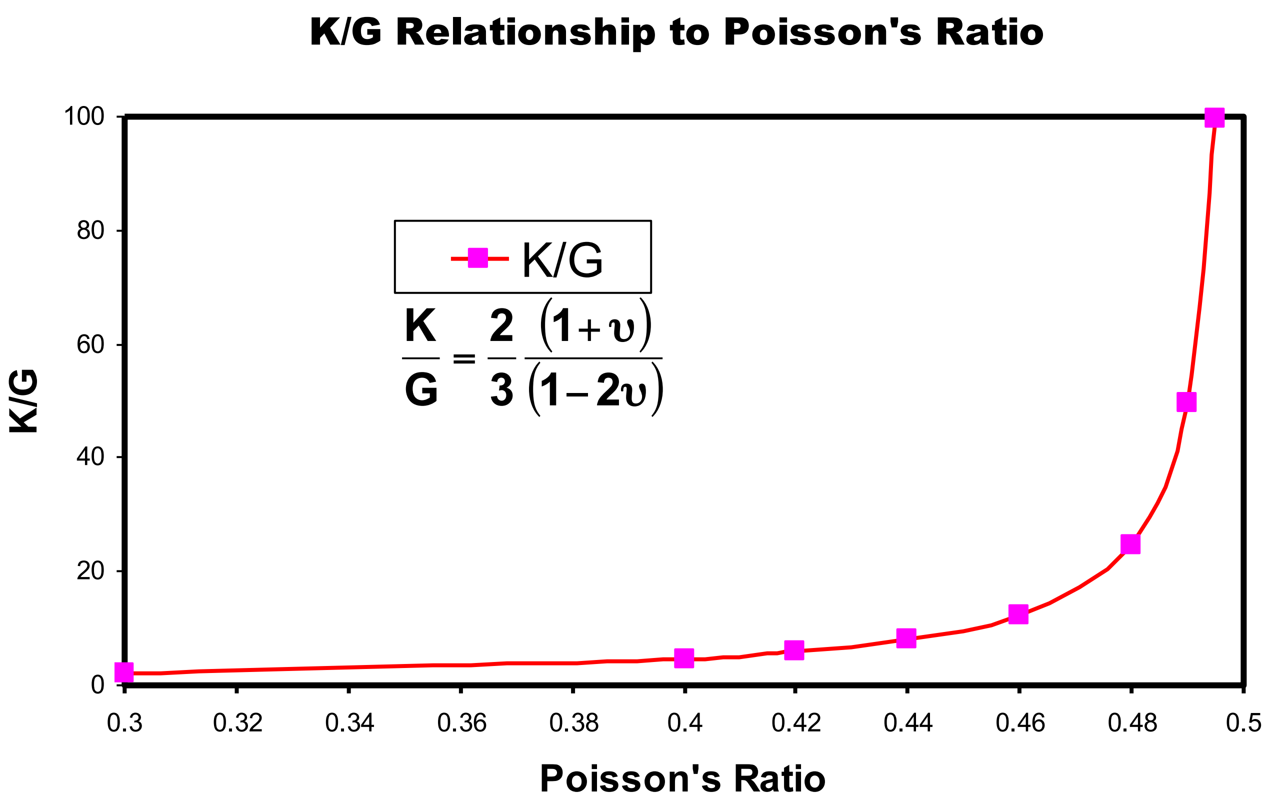




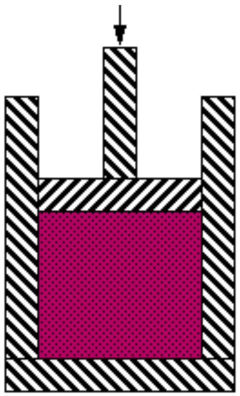
Volumetric Compression

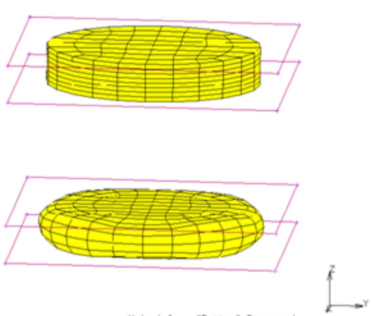
Poisson's ratio approaching 0.5 means infinite bulk modulus, K

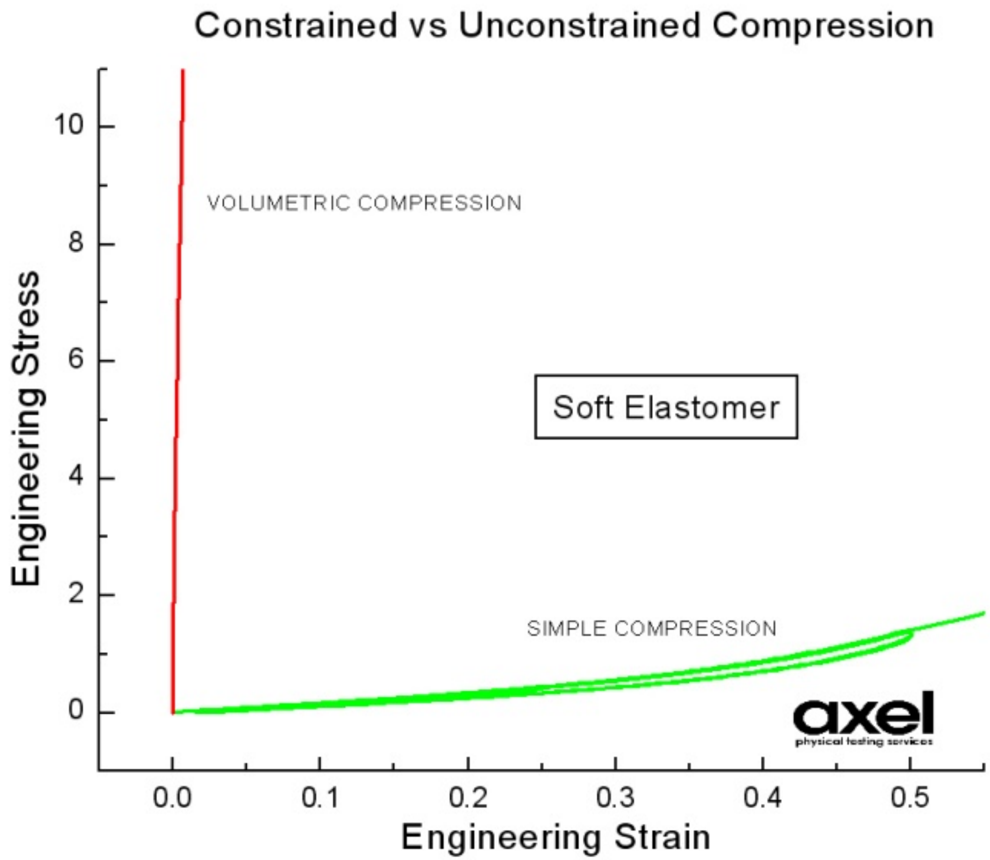
For elastomer materials, Poisson's ratio is difficult or impossible to measure accurately. For plastic materials, it is hard to measure VC accurately.



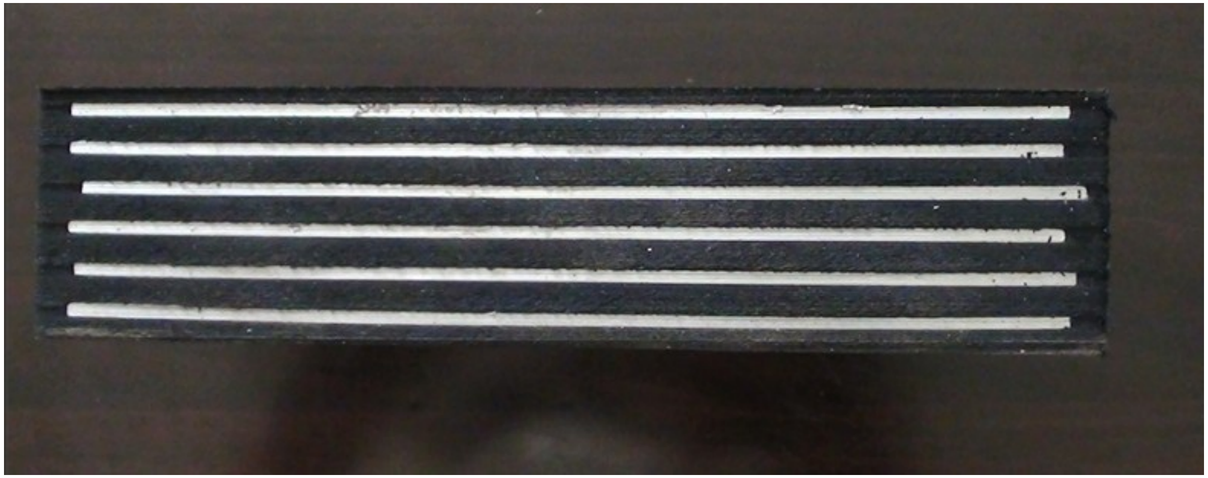
What Does Incompressible Mean?

