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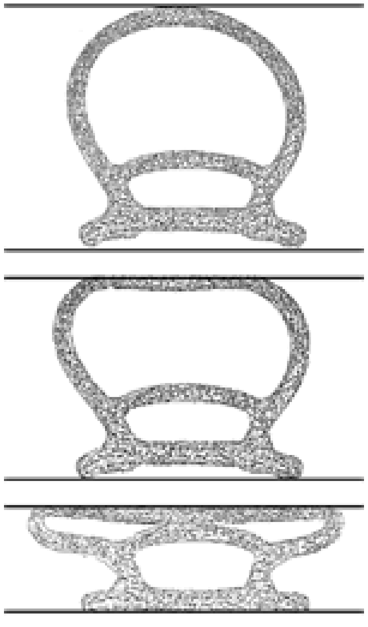
MSC Elastomers Seminar

Some Things About Elastomers



Kurt Miller, Axel Products, Inc.
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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
- Fabric Characterization
- Wire Testing
- Component Tests
- Durability and Crack Growth
- Long Term Creep and Stress Relaxation Tests

Technical Downloads

Popular downloads.

- Testing Elastomers for Hyperelastic Models (PDF)
- Testing Plastics for FEA (PDF)
- Testing at High Strain Rates (PDF)
- Measuring the Shear Properties of Plastic Materials for Finite Element Analysis (PDF)
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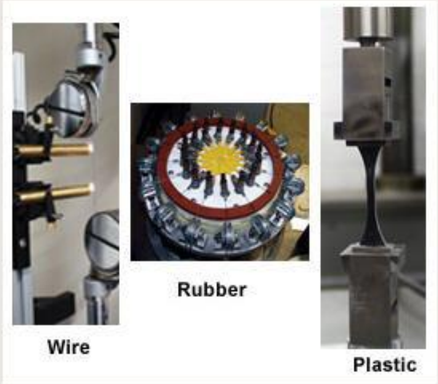
- Elastomer Rate-dependence: A Testing and Material Modeling Methodology (PDF)



Training Courses

SIMULIA

Testing and Analysis of Elastomers with Abaqus

- March 27-29, 2012

Testing and Analysis of Plastics with Abaqus

- To be determined

Endurica

Engineering of Durable Elastomeric Structures

- July 17-19, 2012

MSC Software

Testing and Analysis of Elastomers with Marc

Your Presenter

Kurt Miller

- Founded Axel Products 1994
- Instron Corporation, 1983-1994
  - Instrument Engineering
  - Applications Laboratory
  - Product Management
  - Systems Business Management
- Cornell University, 1983

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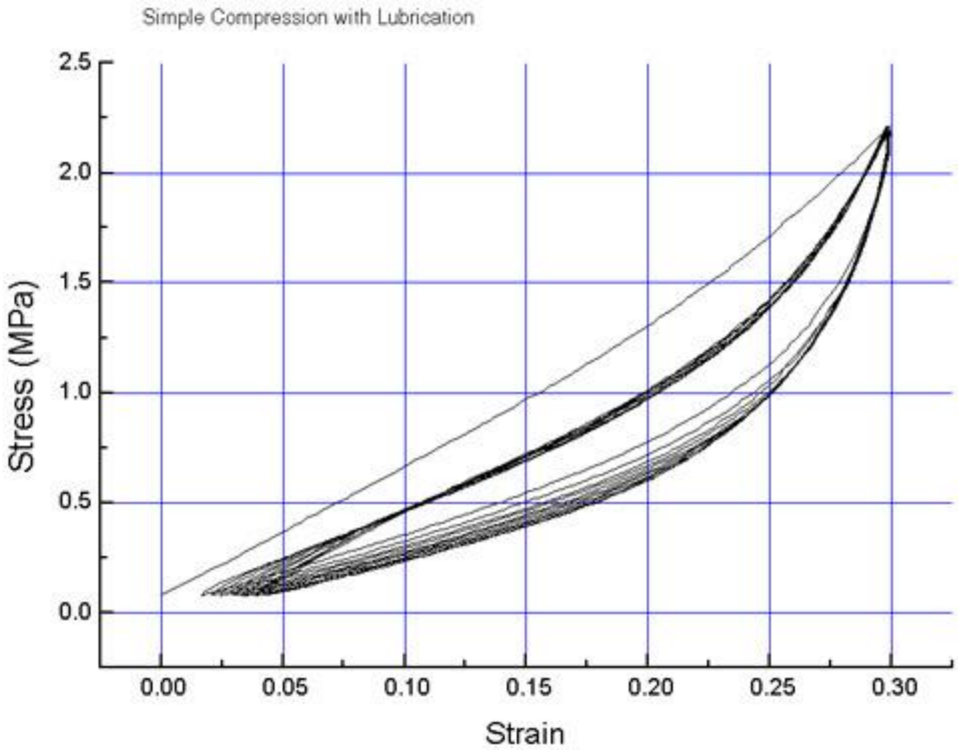
MAR103 - MSC.MARC EXPERIMENTAL ELASTOMER ANALYSIS

Analysis + Testing

Rubber Bands

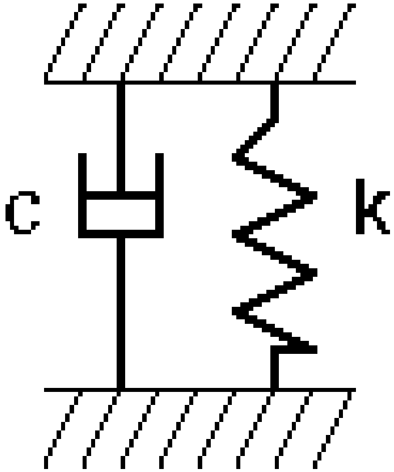
Compression

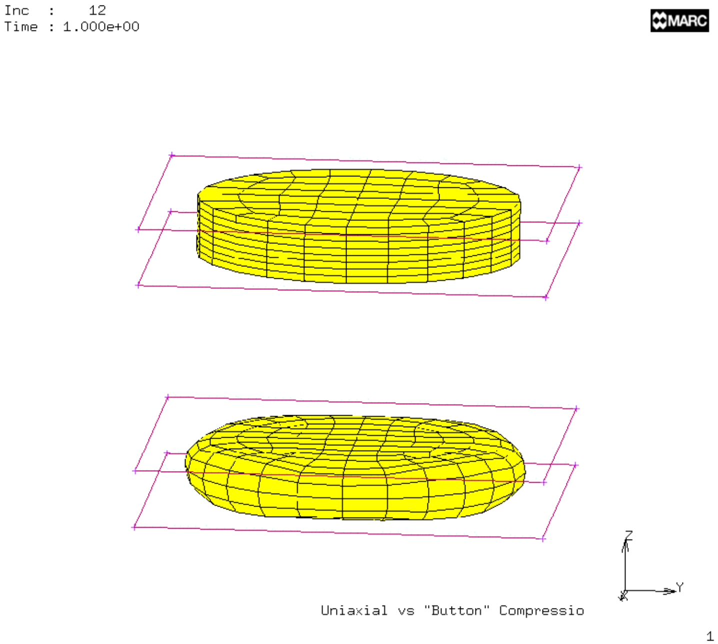
Compression



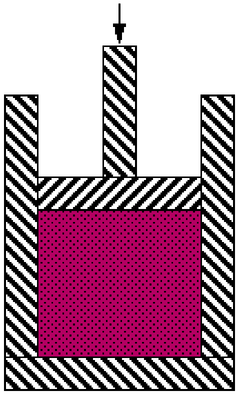
A Spring and a Dashpot?

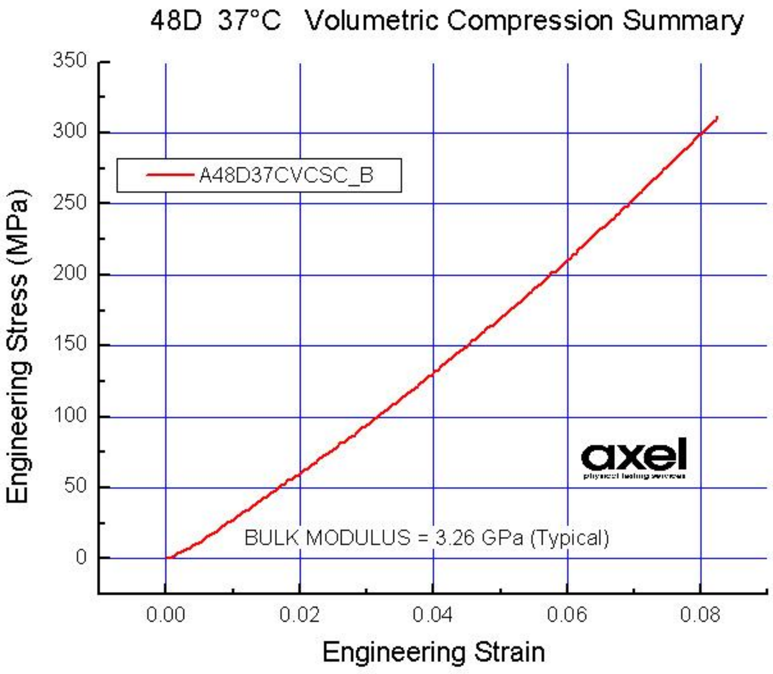
1. Picture of Spring and dashpot



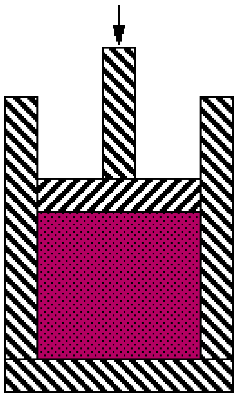


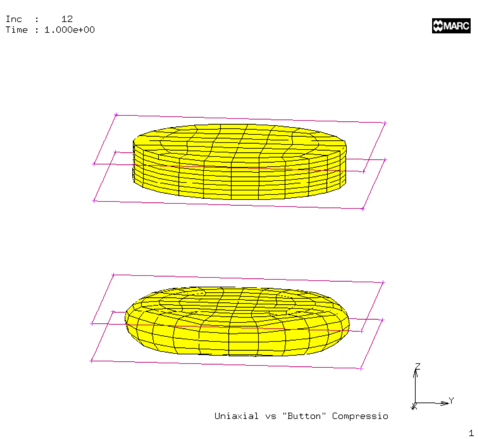
Volumetric Compression

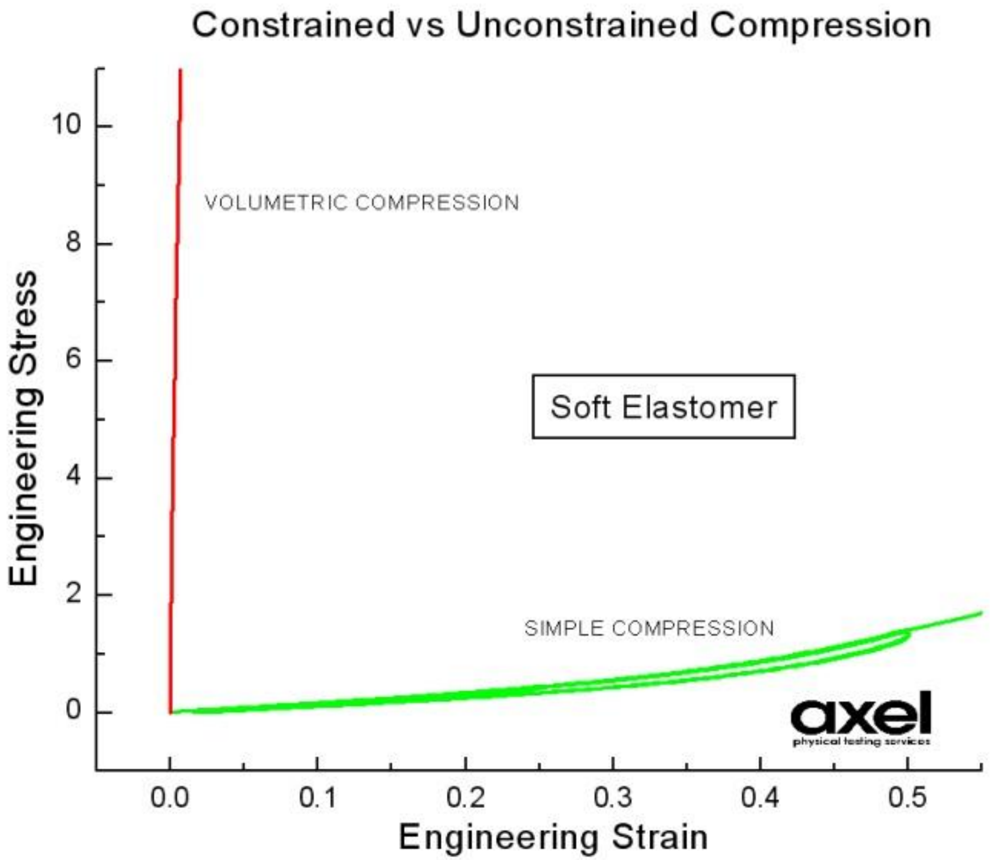




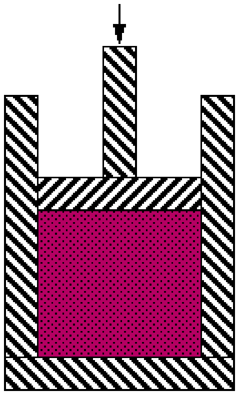
What does Incompressible Mean?