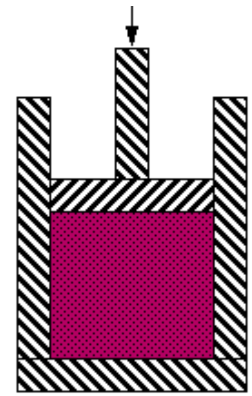






Incompressibility

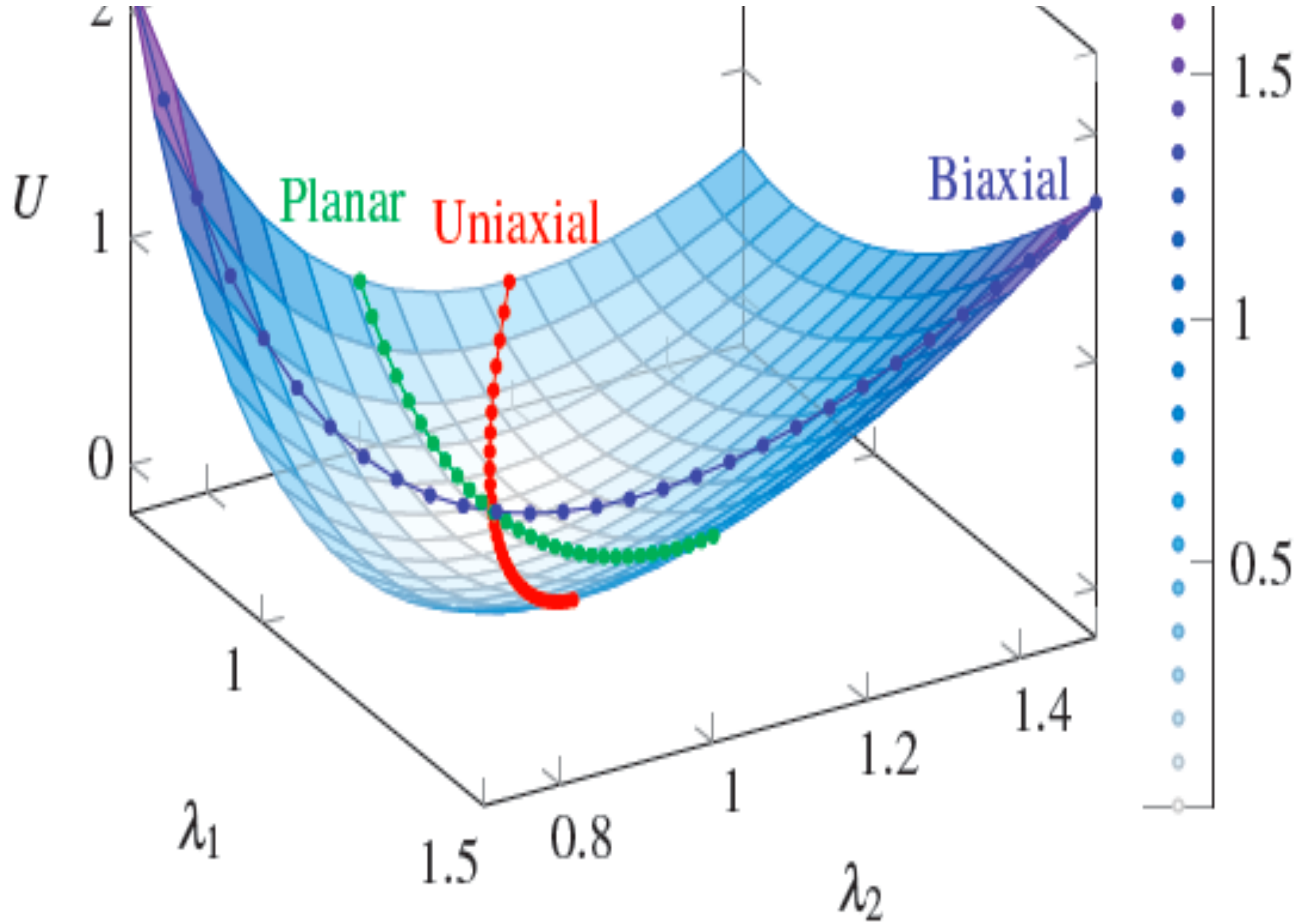


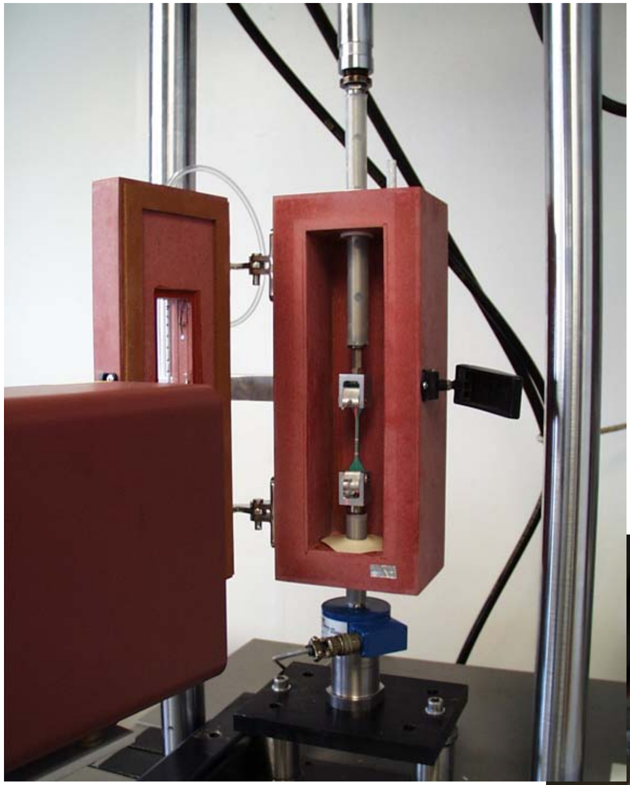


Not a spring and dashpot

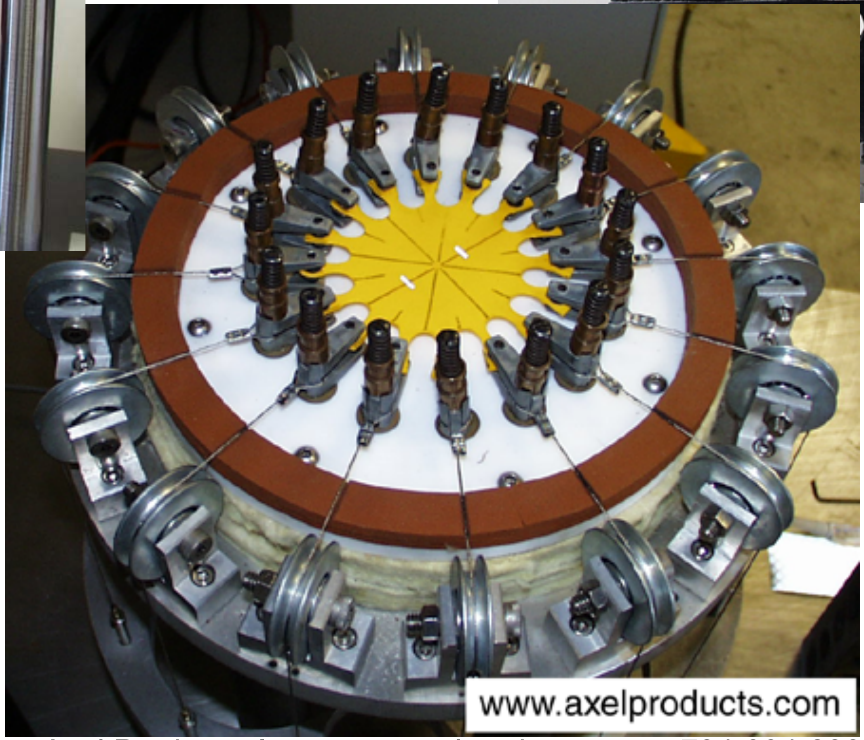
Rubber

Hyperelastic Surface






www.axelproducts.com


www.axelproducts.com

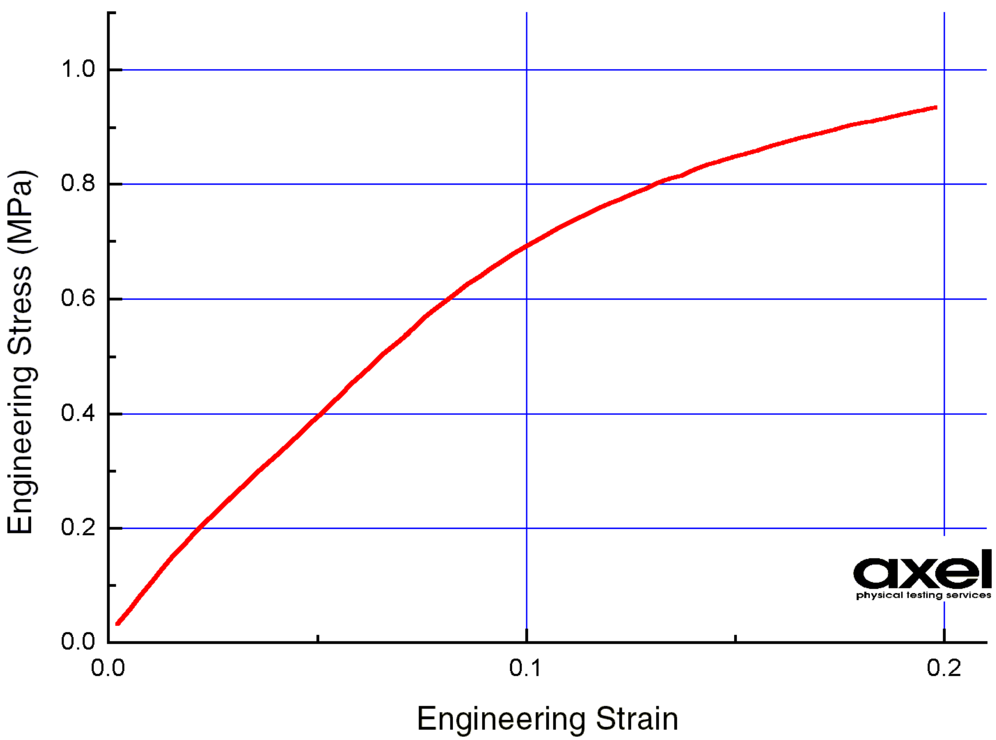
Hyperelastic Material Models

1. There are many in Marc.
2. They capture incompressibility.
3. You don't know which is best until you try to fit real data.
4. Use the simplest math that works.

Loading Conditions

Conclusions:

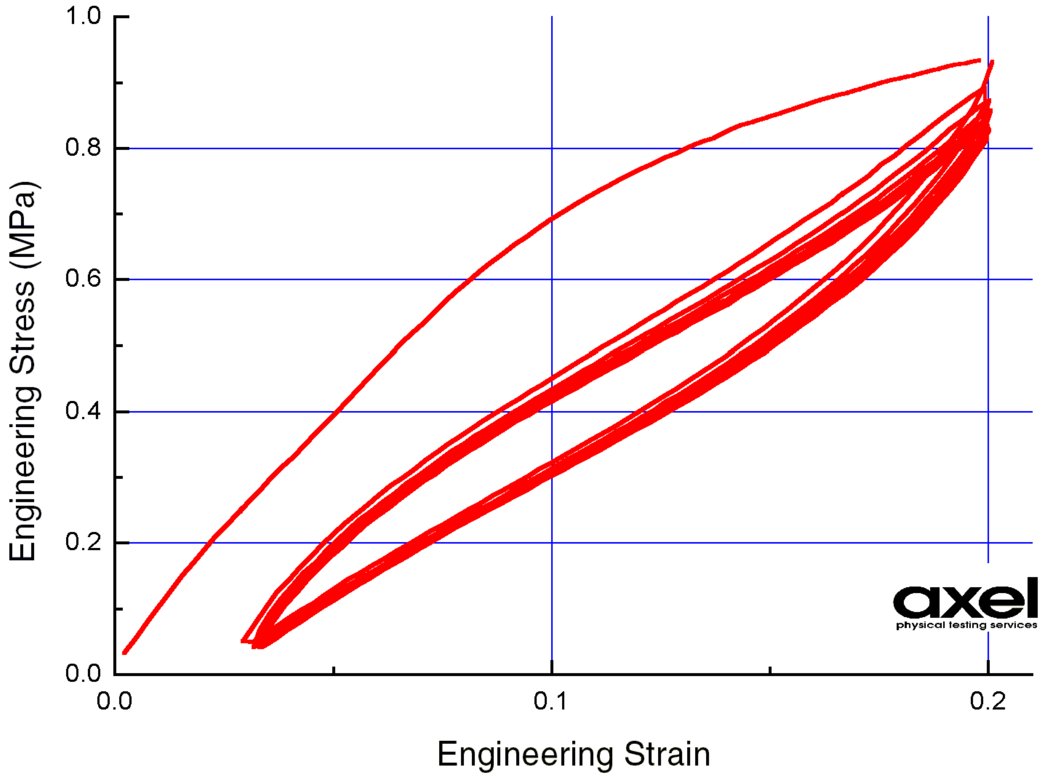
1. Test to realistic strain levels
2. Use application specific loadings to generate material data
3. Need to load and unload to separate elastic from plastic



Loading Conditions

Conclusions:

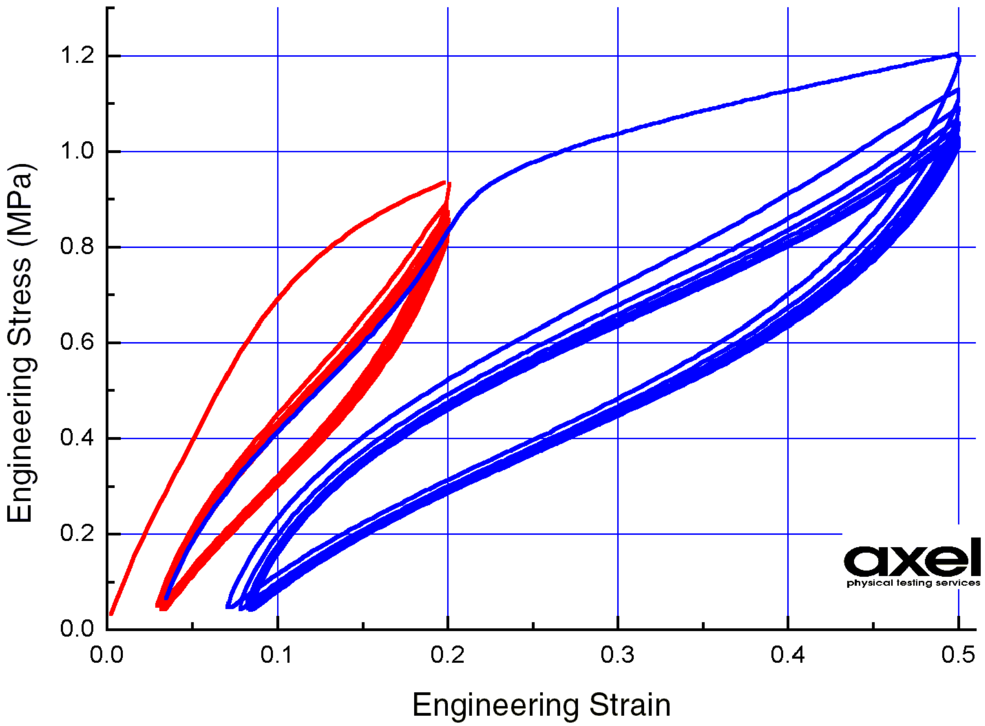
1. Test to realistic strain levels
2. Use application specific loadings to generate material data
3. Need to load and unload to separate elastic from plastic



Loading Conditions

Conclusions:

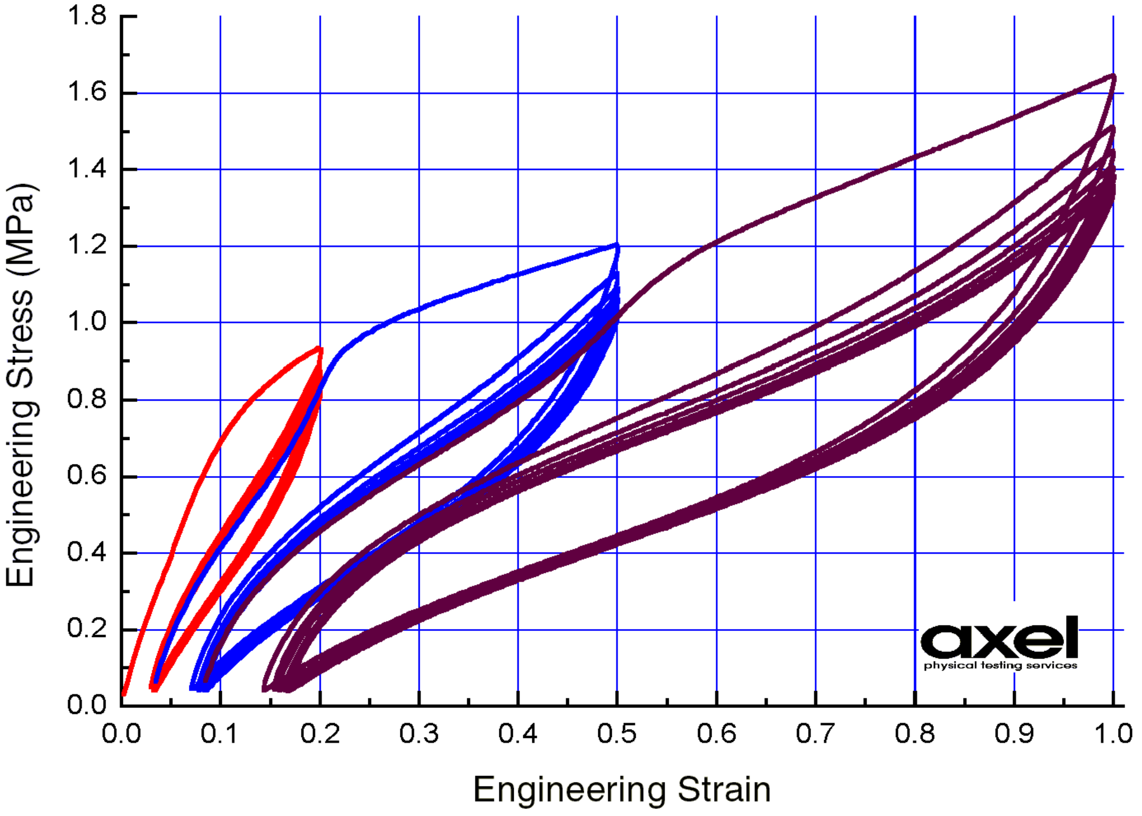
1. Test to realistic strain levels
2. Use application specific loadings to generate material data
3. Need to load and unload to separate elastic from plastic