Incompressibility



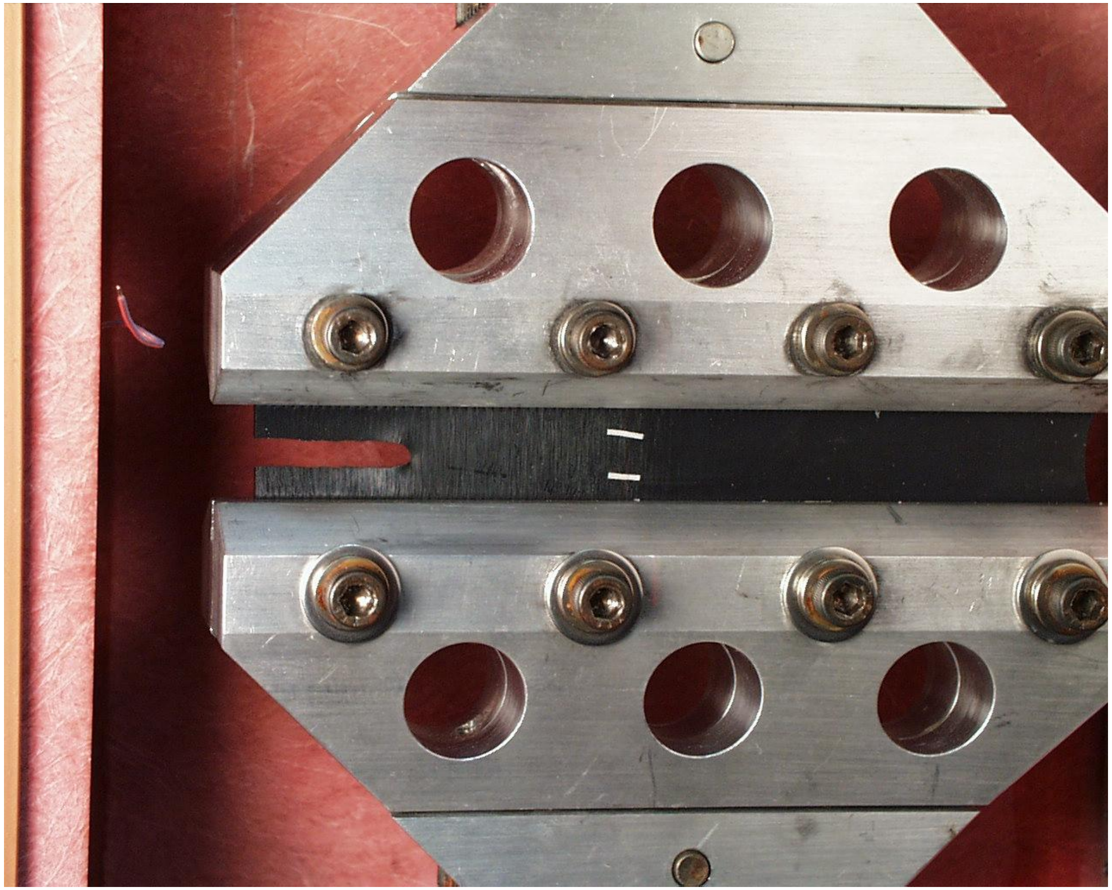
Not a spring and dashpot

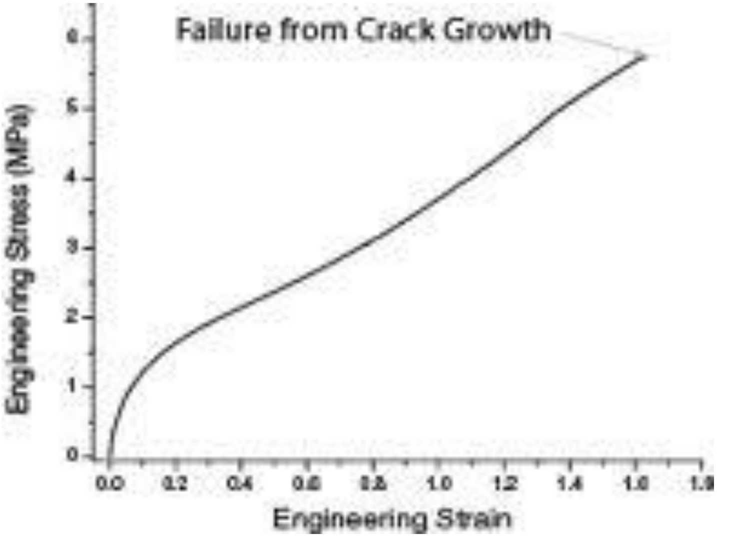
Volumetric Compression

Not a spring and dashpot

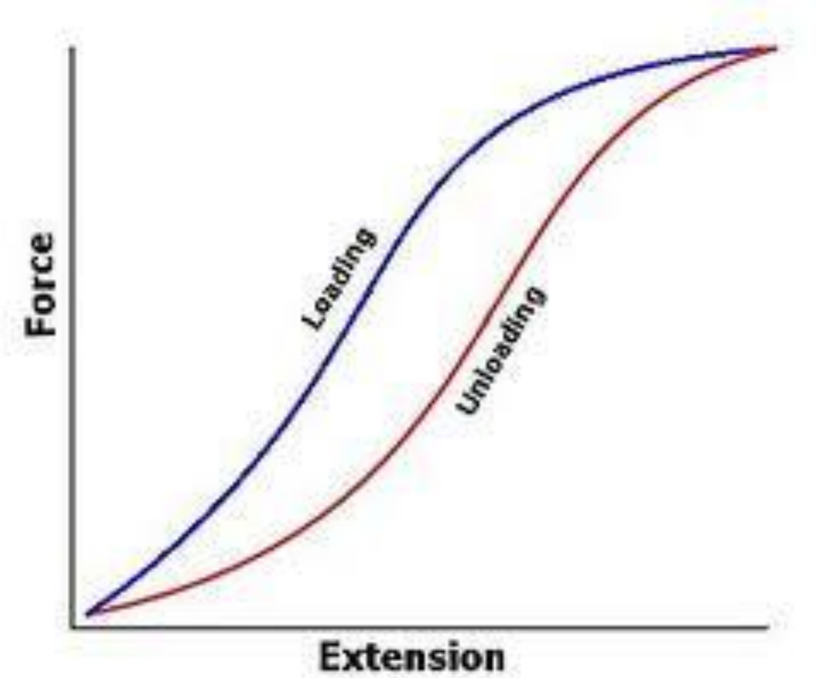
Confinement can be Significant

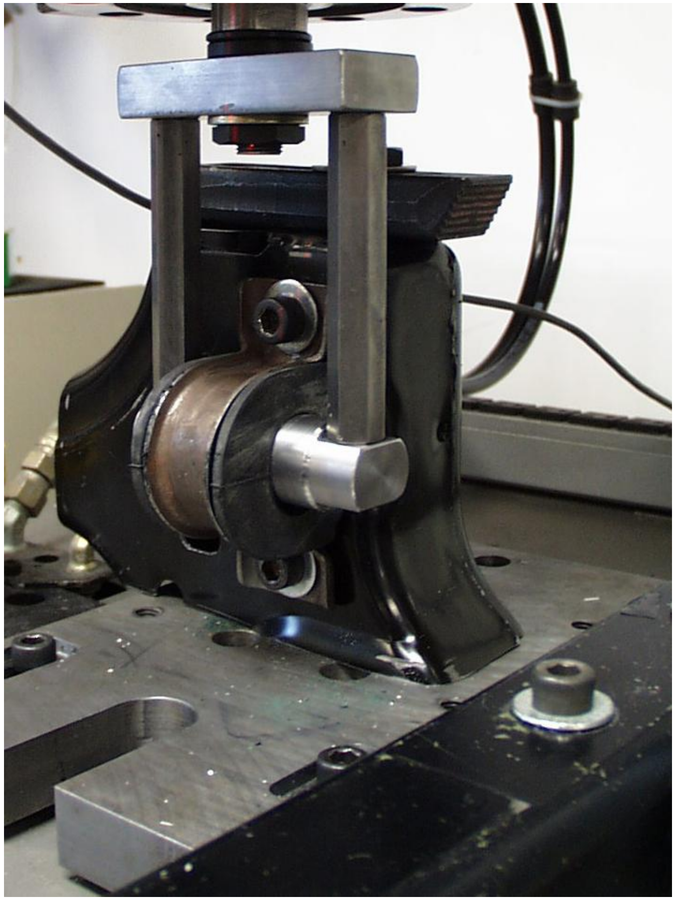
Tough, Resist Tearing



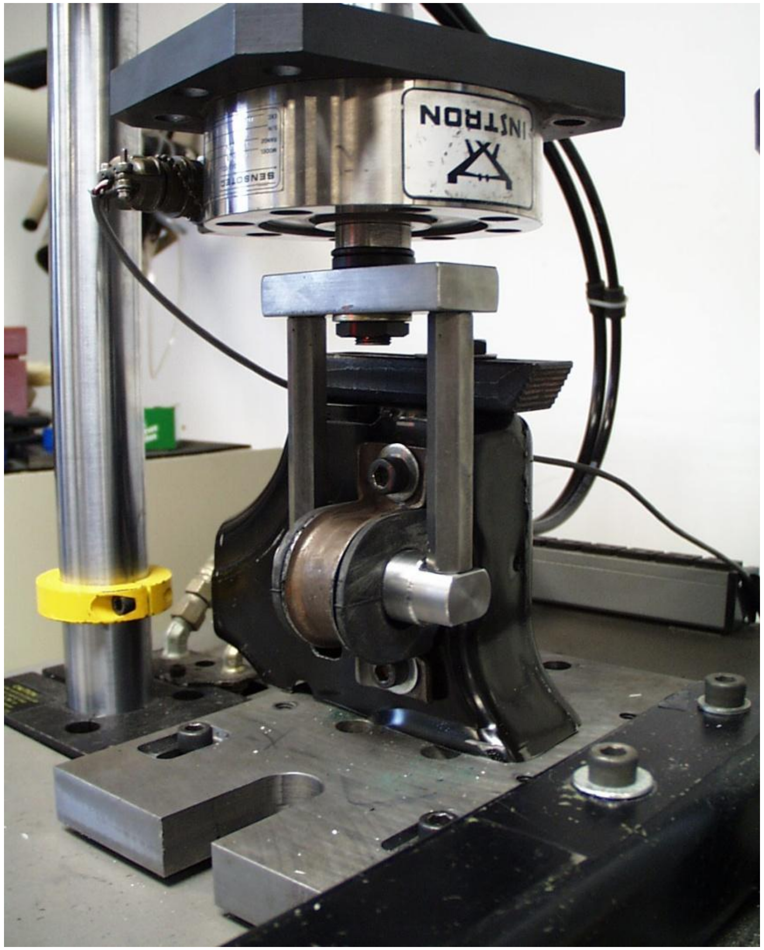


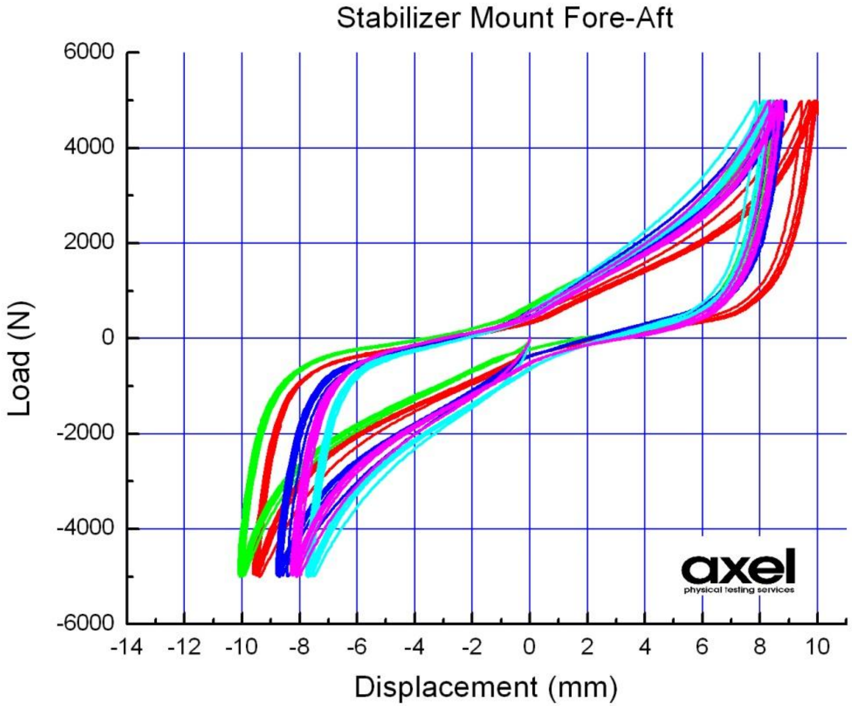
Energy Absorbing





Make Heat, Insulate





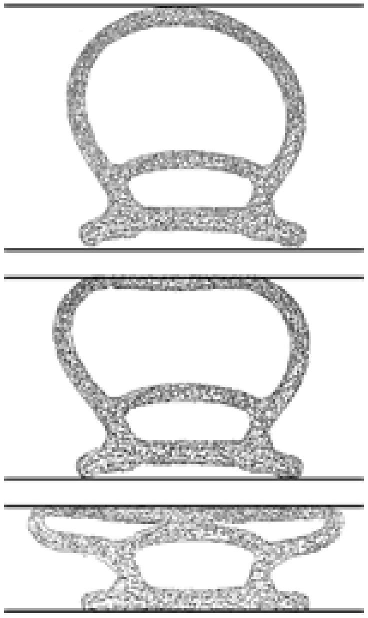
In Summary

- Incompressibility Matters beyond Intuition
- NOT a Spring and Dashpot
- Great advantages can be had
- Can be Tough
- Can Absorb Energy

Thank you for now!

MSC Elastomers Seminar

Measuring Properties for Analysis



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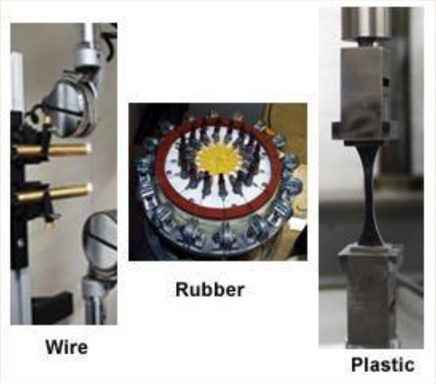

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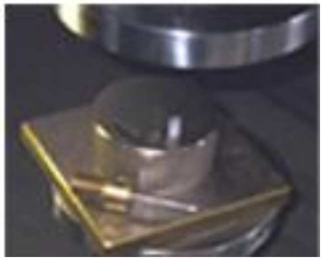


Overview

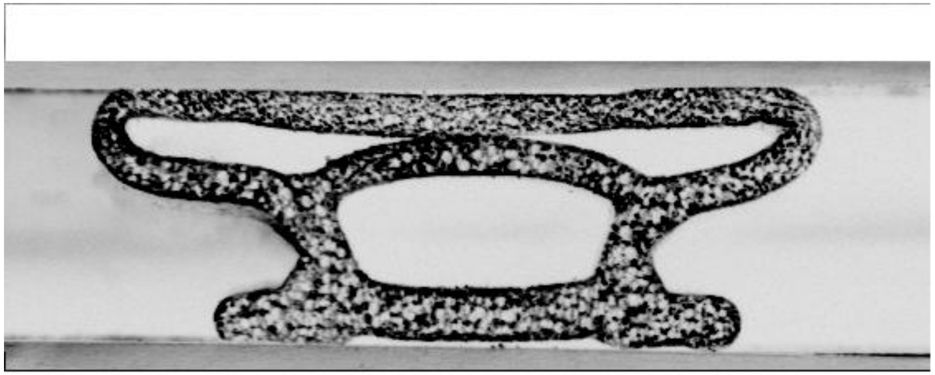
1. General Strategy
2. Basic Hyperelastic
3. Basic Viscoelastic