Loading Conditions

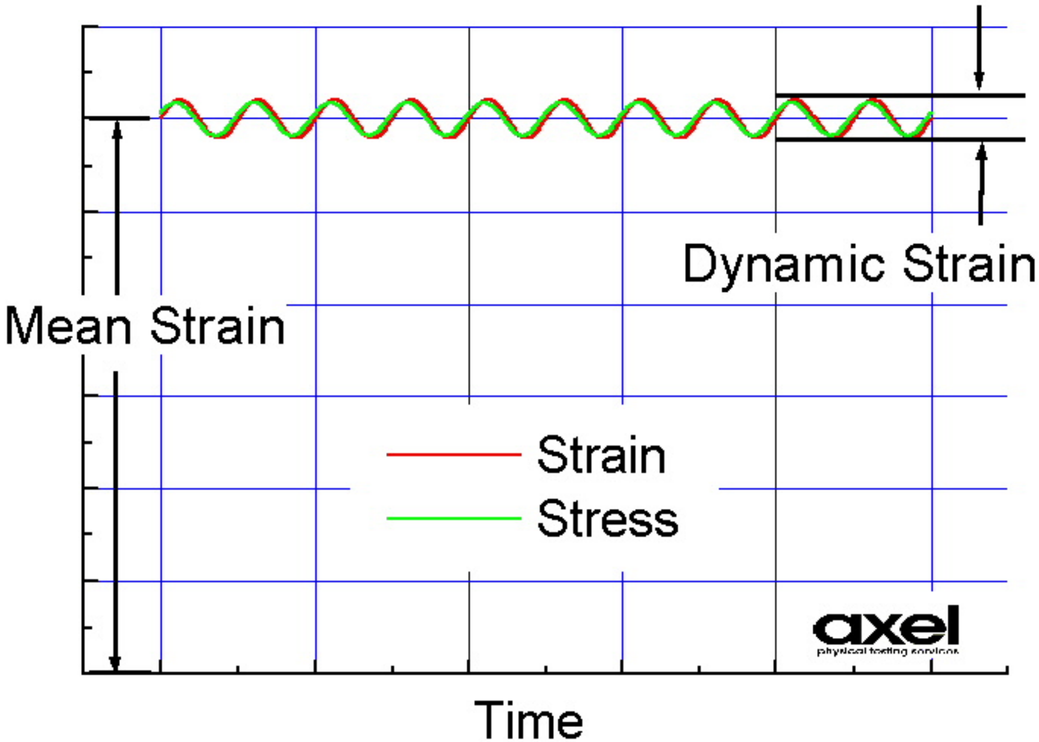
Conclusions:

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



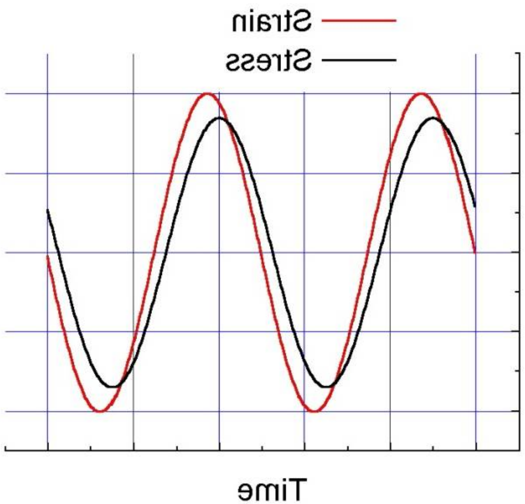
Harmonic Vibrations

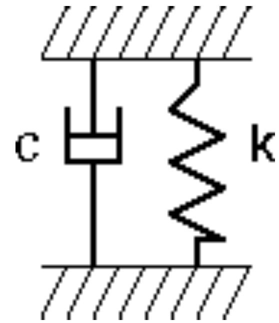
1. Types of Dynamic Behavior
2. Large strains at high velocity
3. Small sinusoidal strains superimposed on large mean strains



Vibrations

axel
physical testing services





No inertia effect

Long Wave Length vs Measurement

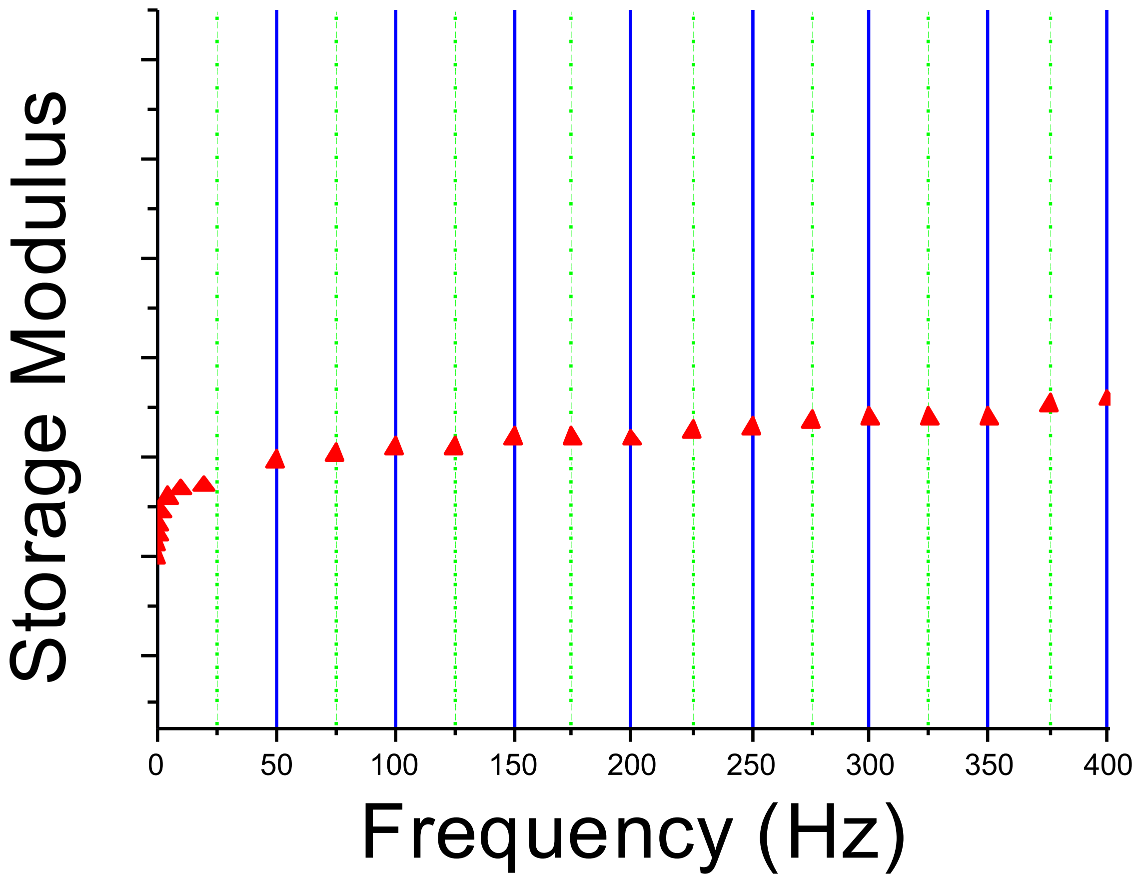
Dynamic Modulus = Peak Stress/ Peak Strain

Storage Modulus = E*cosδ

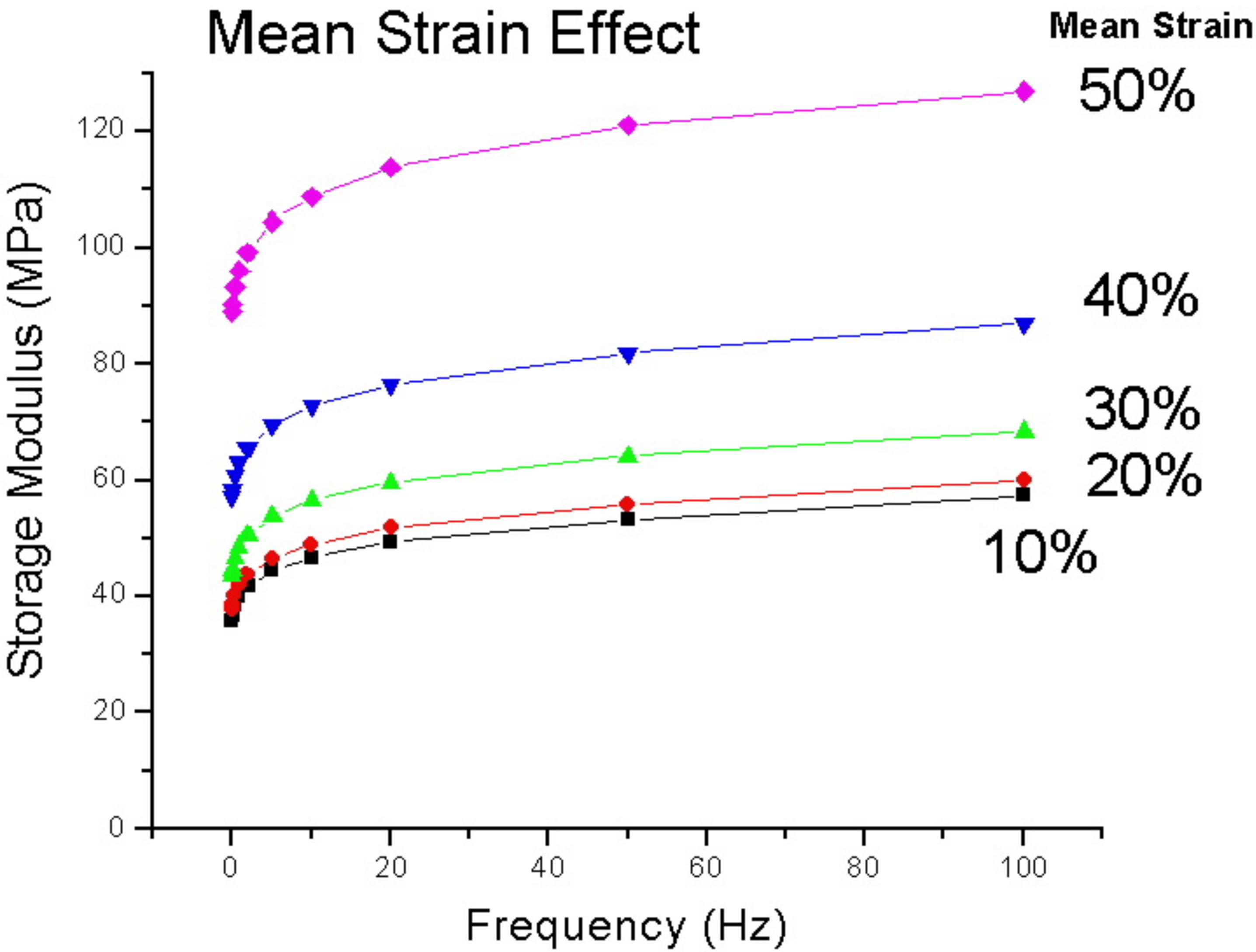
Loss Modulus = E*sinδ

Vibrations

Data at 30% Mean Strain

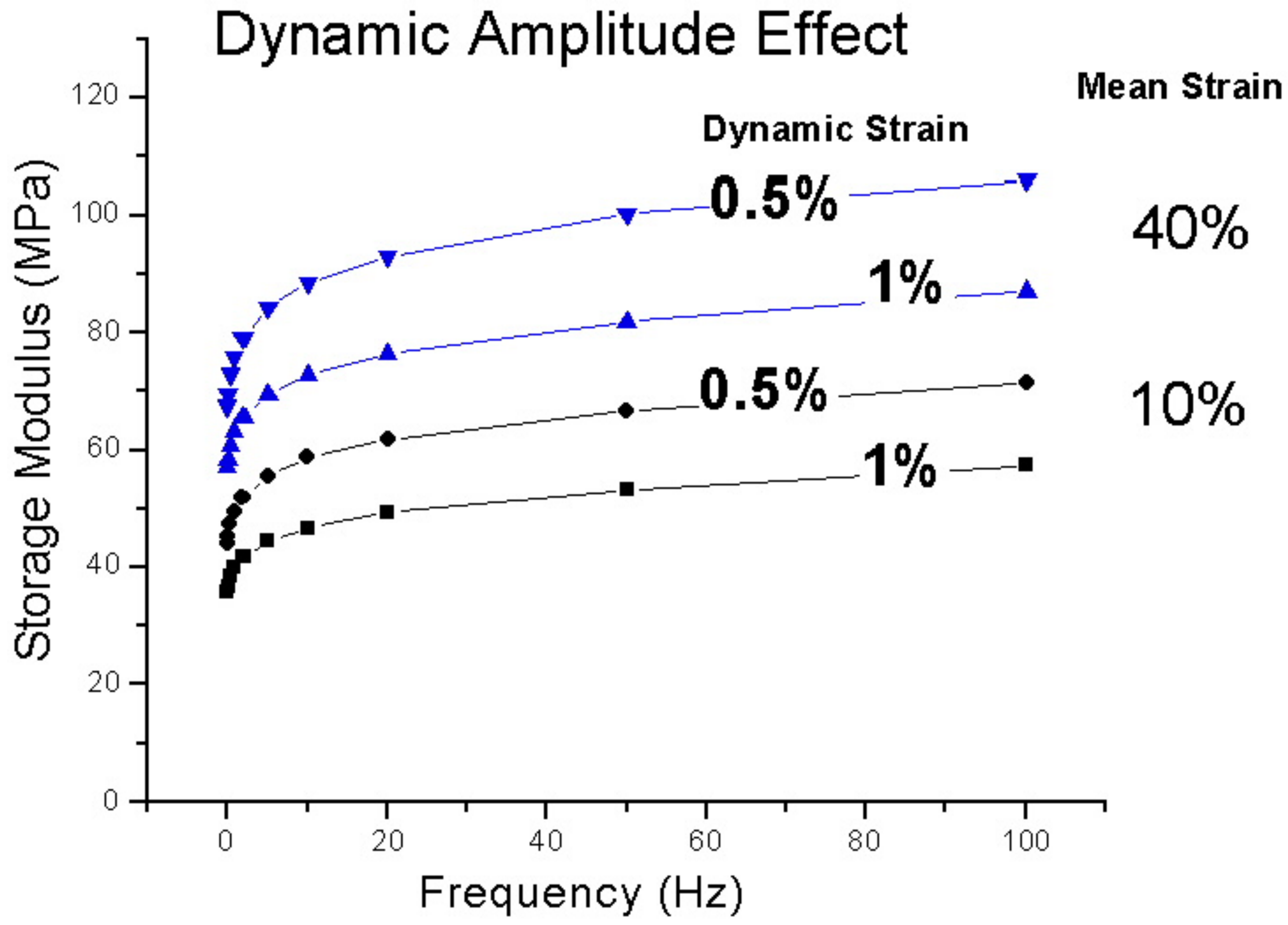


Vibrations



Mean Strain Effect
Mean Strain
50%
40%
30%
20%
10%
Storage Modulus (MPa)
Frequency (Hz)
0
20
40
60
80
100
120

Vibrations



Dynamic Amplitude Effect
Mean Strain
Dynamic Strain
0.5%
40%
1%
0.5%
10%
1%
Storage Modulus (MPa)
Frequency (Hz)
0
20
40
60
80
100
120

Amplitude Dependent Harmonic Models

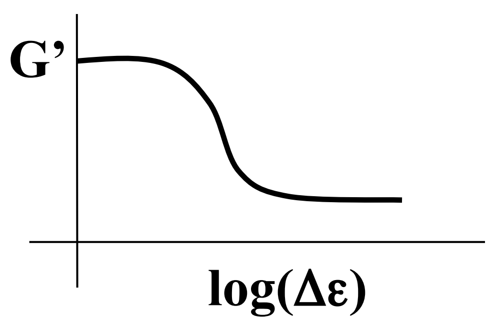
- Phenomenological models
  - Thixotropic (Lion)
    - Process dependent relaxation times (viscosities)
  - Triboelastic
    - Cyclic plasticity
  - Direct
    - Kraus/Ulmer
  - Combined thixotropic and triboelastic
- General models
  - Tabular
  - User defined

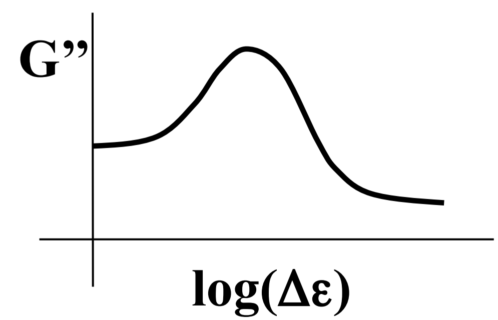
This Slide is Borrowed from MSC

This Slide is Borrowed from MSC

Payne Effect - Introduction

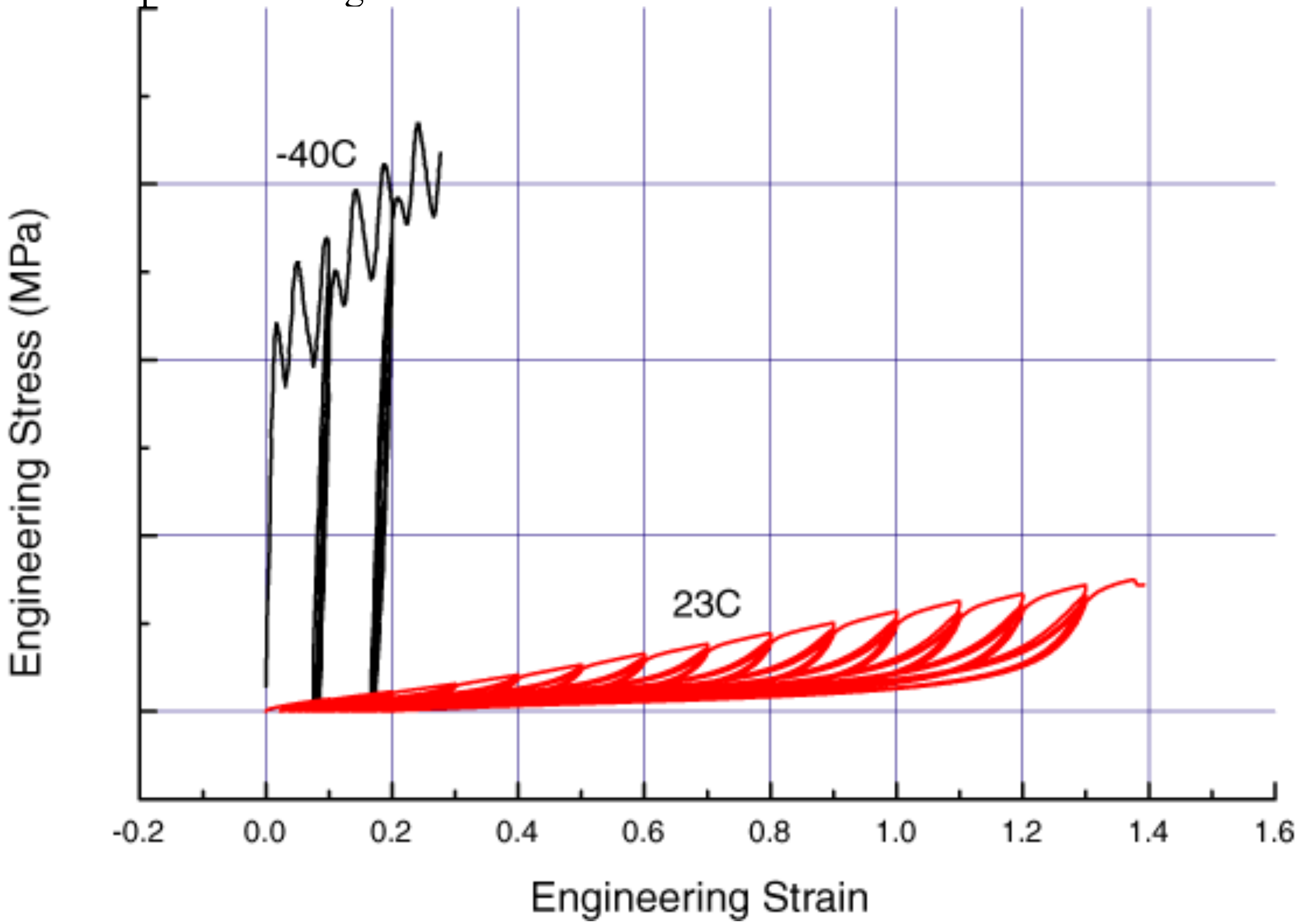
- Payne effect or Fletcher-Gent effect
  - Many filled rubbers show a pronounced effect of amplitude on storage (G’) and loss (G’’) modulus when subjected to harmonic loads.
  - Frequency dependent damping, incorporating the effect of the excitation magnitude
- Marc Implementation
  - With Marc Harmonic approach the complete analysis can be done as one job, stepping through the preload, stepping through the harmonic frequency and stepping through the harmonic excitation magnitude



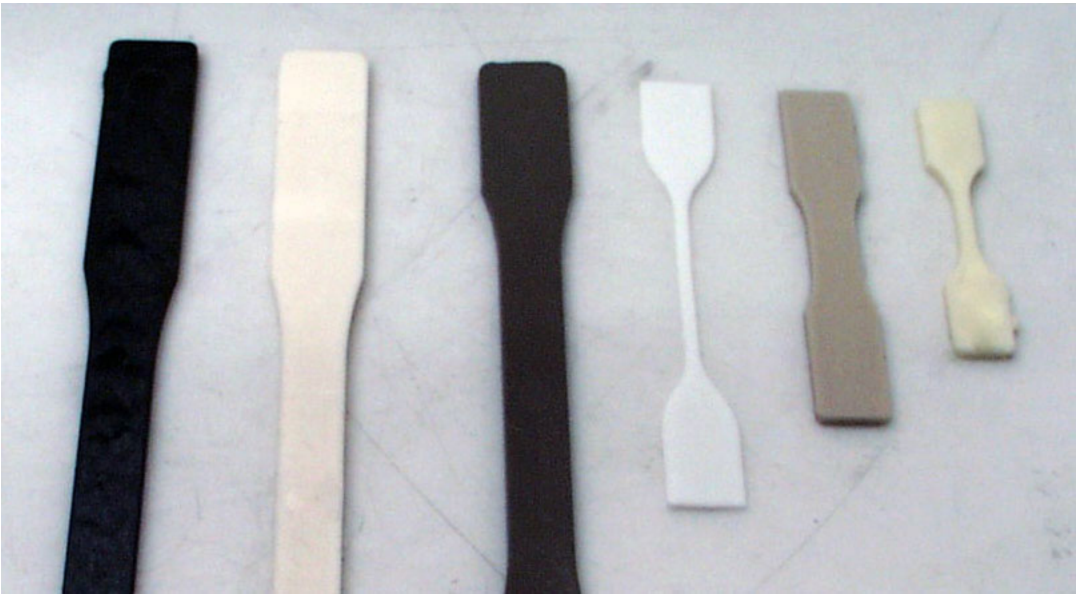


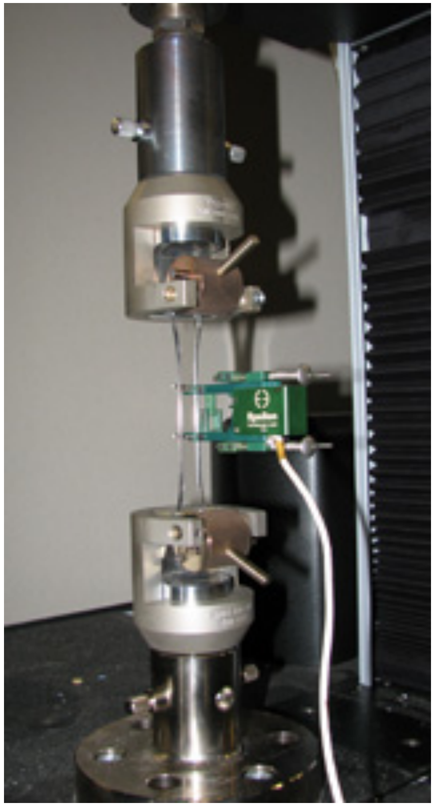
Cold and Hot

■Elastomers Properties Can Change by Orders of Magnitude in the Application Temperature Range.



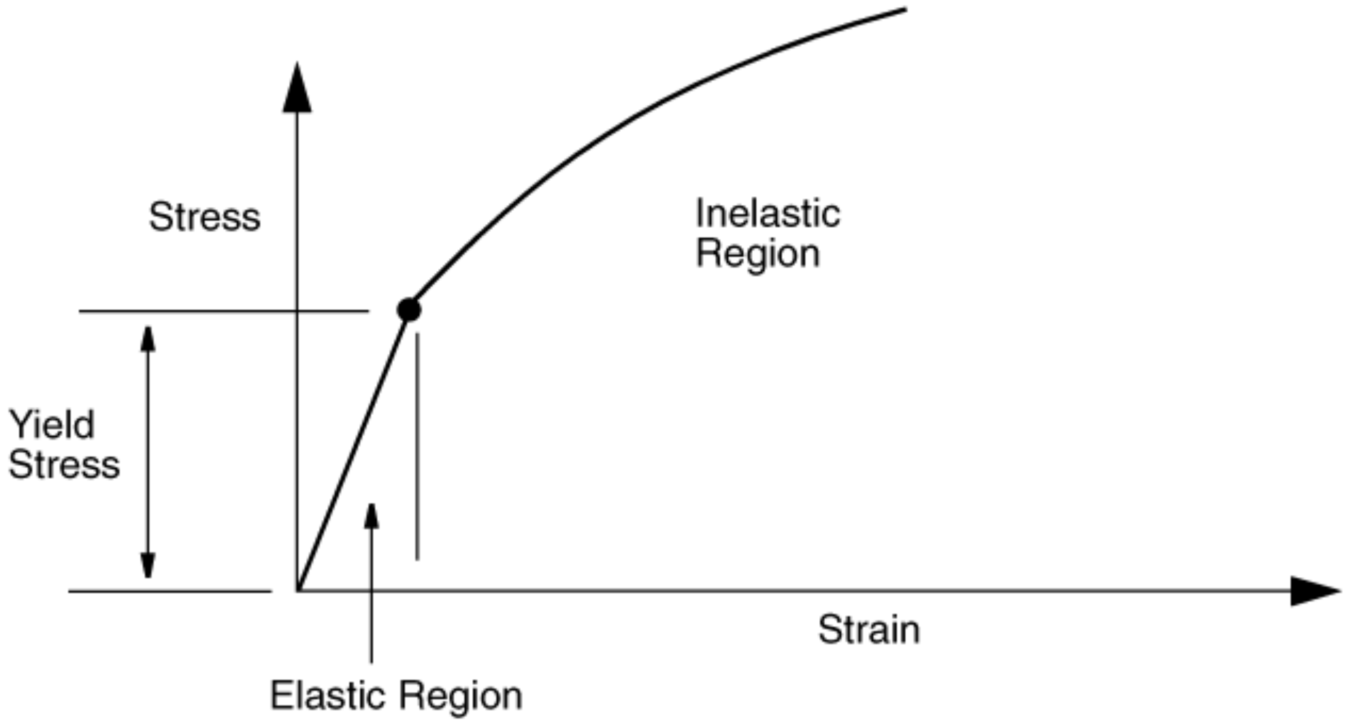
Structural Properties - Plastic





Plastic is NOT incompressible.