4. Thermal Effects
5. Dynamic Measurements

A General Strategy

1. Understand the Loading Conditions of the Part
2. Understand the General Behavior of the Materials Involved
3. Select the Material Behaviors Significant to the Simulation Effort
4. Use Existing or Develop Material Models to Describe the Behavior
5. Verify the Performance of the Material Model

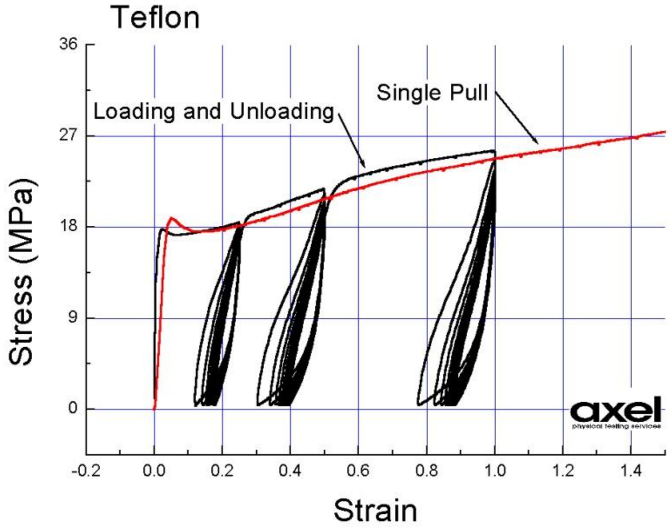
Loading Conditions of the Part

1. Stress and Strain Estimates
2. Thermal Estimates
3. History of the part from Birth to Use



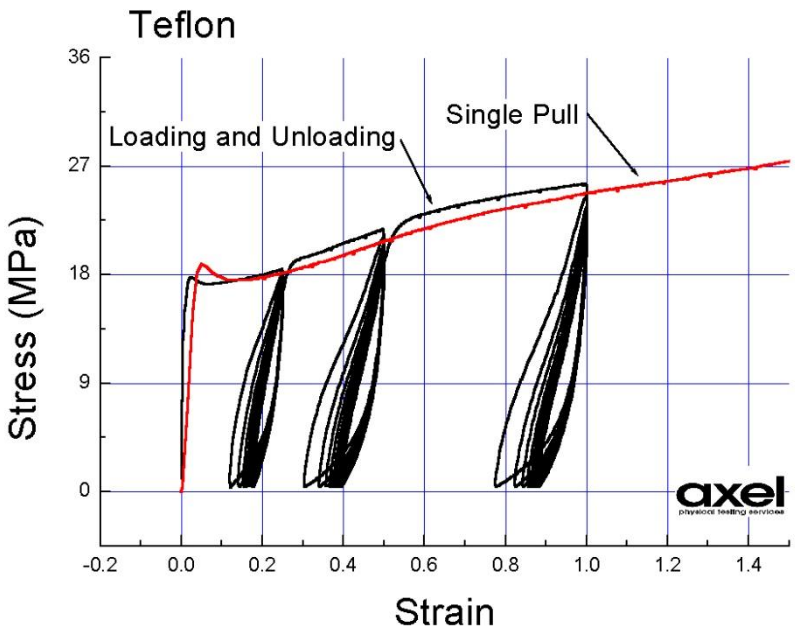
Understand the General Behavior of the Materials Involved

1. Is it elastic?
2. Does it melt?
3. Have we used this stuff before?



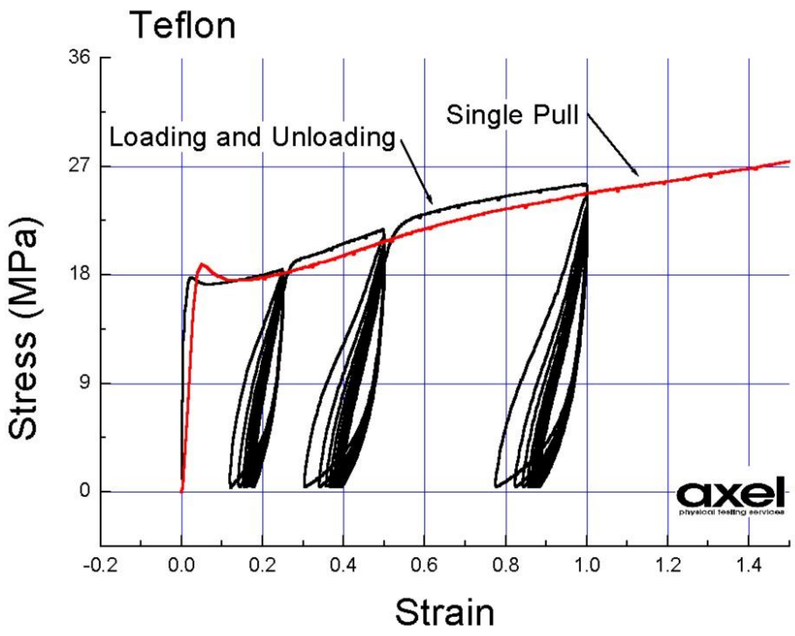
Select the Material Behaviors Significant to the Simulation Effort

1. You can't model it all.
2. Is it really rate sensitive?
3. This requires judgment.



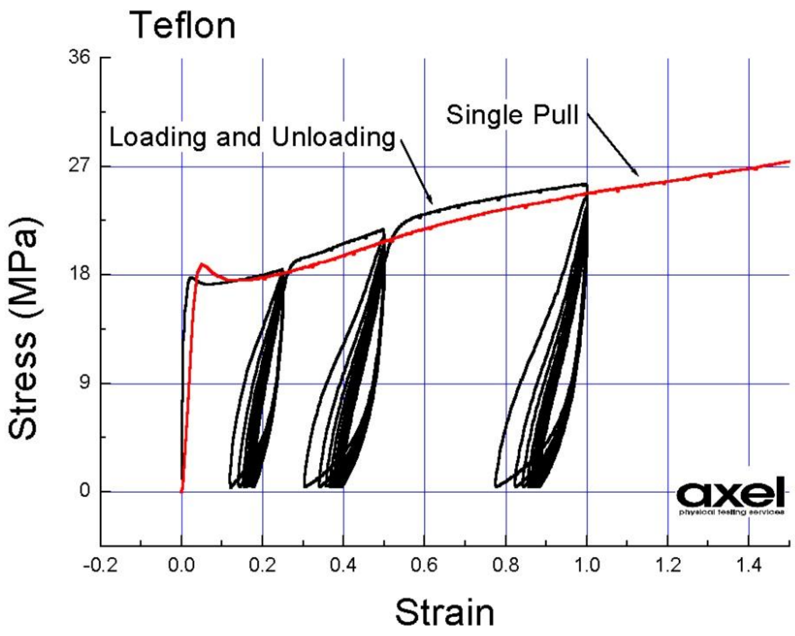
Use Existing or Develop Material Models to Describe the Behavior