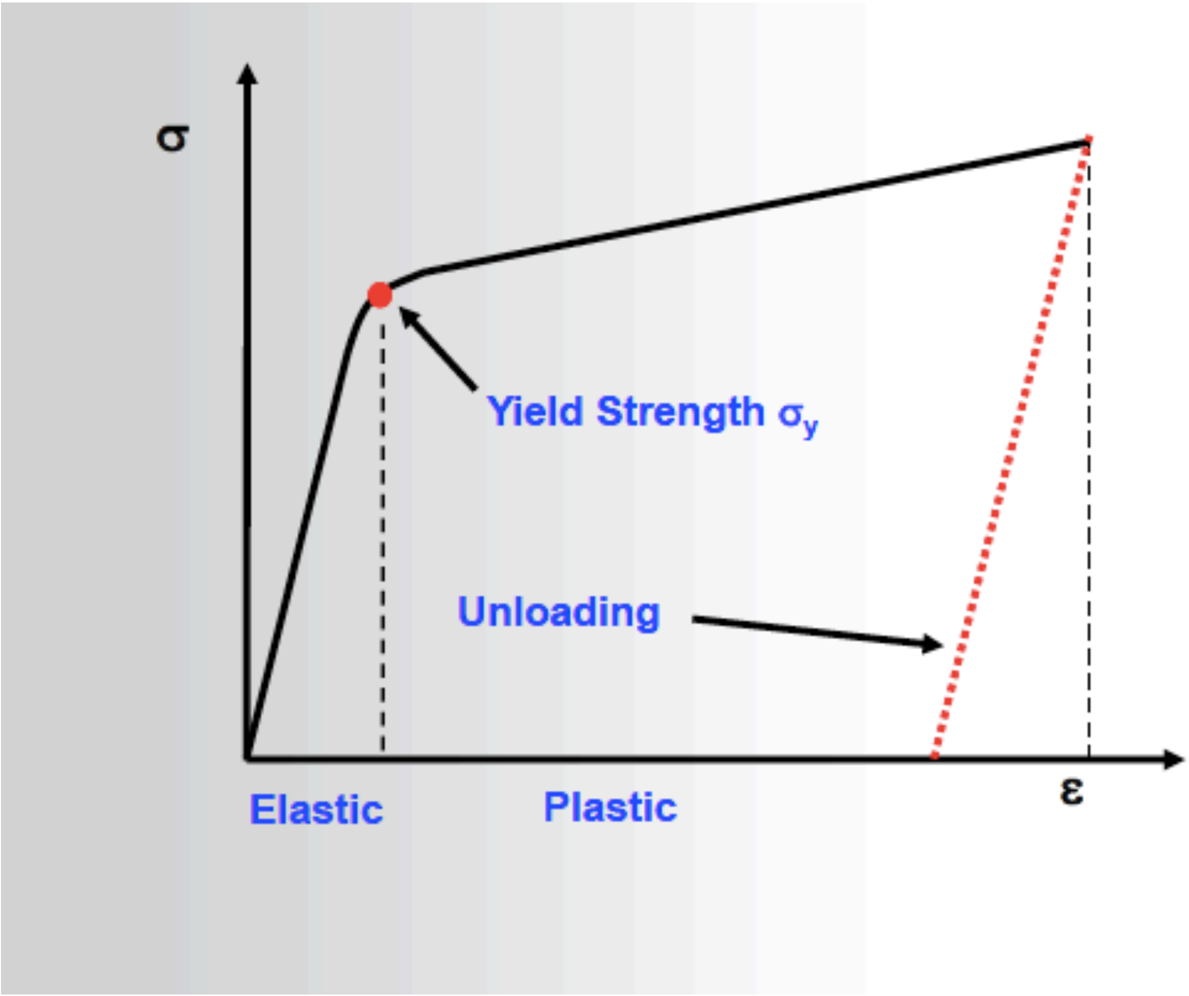
Plastic



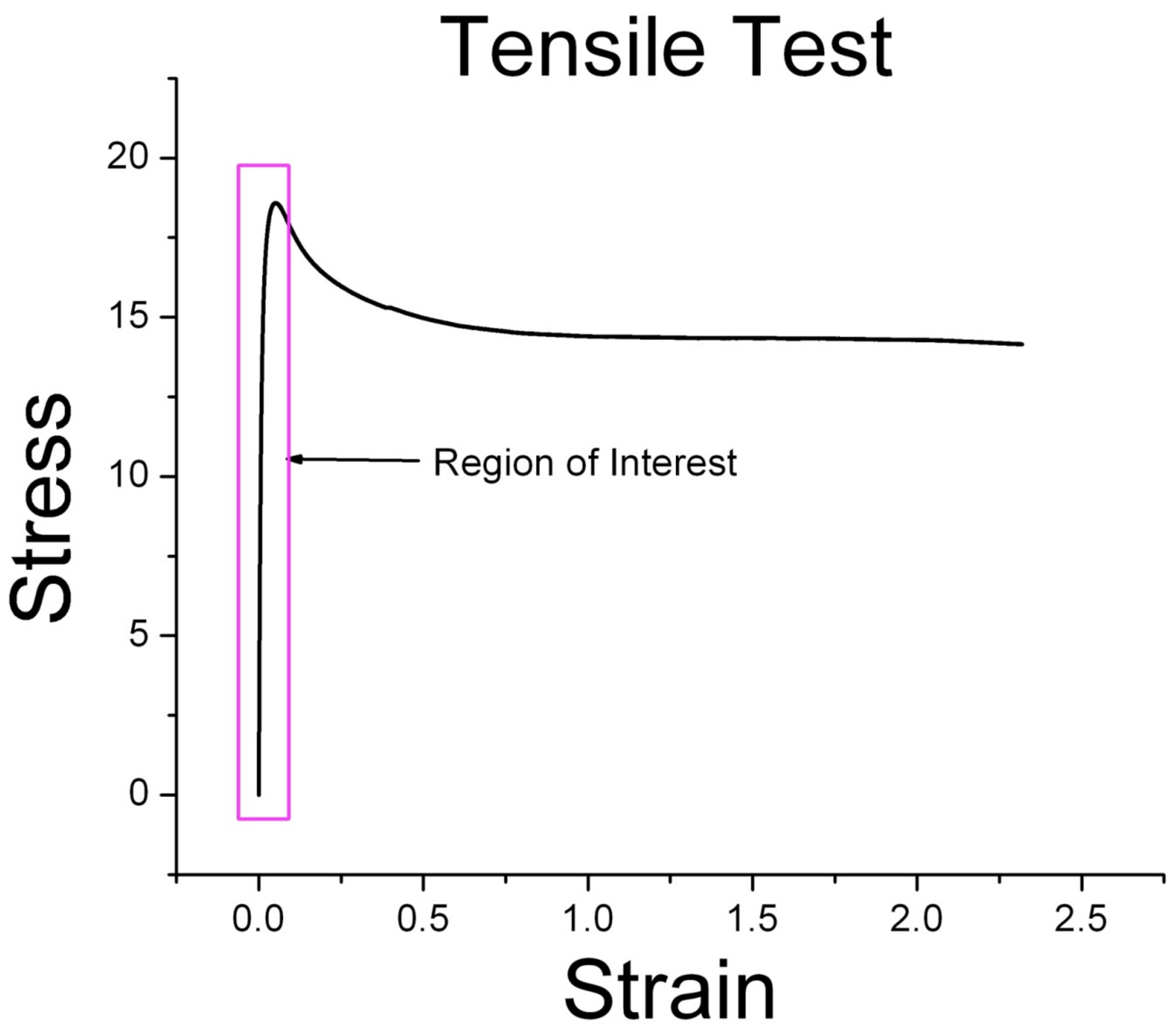
Note: Stress and strain are total quantities.

Plastic

(small deformation plasticity)

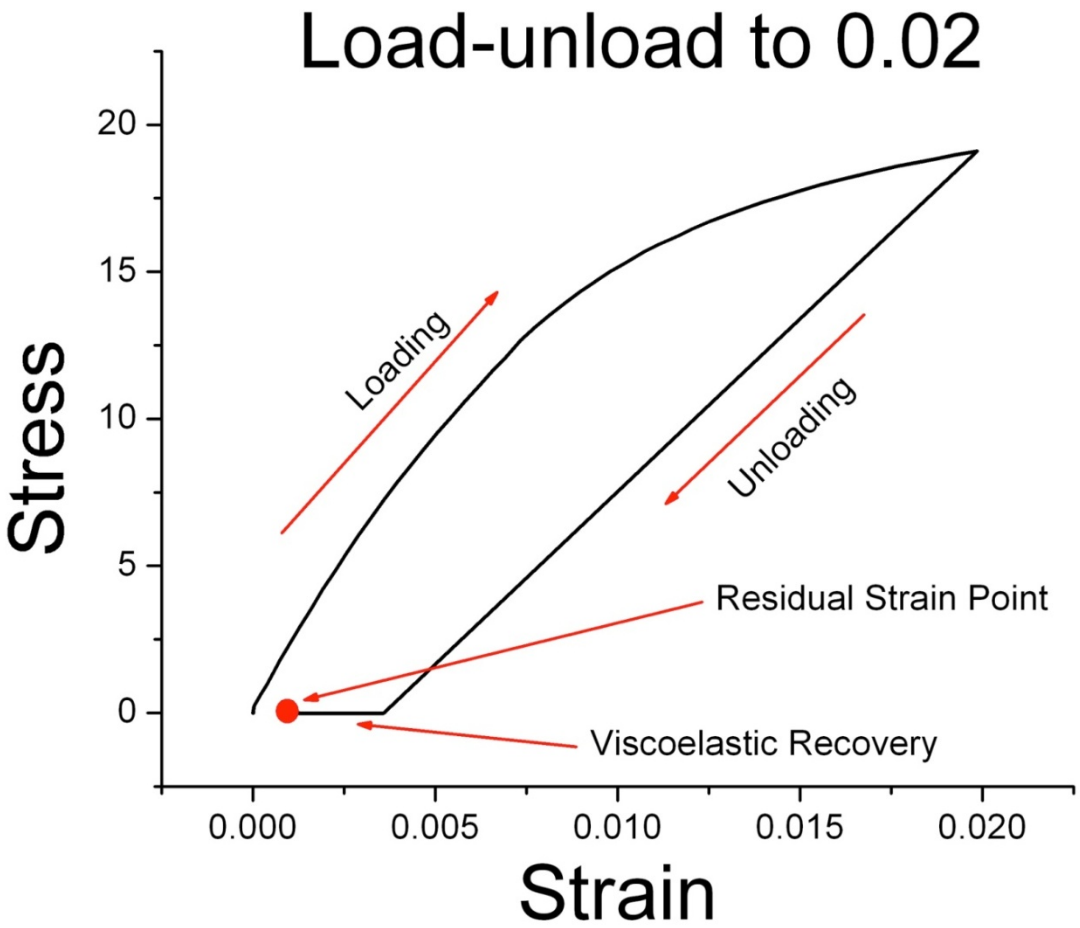


Plastic

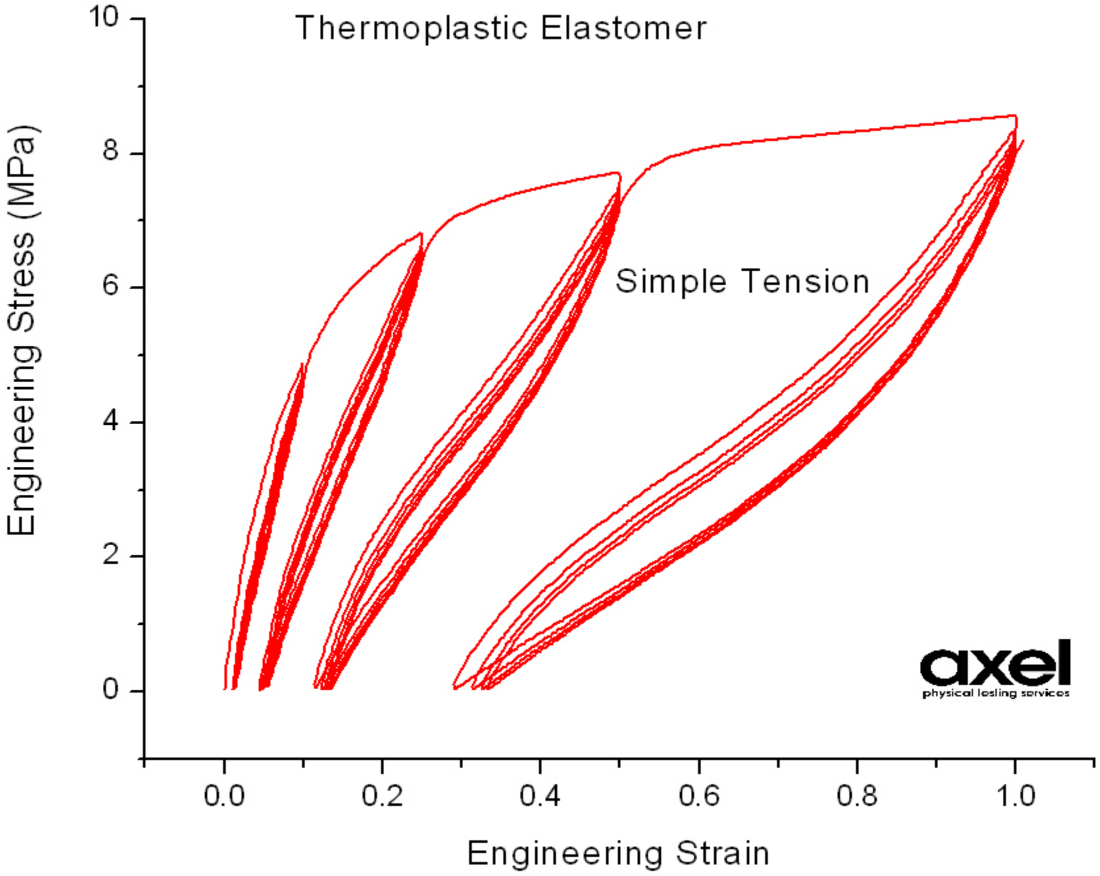

Tensile Test
20
15
10
5
0
Stress
0.0
0.5
1.0
1.5
2.0
2.5
Strain
Region of Interest

Plastic

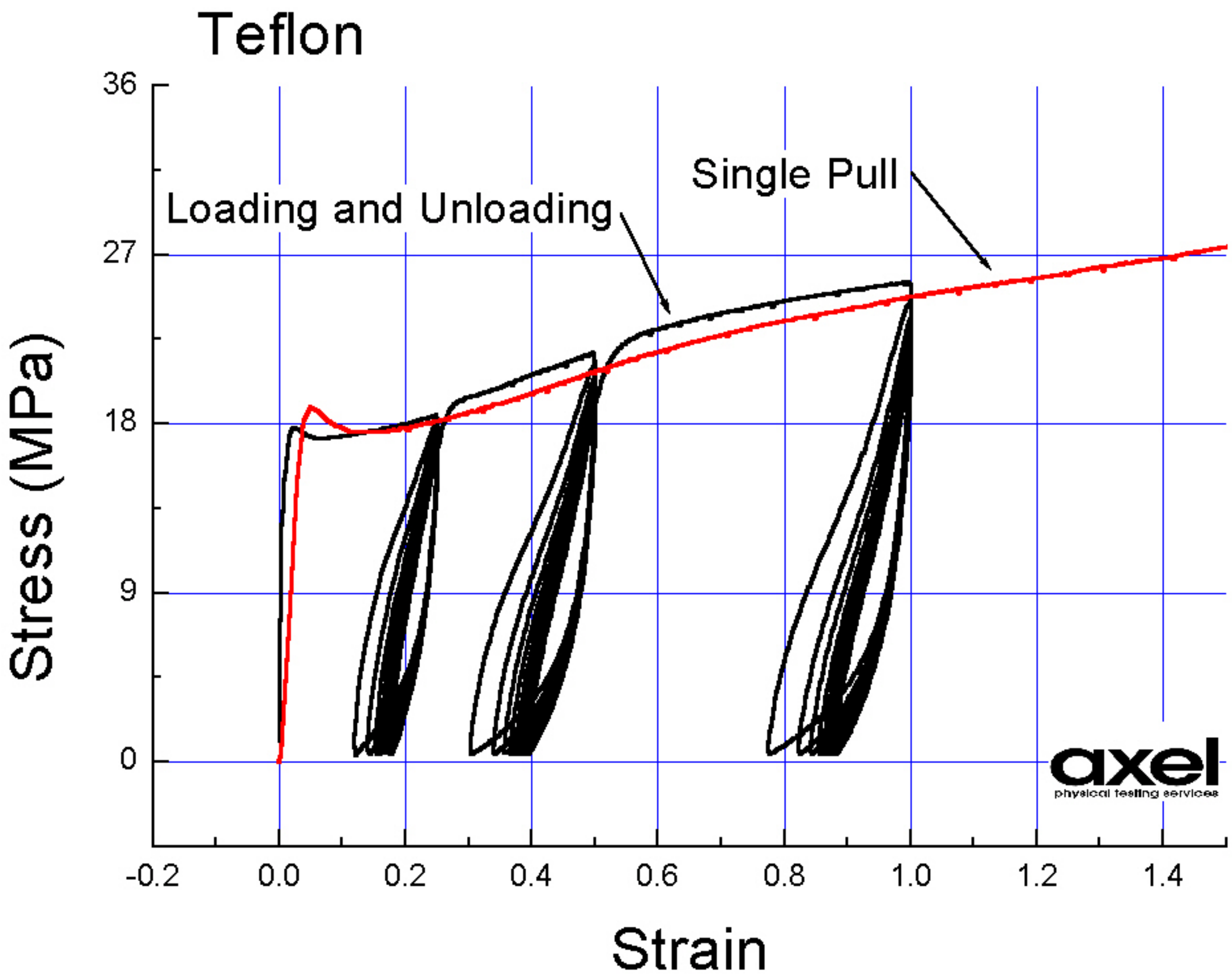
- Modulus is Unclear
- Yield is Unclear
- Load = Unload?
- Set