1. What material model fits if any?
2. Write a material model of your own.
3. What are the limitations of the model?



Verify the Performance of the Material Model

1. Don’t trust the model.
2. Model back experimental data.
3. Design partial part experiments.

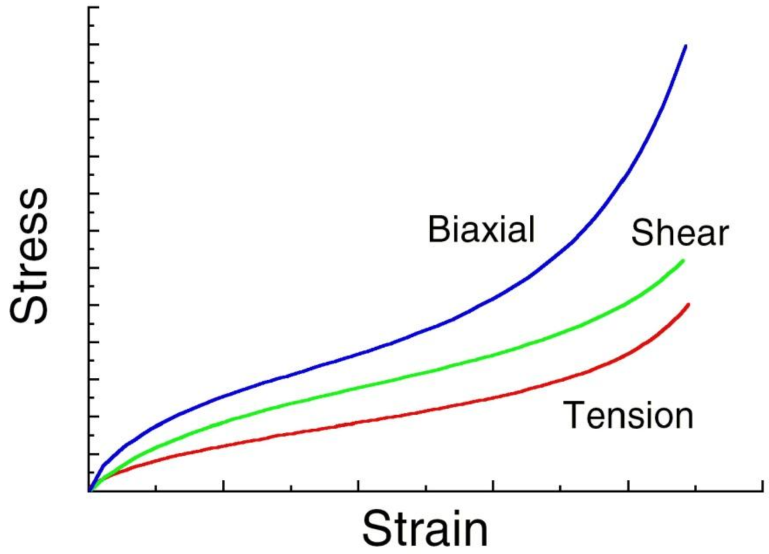


Laboratory Experiments

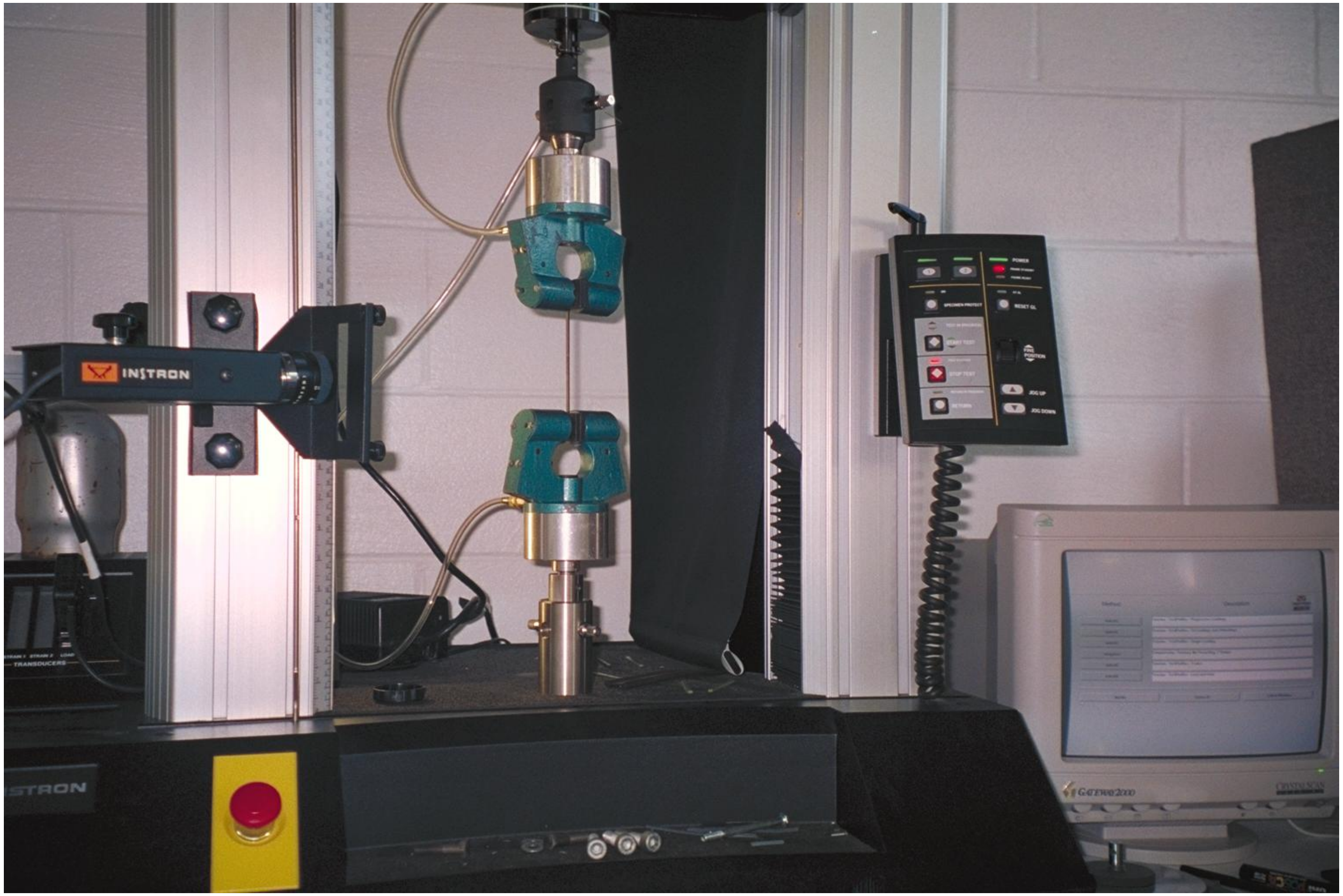
1. Defined by Standards Organizations such as ISO, ASTM or UL Labs
2. Experiments Defined within your Company by Somebody Else, Historical
3. Experiments to Simulate Product In Use
4. Investigative Experiments to Determine Fundamental Material Properties

Basic Hyperelastic

1. Pure States of Strain or Stress
2. Loading Conditions
3. The Right Material



Pure States of Strain or Stress



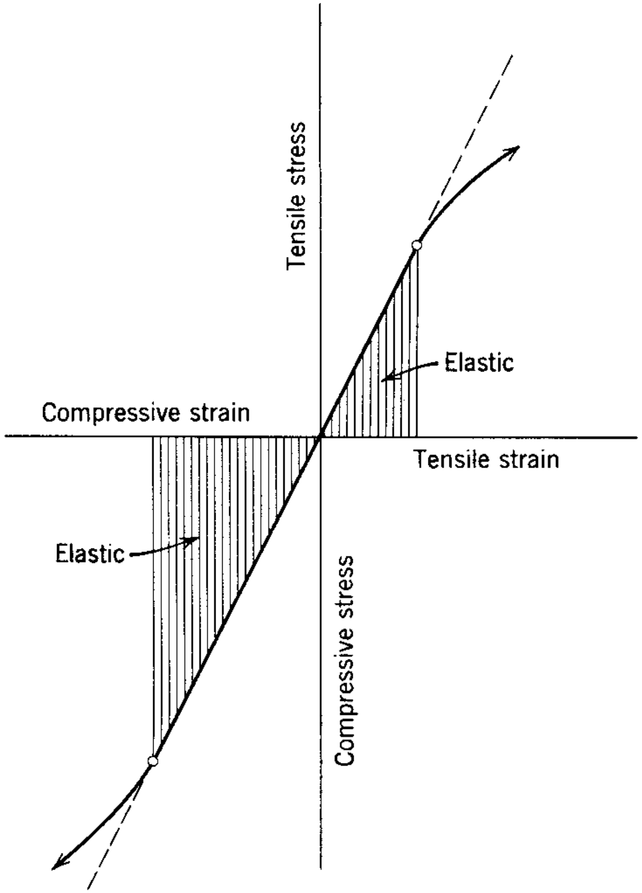
Pure States of Strain or Stress

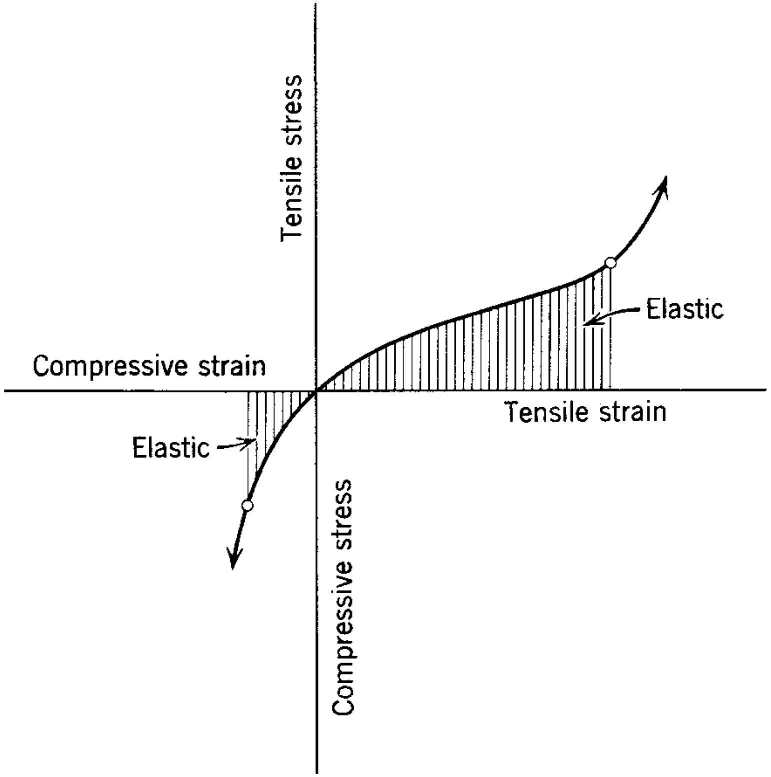
Crystalline Solid

Small elastic strain (.2%)
Plastic yielding
Tension / Comp. Similar

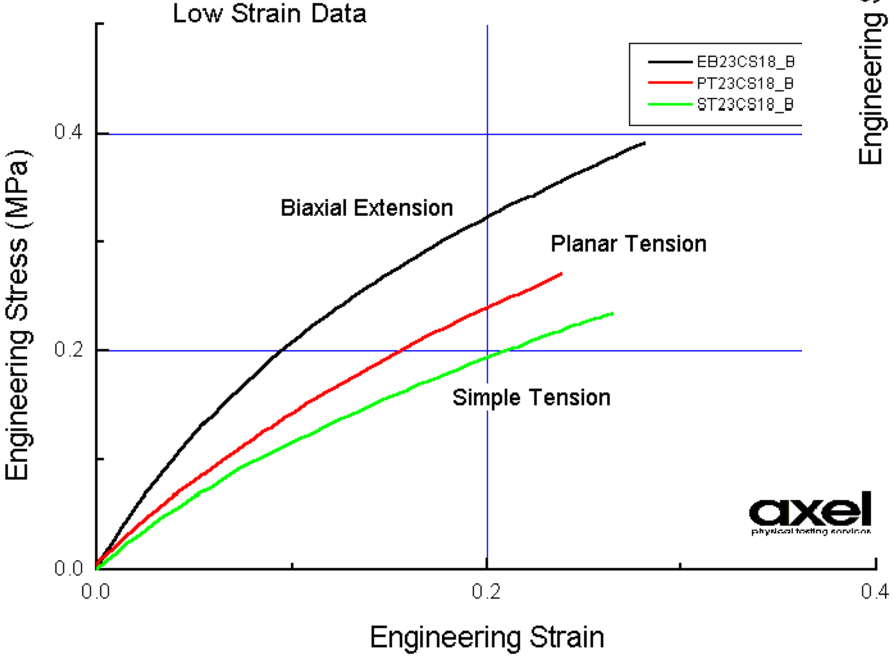
Rubber

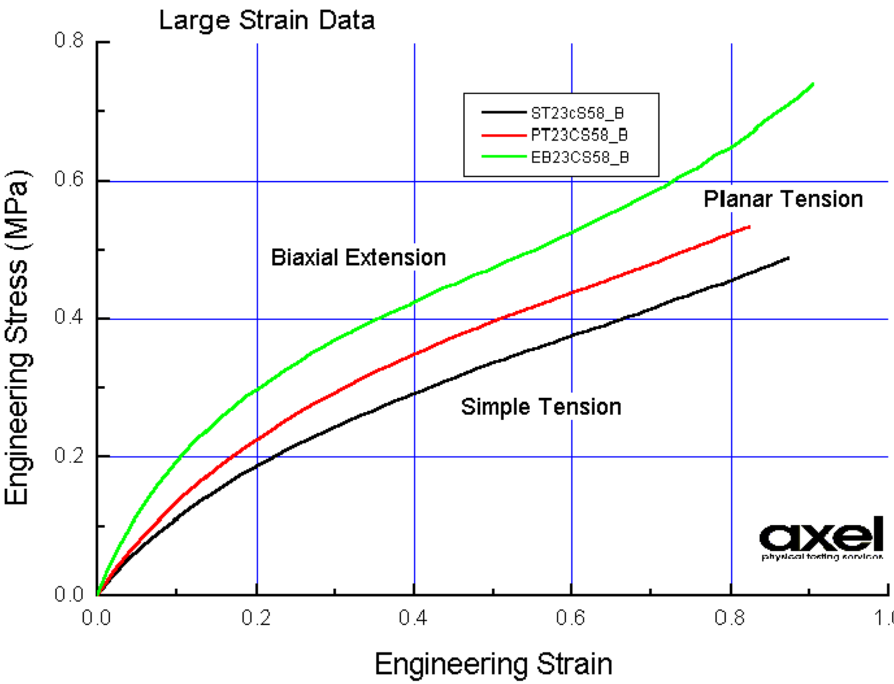
Large Elastic Strains (600%)
Complex Damage
Tension / Comp very different
Viscoelastic, Hysteresis