Thermoplastic Elastomers



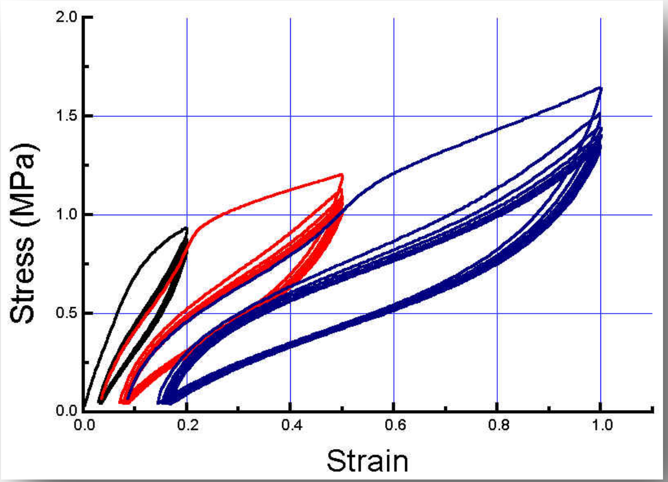
Teflon



Teflon
Loading and Unloading
Single Pull
Stress (MPa)
Strain
36
27
18
9
0
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
axel
physical testing services

Nonlinear Elasticity with Permanent Set

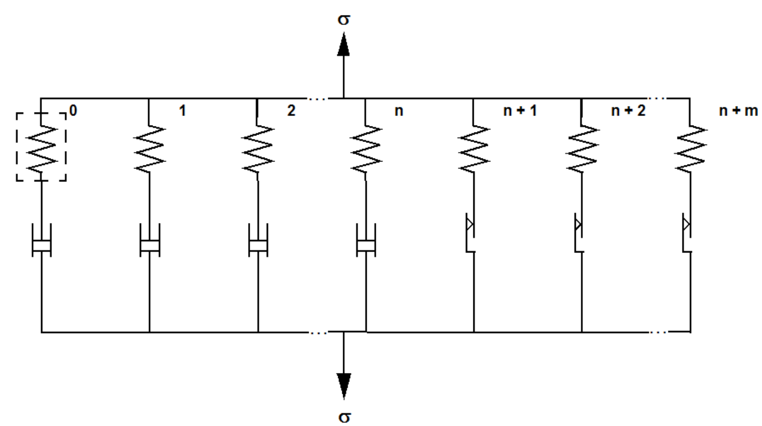
- Parallel Rheological Framework - Behavior Supported
- Nonlinear Elasticity
- Viscoelastic
- Plasticity
- Damage



This Slide is Borrowed from MSC

Parallel Rheological Framework (PRF)

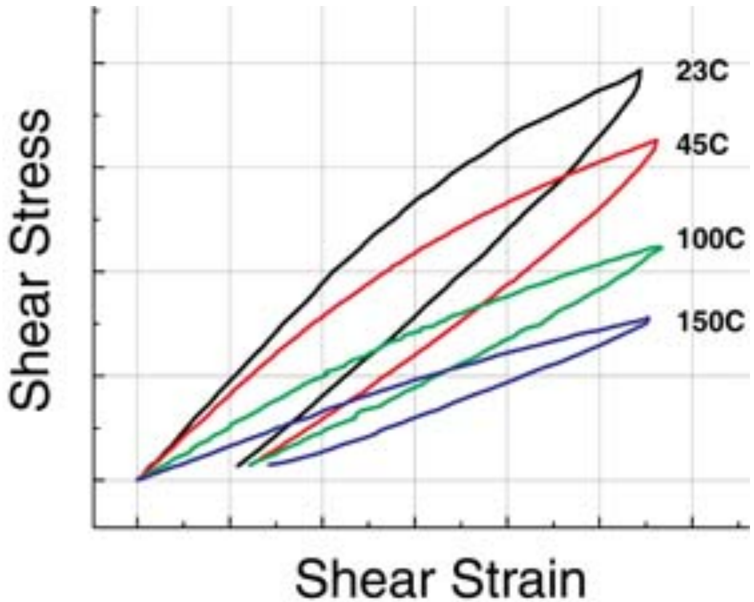
- Primary Network (0)
  - Mooney
  - Ogden
  - Gent
  - Arruda-Boyce
  - Foam
  - Isotropic
- Viscoelastic (1 to n) – Visco Hype
  - Arruda-Boyce
- Plasticity (n+1 to m) – Perm Set
  - Ogden
  - Arruda-Boyce
  - Isotropic