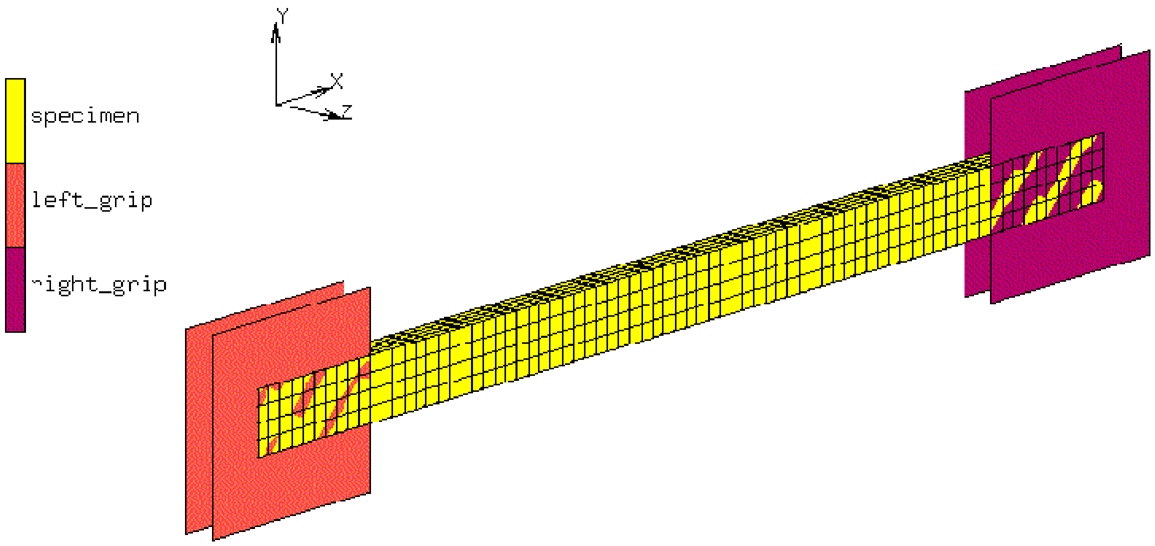
Pure States of Strain or Stress





What is a pure strain state?

1. The states of strain imposed have an analytical solution.
2. A significantly large known strain condition exists free of gradients such that strain can be measured.
3. The state of strain is homogeneous for homogeneous materials.



Pure States of Strain or Stress

1. Simple Tension
2. Pure Shear
3. Simple Compression, Biaxial Extension
4. Bulk Compression

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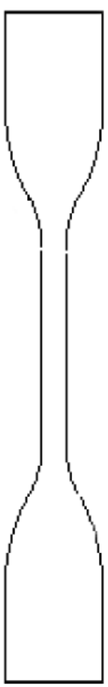
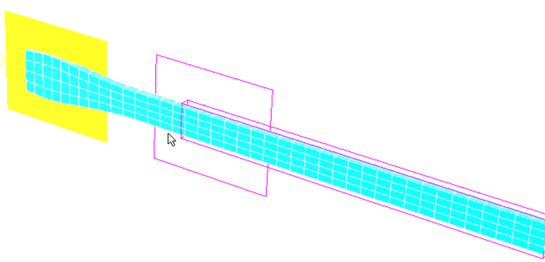
Simple Tension

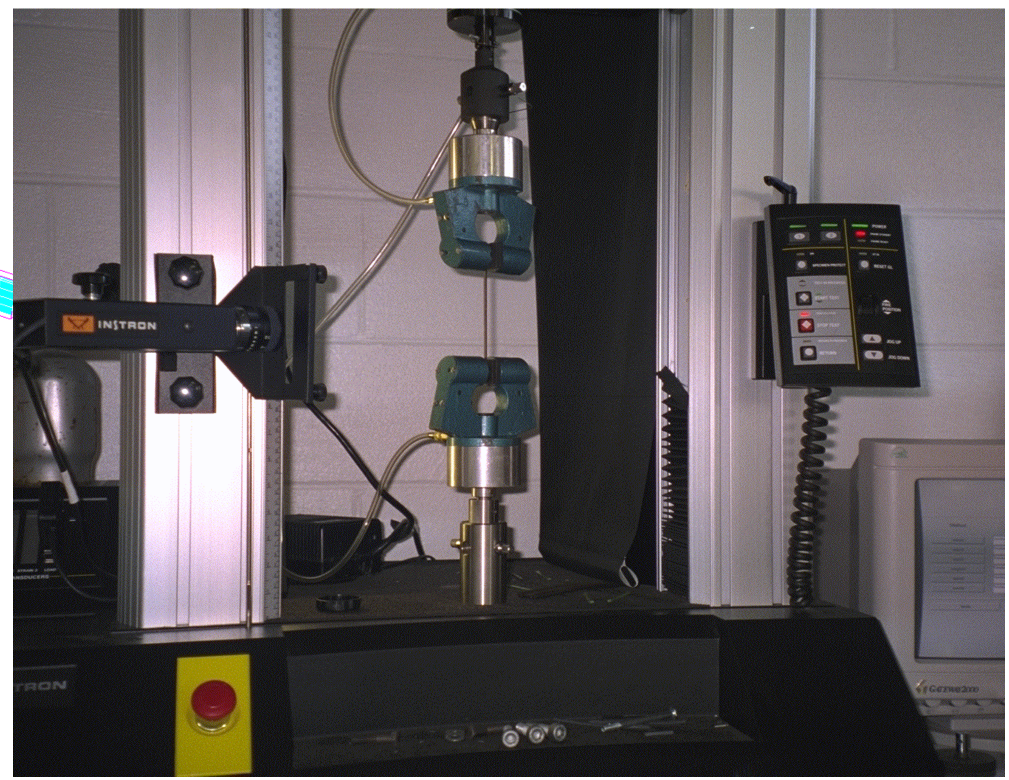
Uniaxial Loading

Free of Lateral Constraint

Gage Section:
Length:Width
>10:1

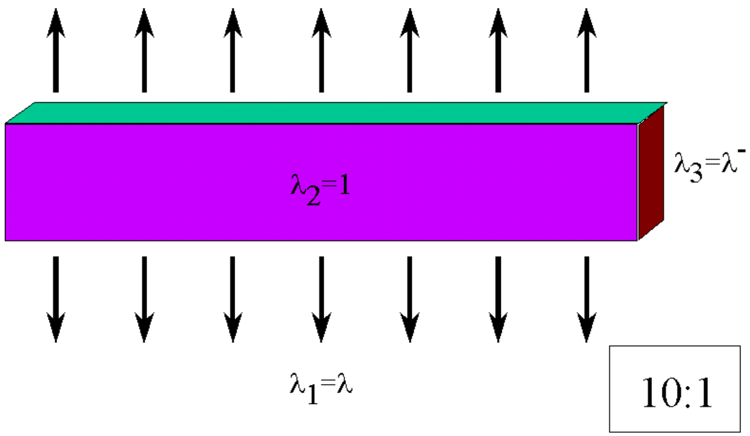






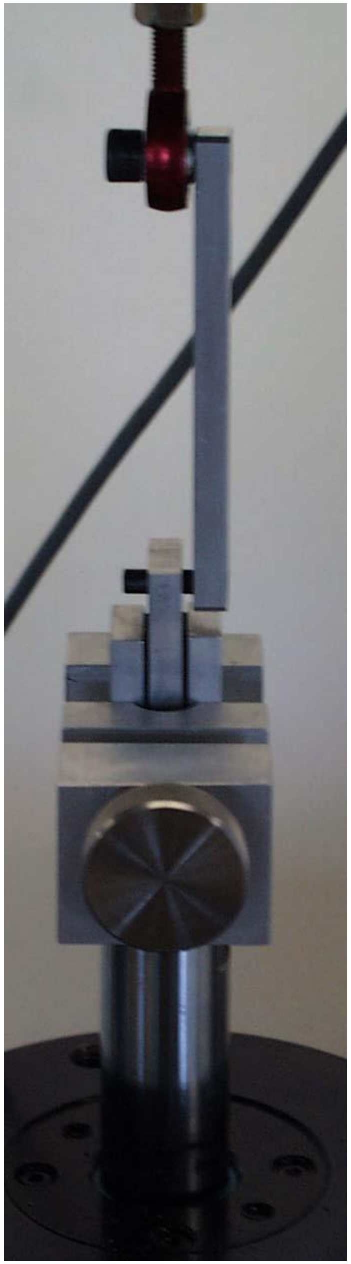
Planar Tension

1. Uniaxial Loading
2. Perfect Lateral Constraint
3. All Thinning Occurs in One Direction



Simple Shear

1. Shear Loading
2. No Thinning Permitted
3. Bonding can be difficult.
4. May be used for Foams



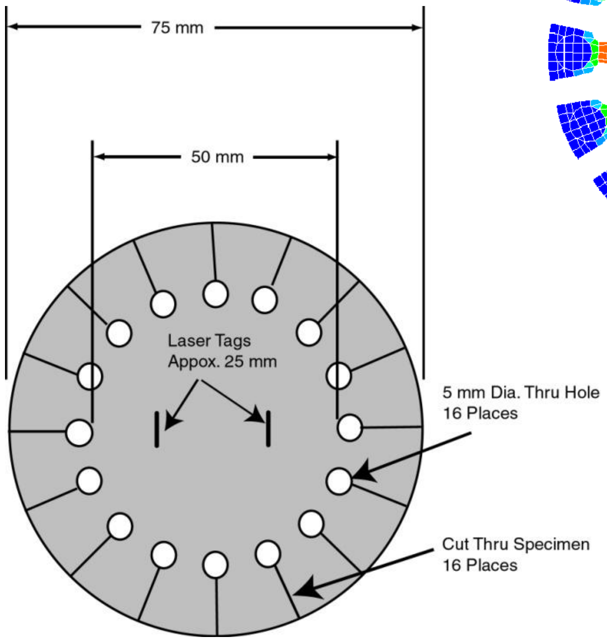
Equal Biaxial Extension

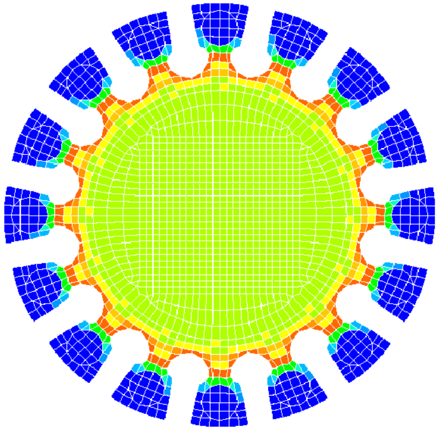
Why?

1. Same Strain State as Compression
2. Can Not Do Pure Compression
3. Can Do Pure Biaxial

Equal Biaxial Extension

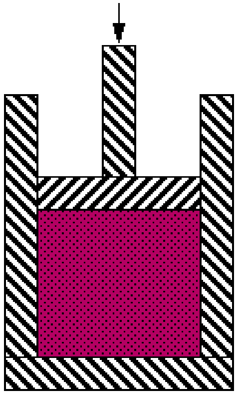
Analysis of the Specimen Justifies Geometry

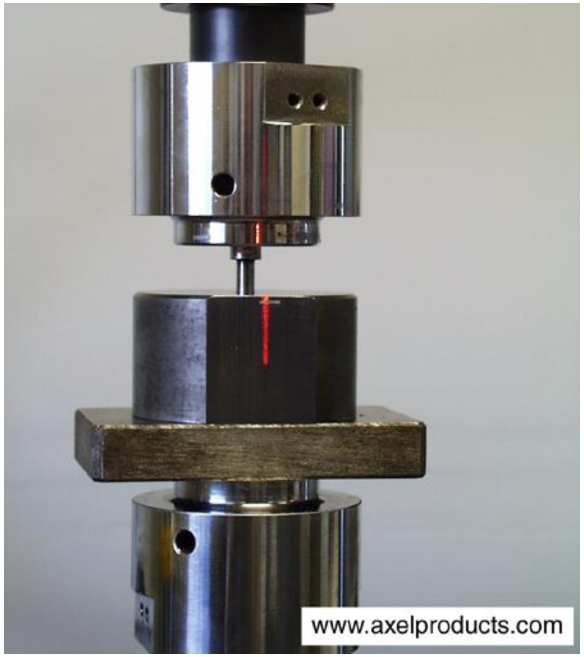




Volumetric Compression

1. The Stress Required to Change the Volume of an Elastomer
2. Requires Resolute Displacement Measurement at the Fixture
3. NOT for Foams!

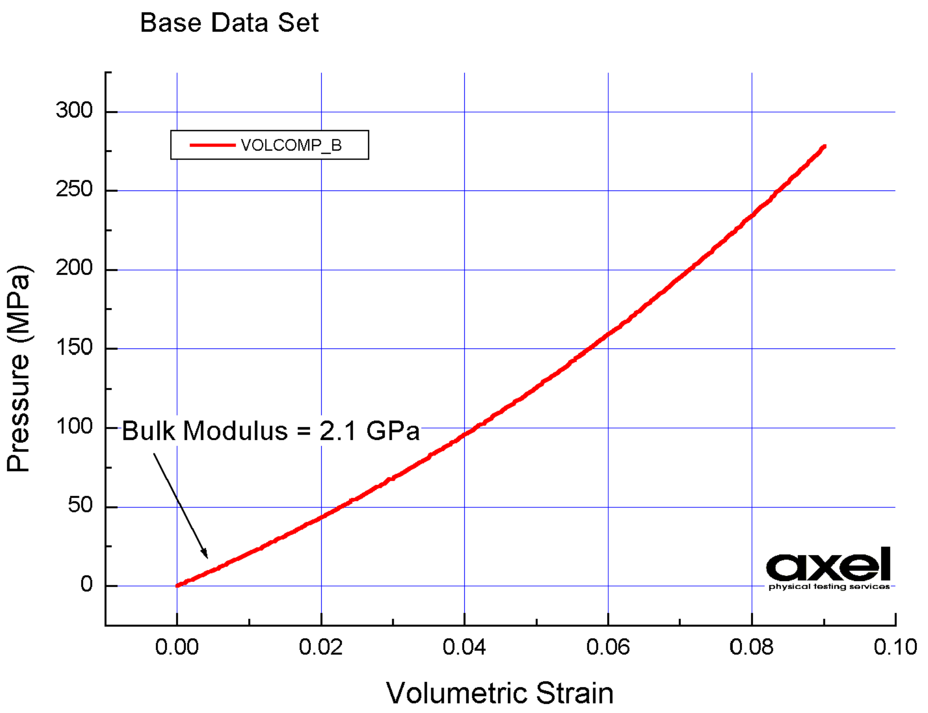




Volumetric Compression

Initial Slope = Bulk Modulus

Typically, only highly constrained applications require an accurate measure of the entire Pressure-Volume relationship.

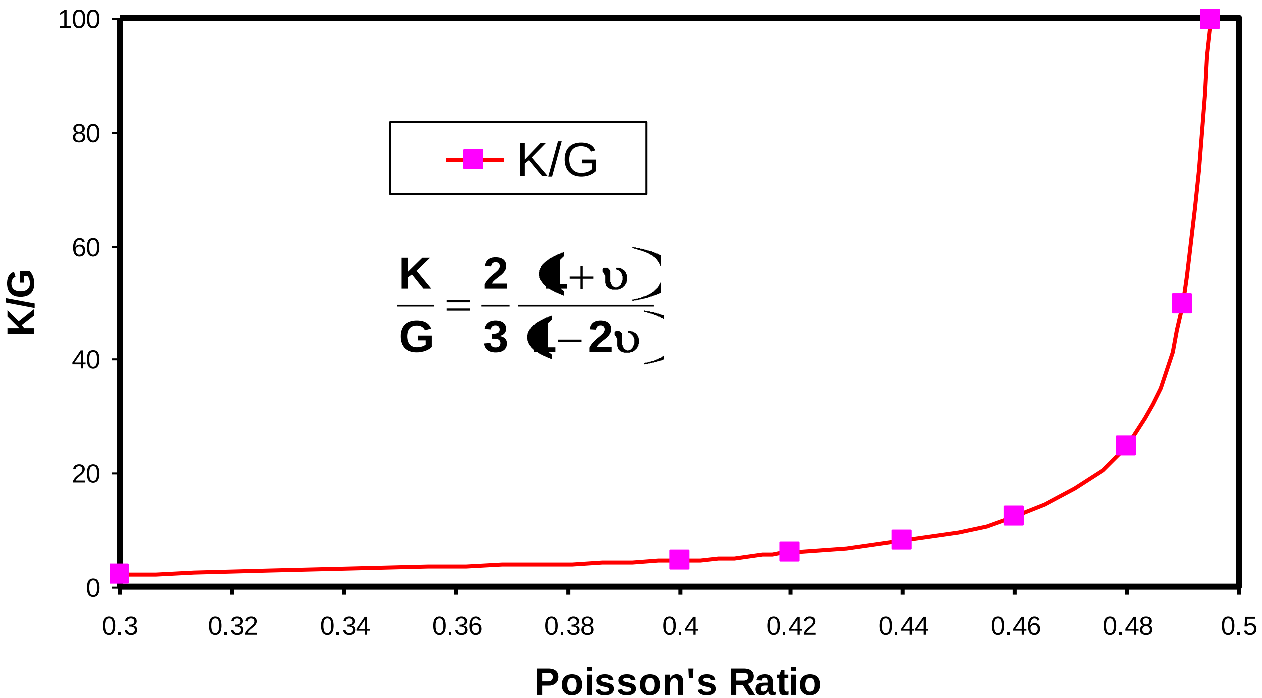


Volumetric Compression

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

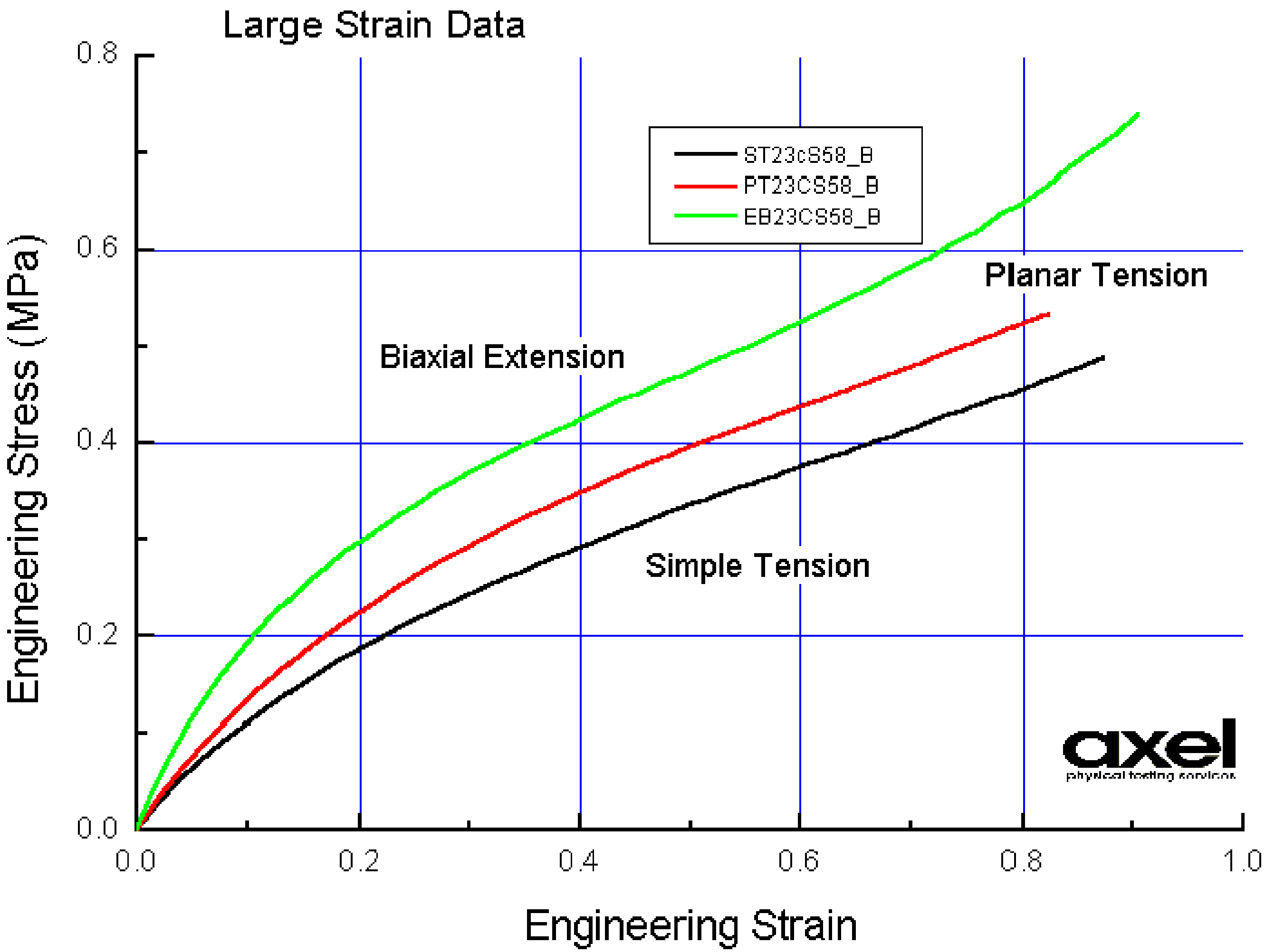
For elastomer materials Poisson's ratio is difficult or impossible to measure accurately. Measure Pressure-Volume directly, compute K (or D_1 in ABAQUS)

K/G Relationship to Poisson's Ratio



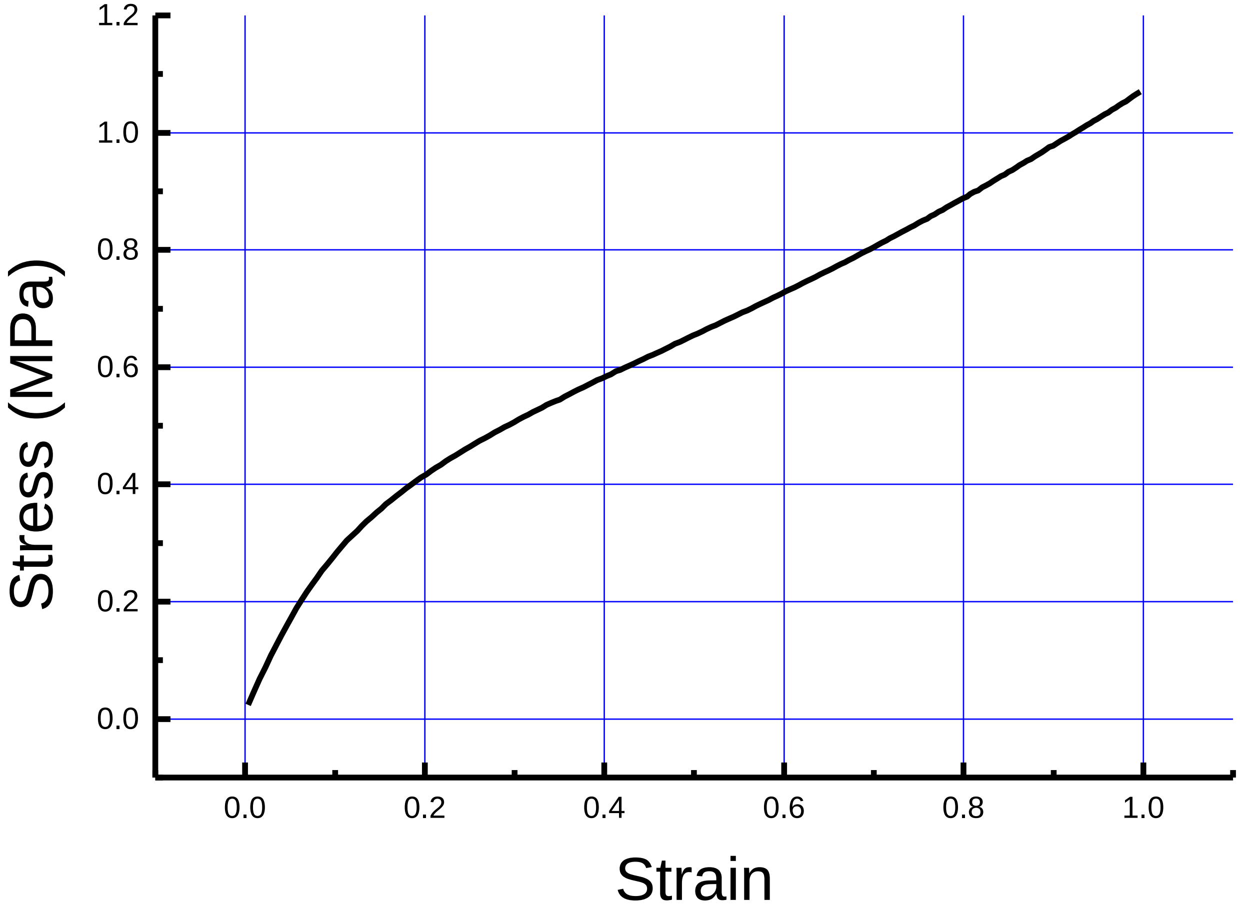
$$\frac{K}{G} = \frac{2}{3}\frac{(1+\upsilon)}{(1-2\upsilon)}$$