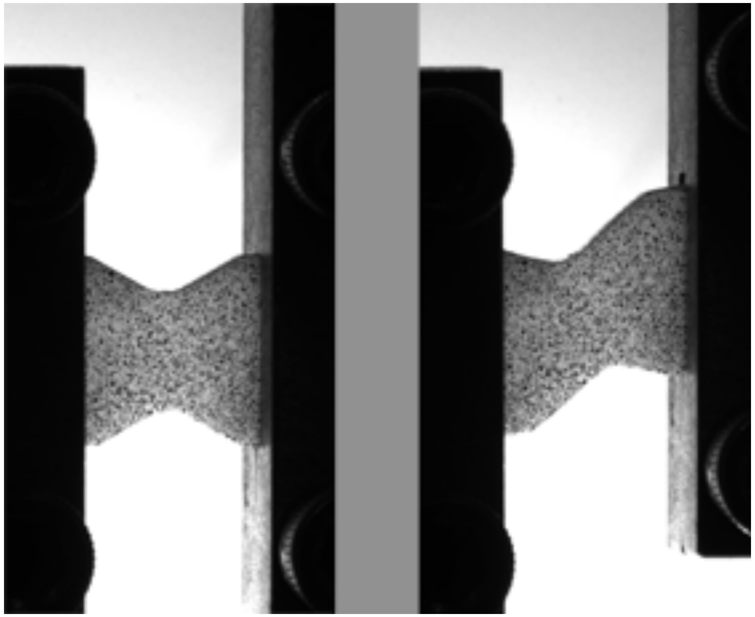


This Slide is Borrowed from MSC

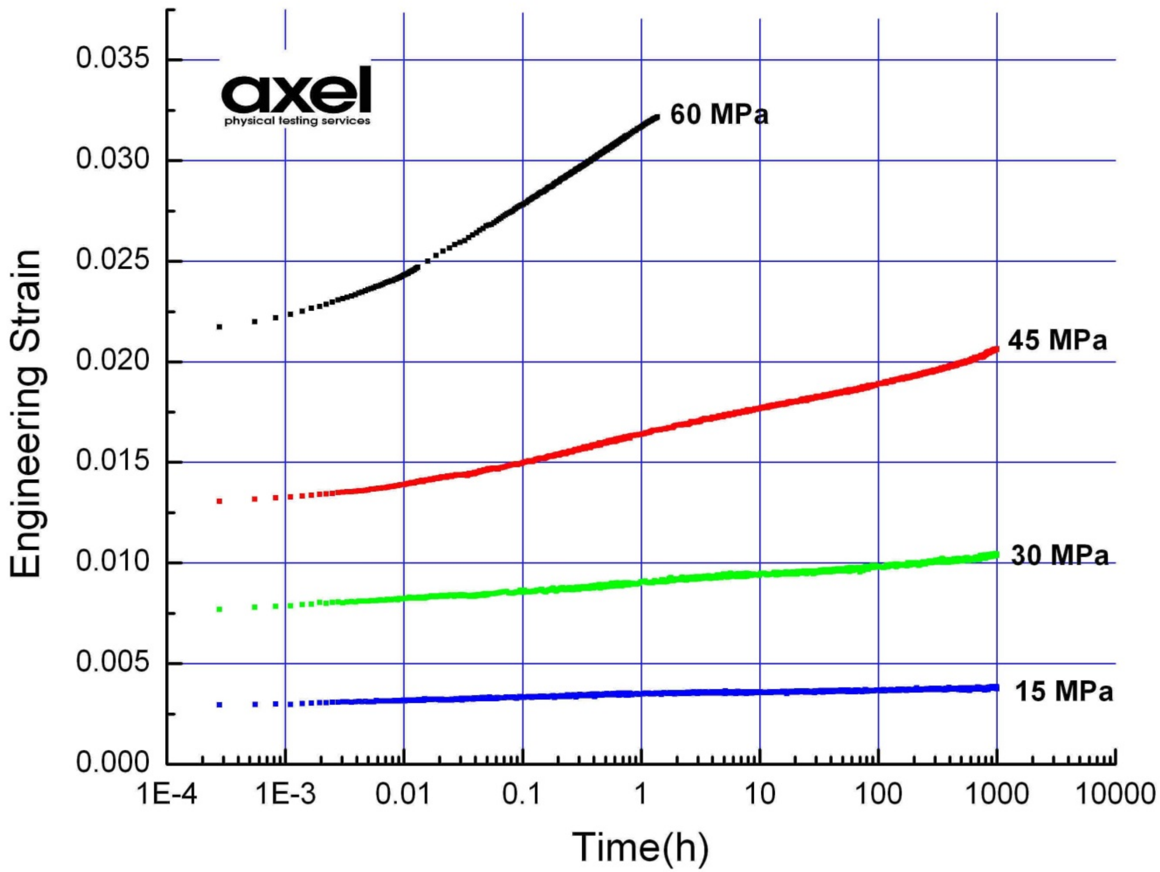
Simple Shear

1. Additional Strain State
2. Using DIC Strain Measuring

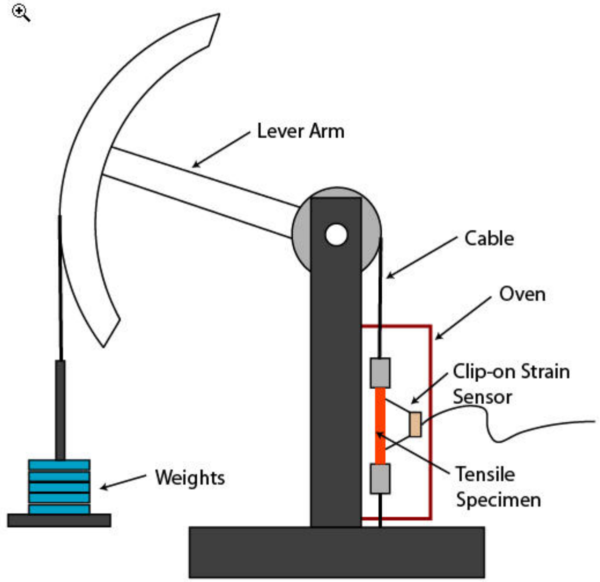




Long Term Creep

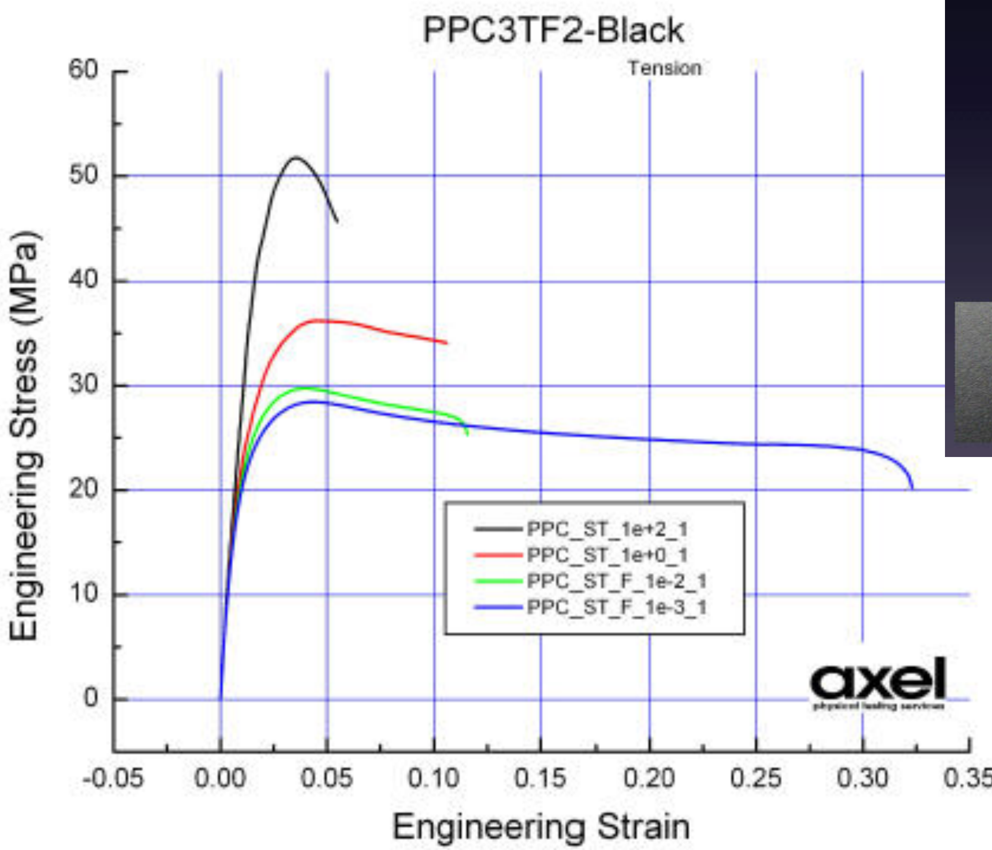


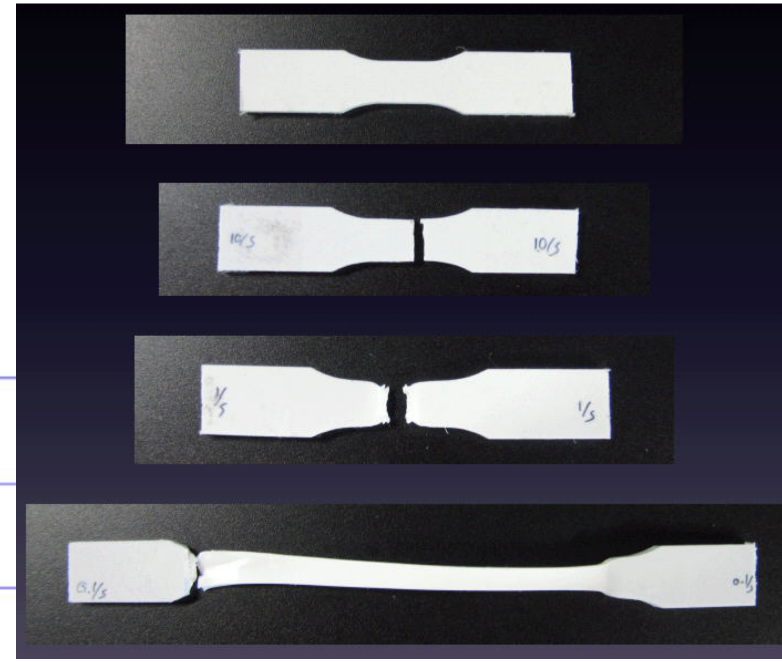
Plastic



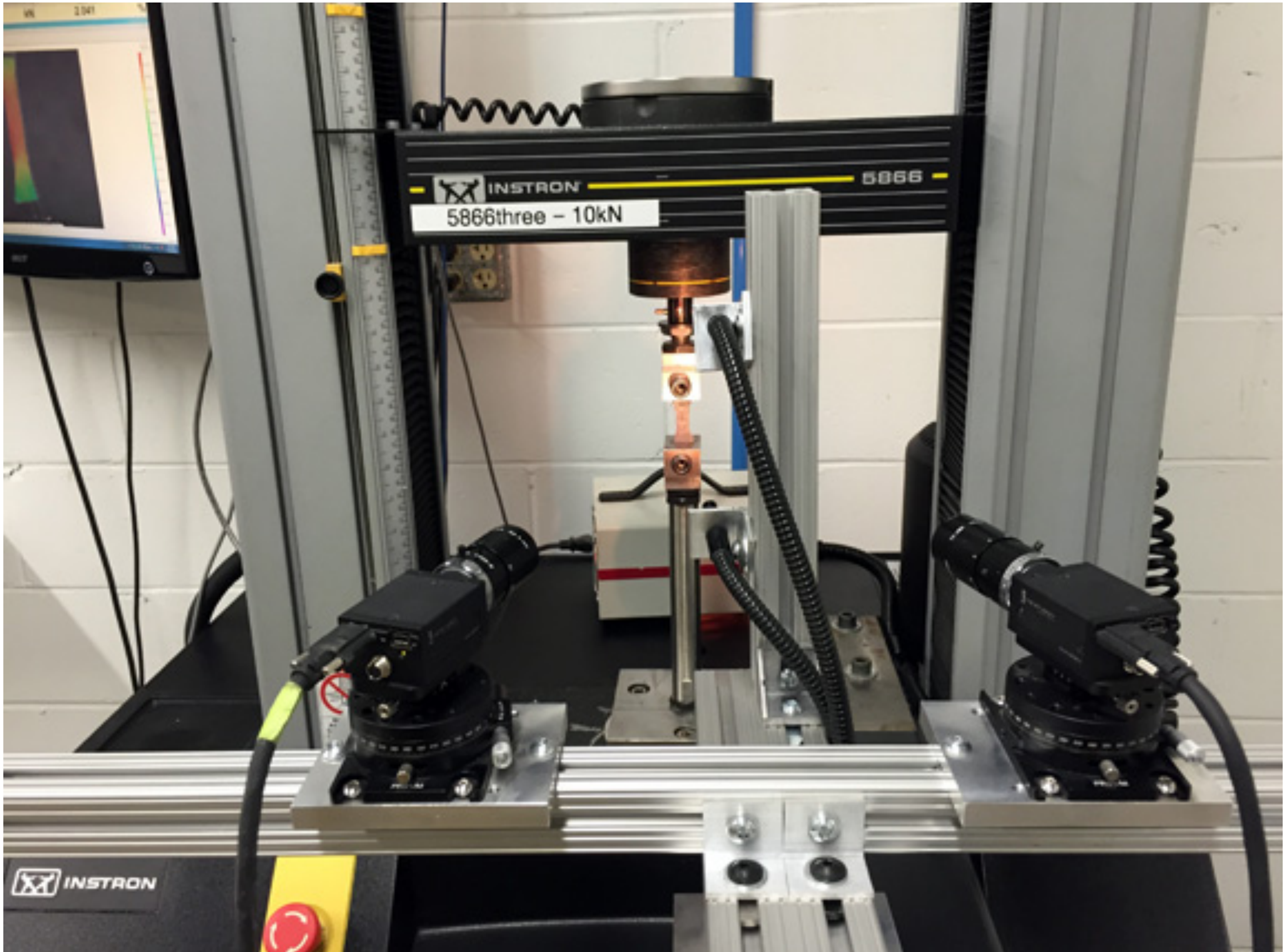
- Long Term Creep Experiments
  - Often Required for Metal Replacement Applications
  - Structural Applications May Require a Range of Stress Levels and Temperatures

Plastic Rates

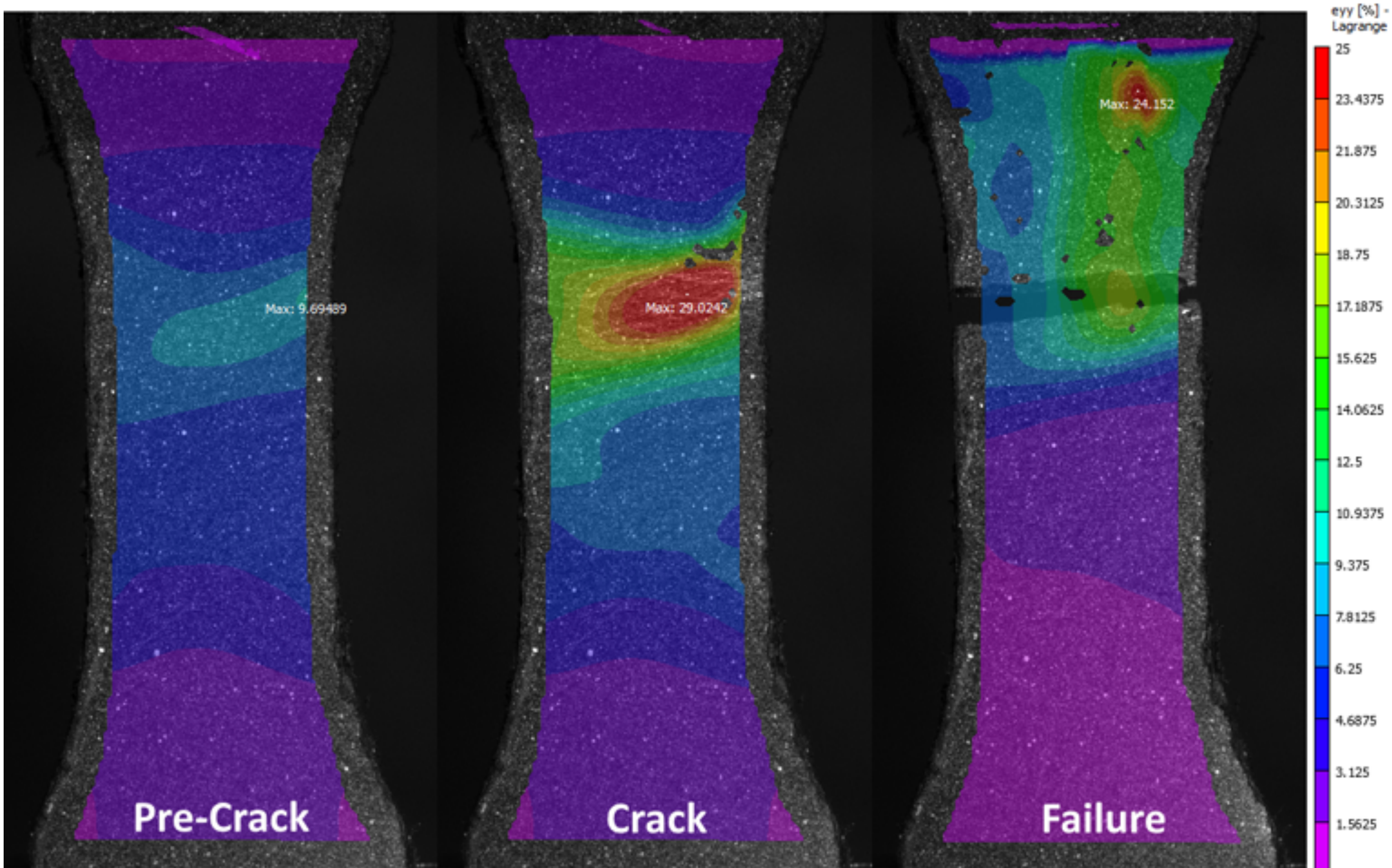




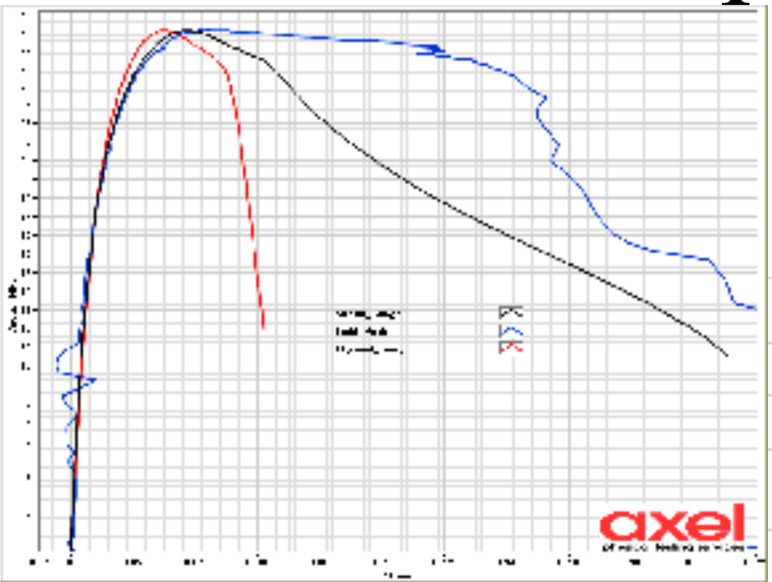
Structural Properties

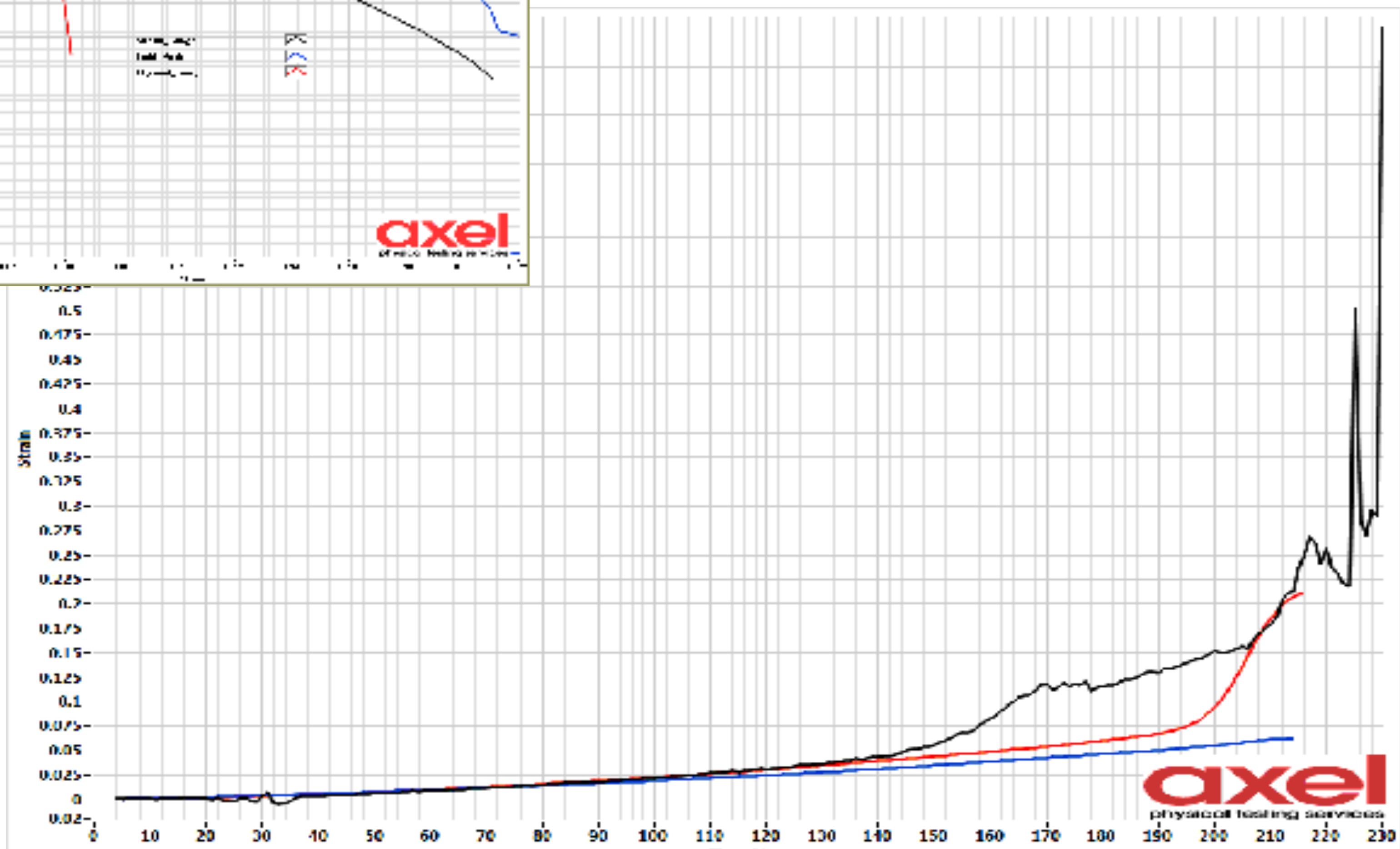


Structural Properties

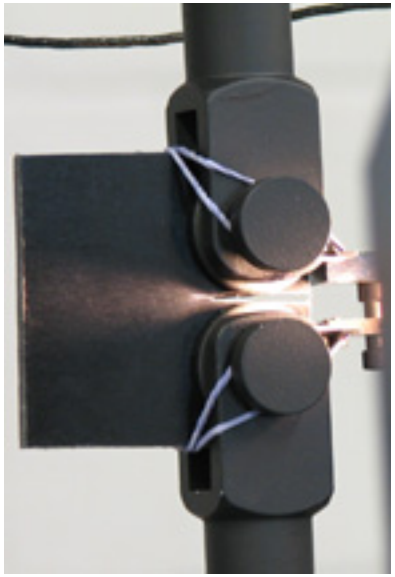


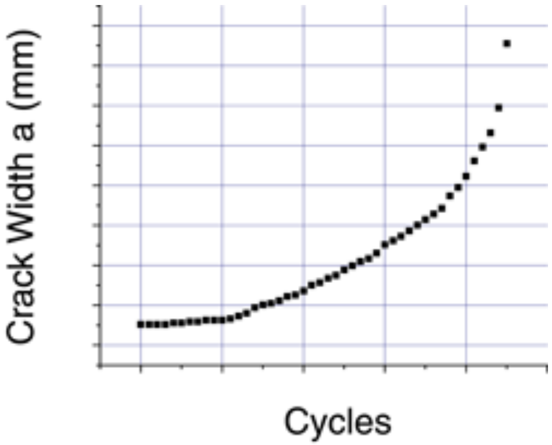
Structural Properties

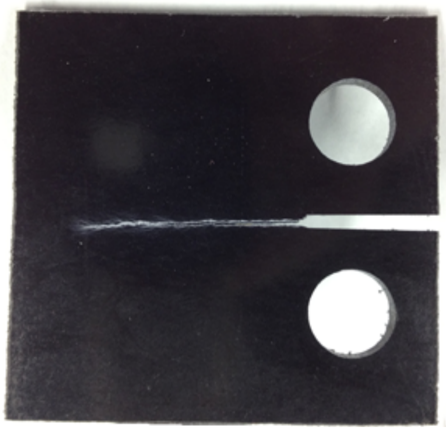




Fracture in Plastic

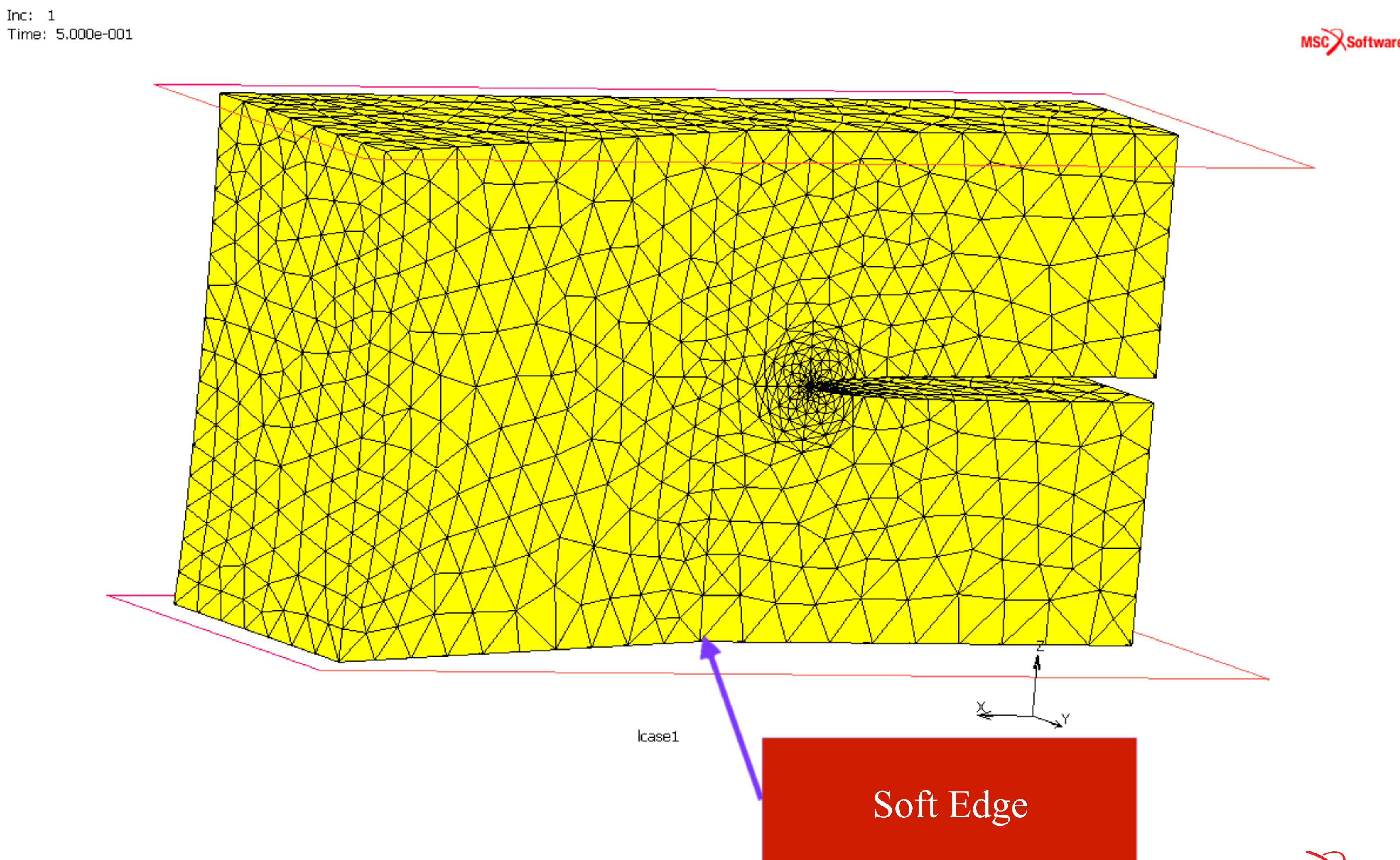




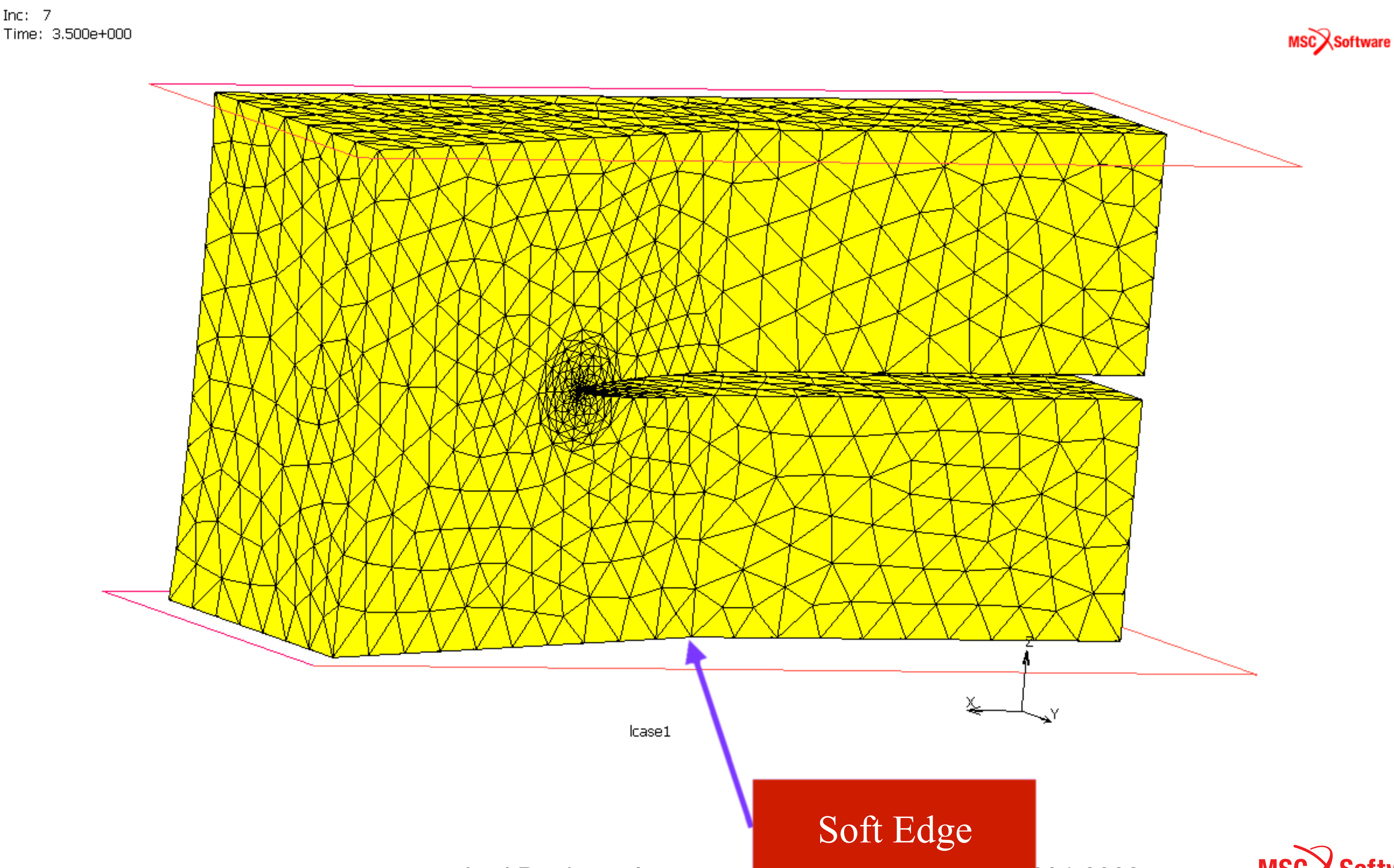


This Slide is Borrowed from MSC

Soft Edge - Initial Crack

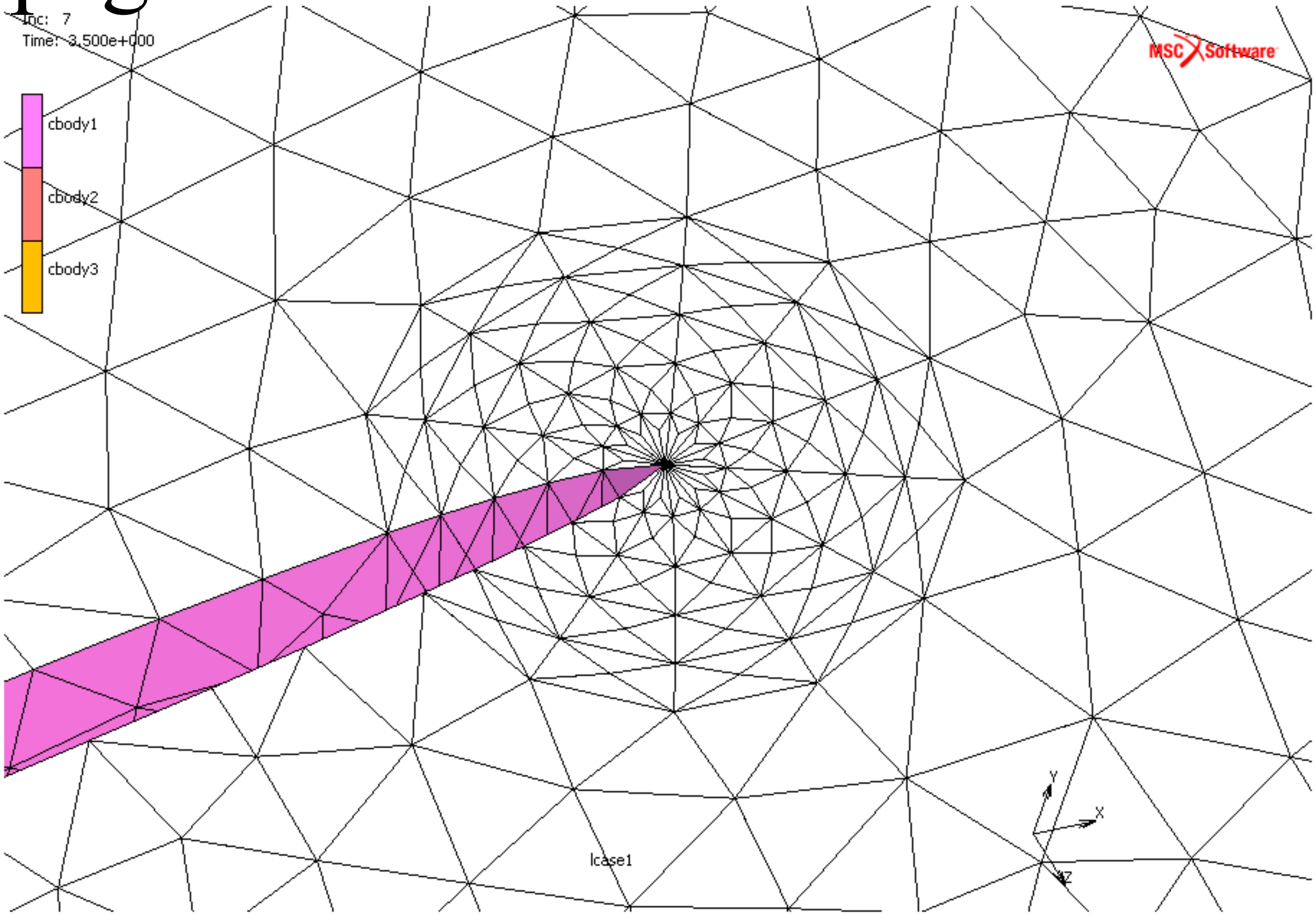


Soft Edge - Crack Propagation



This Slide is Borrowed from MSC

Focused Mesh at Crack Tip after Crack Propagation



In Summary

- Marc has Great Material Models
- Understand the General Behavior of Material
- Capture Only what is Needed

Thank you!

... *Kurt*

• kurt@axelproducts.com