Loading Conditions



Loading Conditions

1. Initial Loading
2. Typical of Data Existing Standa



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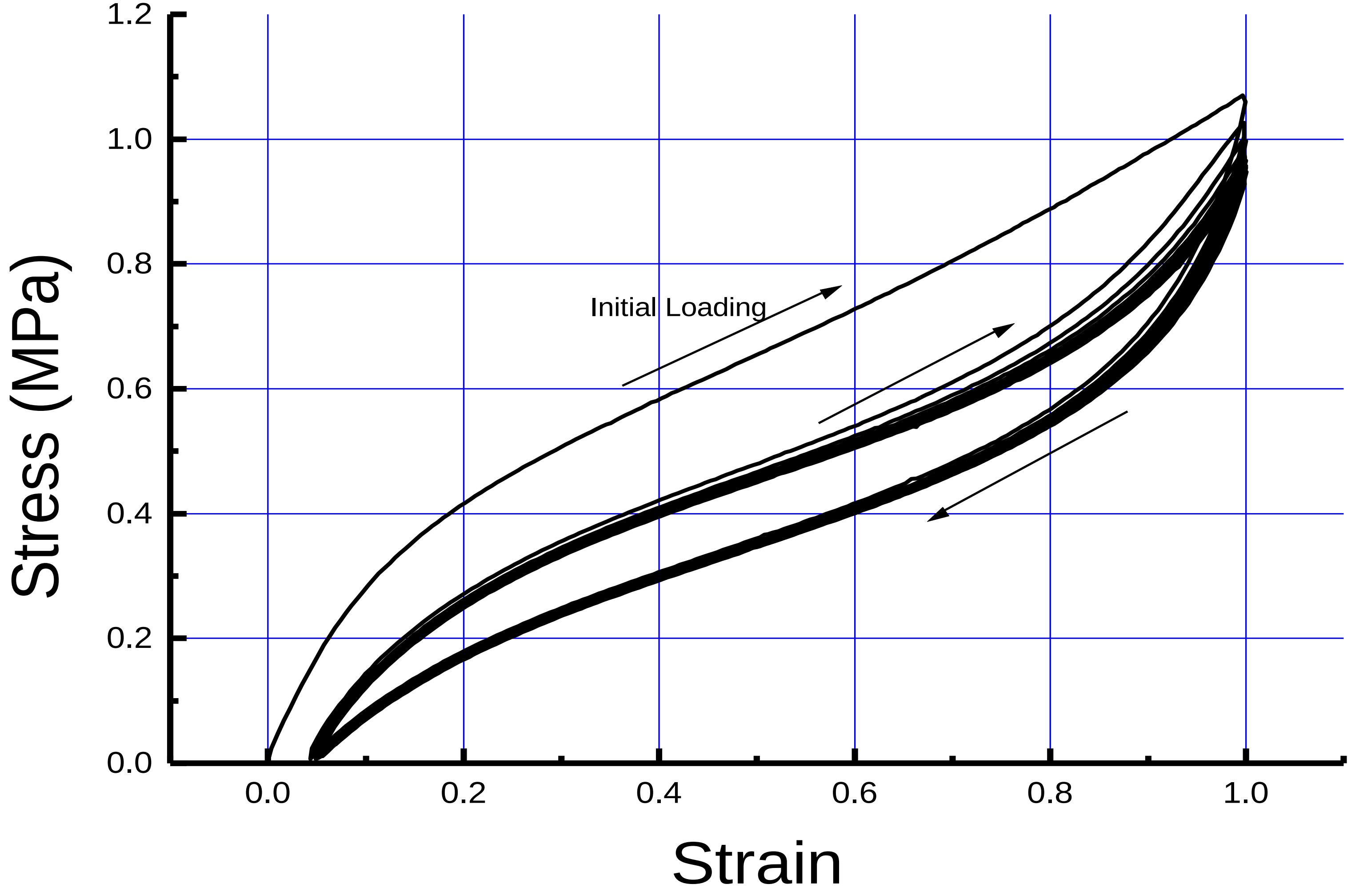
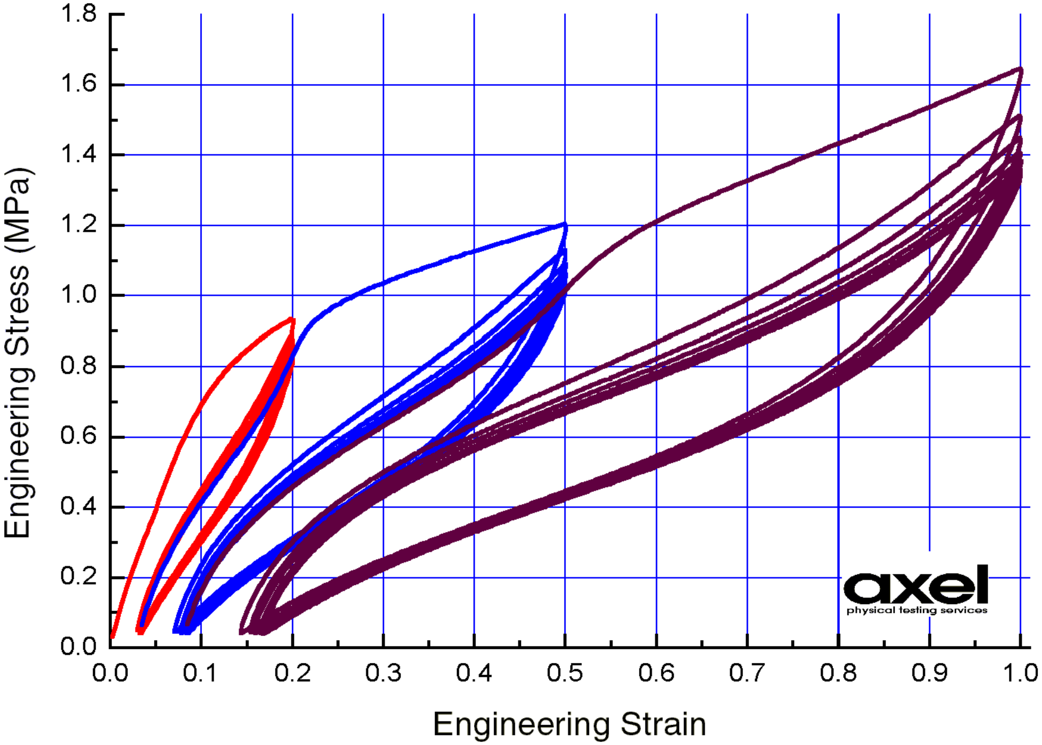


Loading Conditions

Some Common Elastomers Exhibit Dramatic Strain Amplitude and Cycling Effects at Moderate Strain Levels

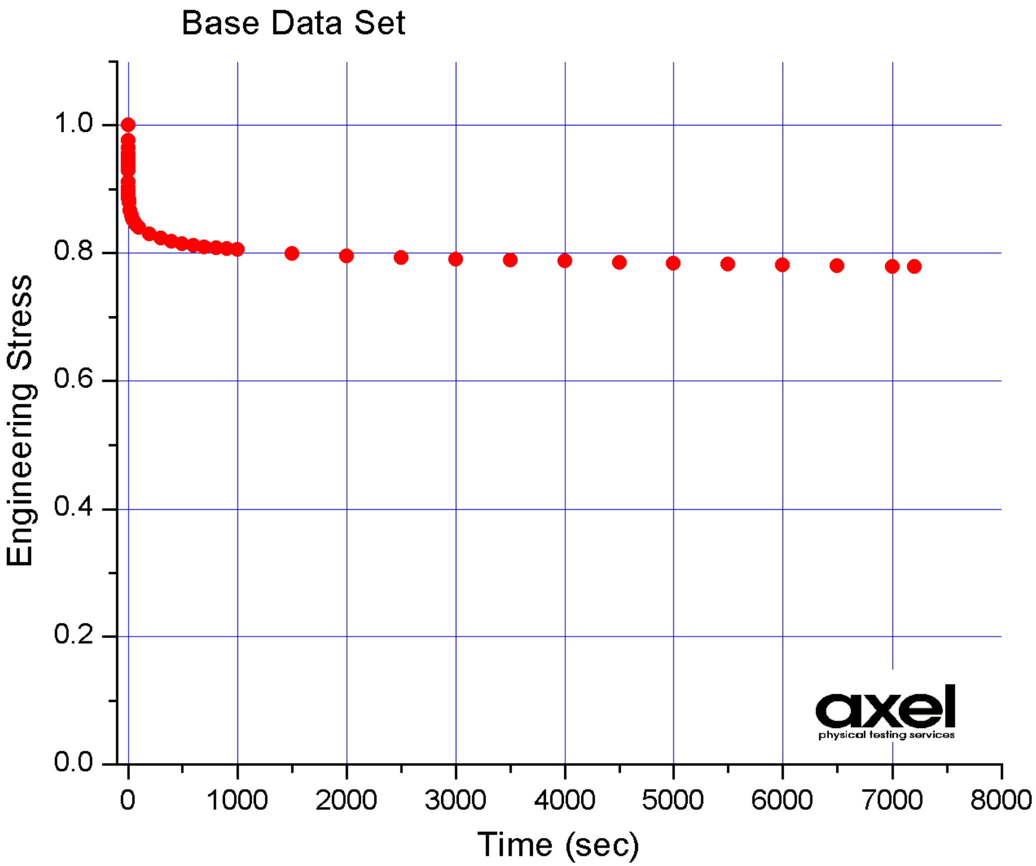
Conclusions:

1. Test to Realistic Strain Levels
2. Use Application Specific Loadings to Generate Material Data



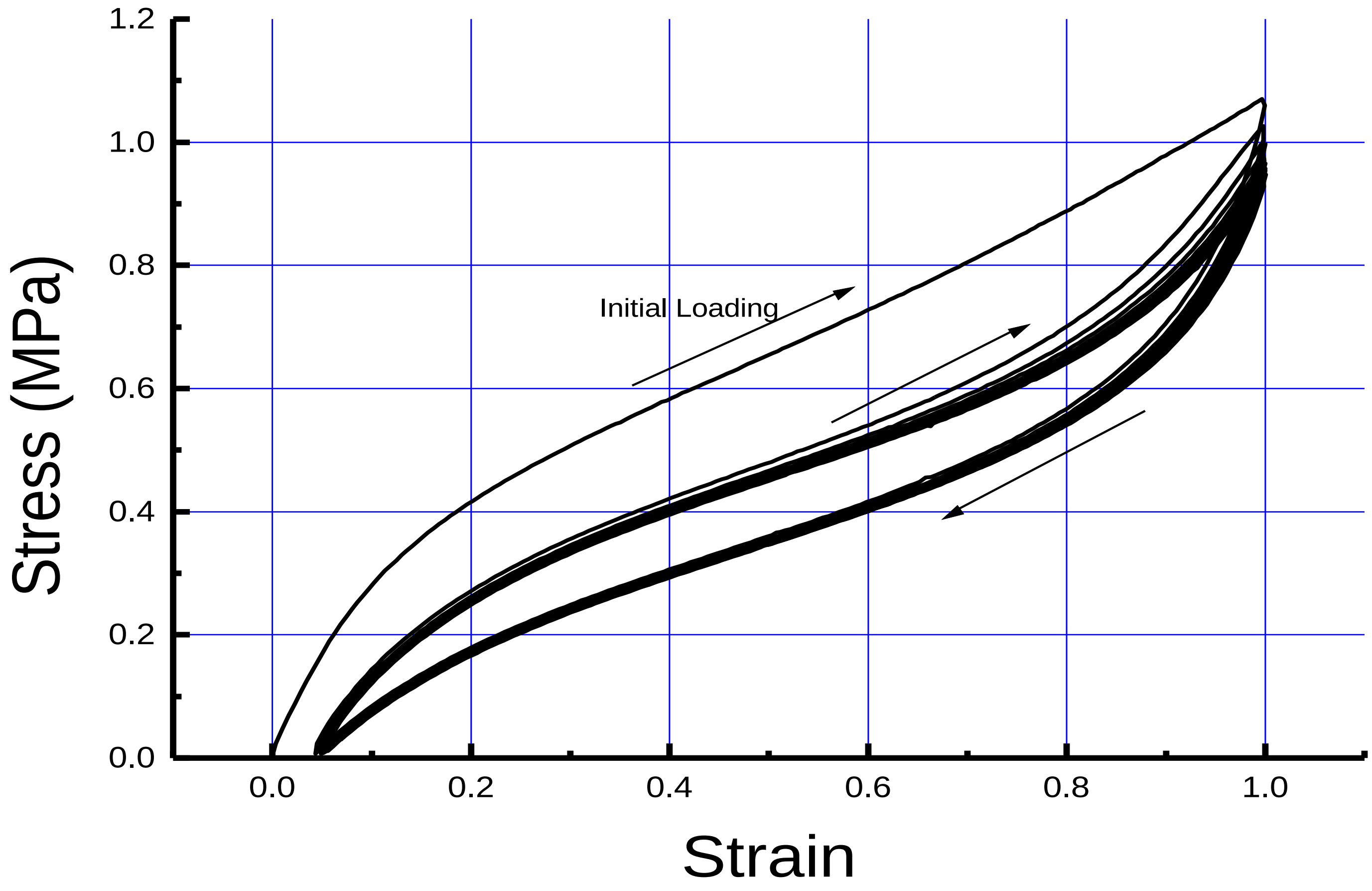
Basic Viscoelastic

1. Assumed to be Linear Viscoelastic Behavior
2. Is not the same as aging!
3. Describes the short term reversible behavior of elastomers.
4. Tensile, shear and biax have similar viscoelastic properties!



Basic Viscoelastic

Viscoelastic will not predict this.



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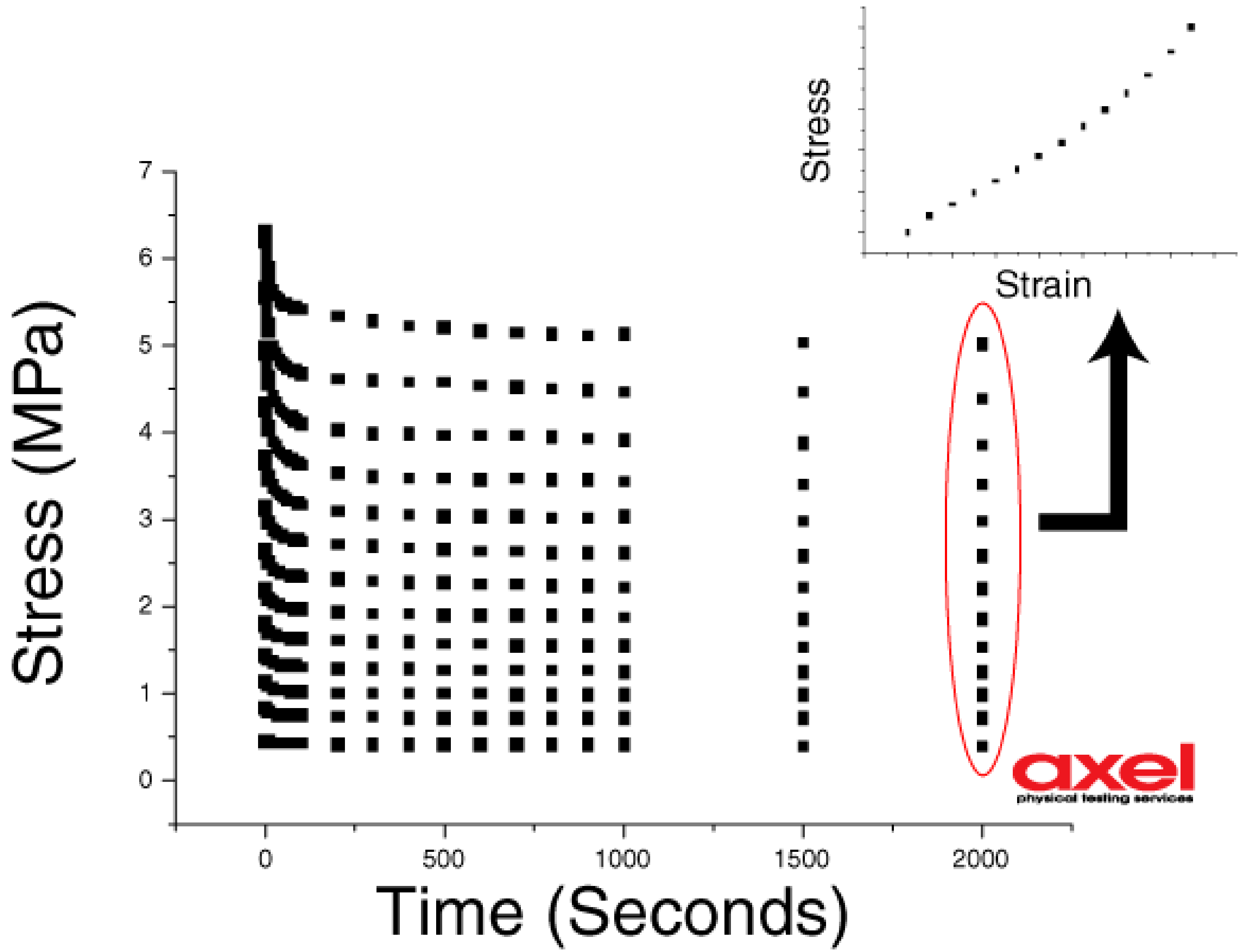
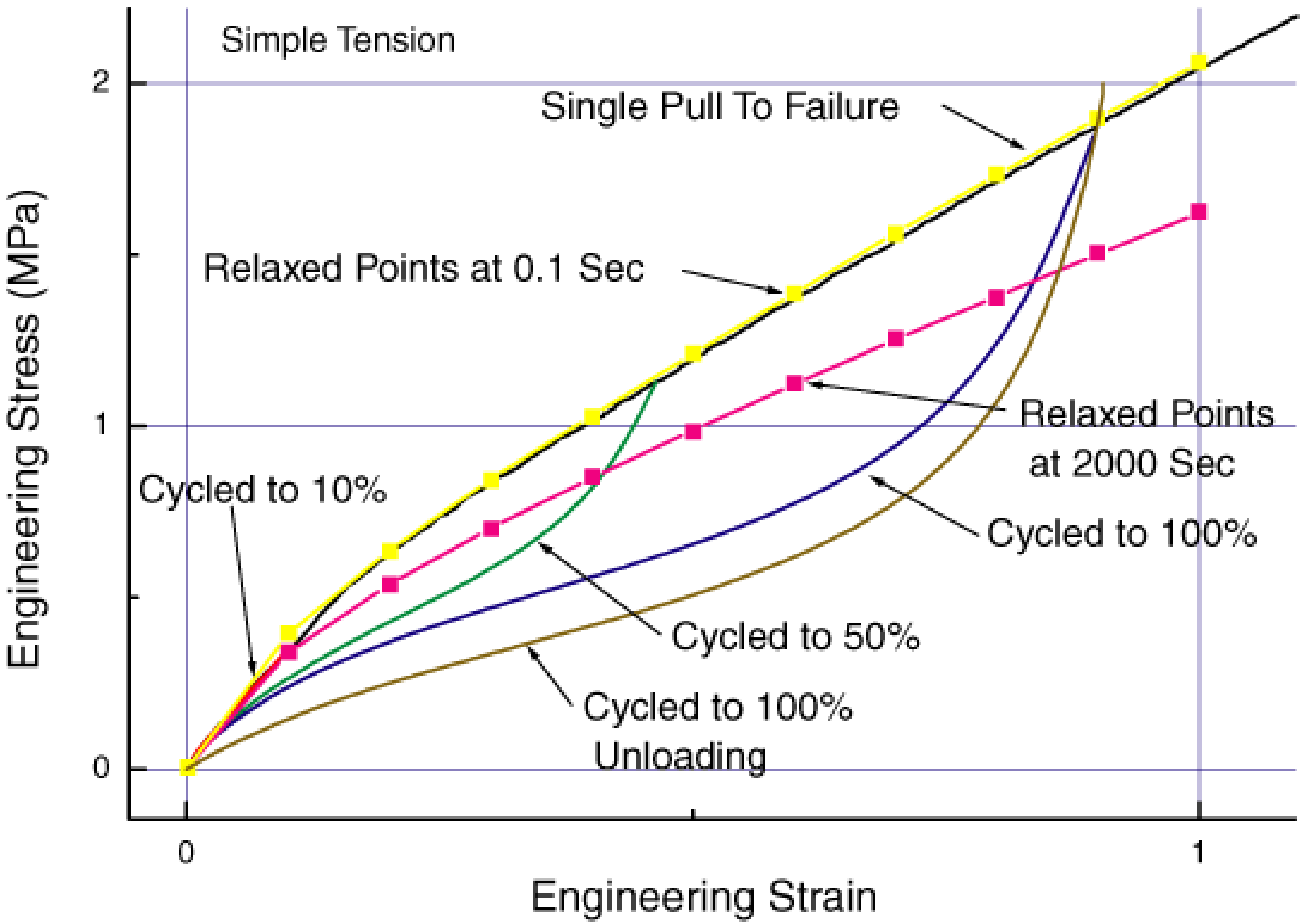
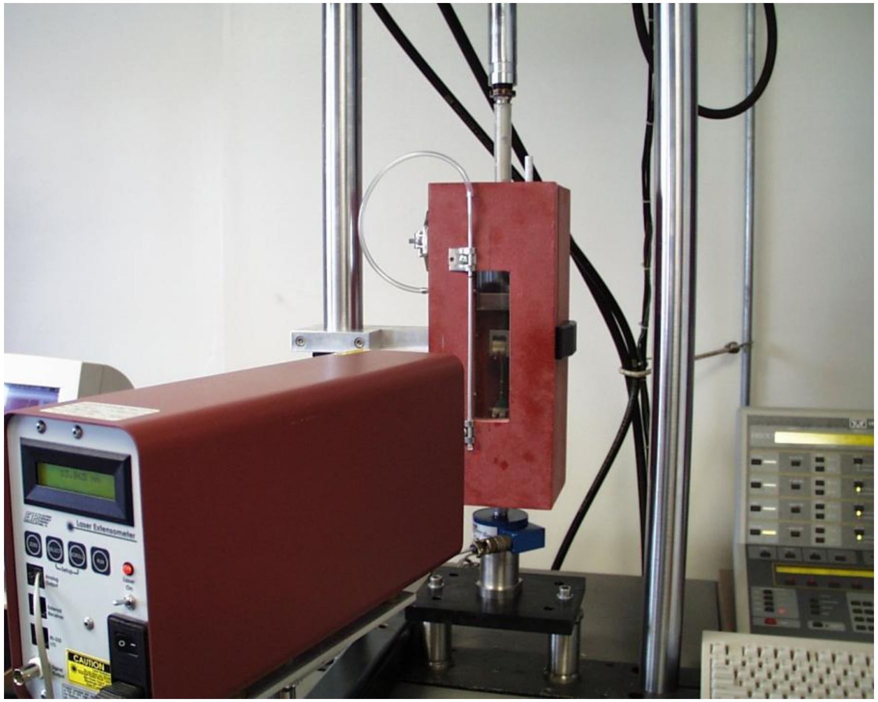


Loading Comparison?



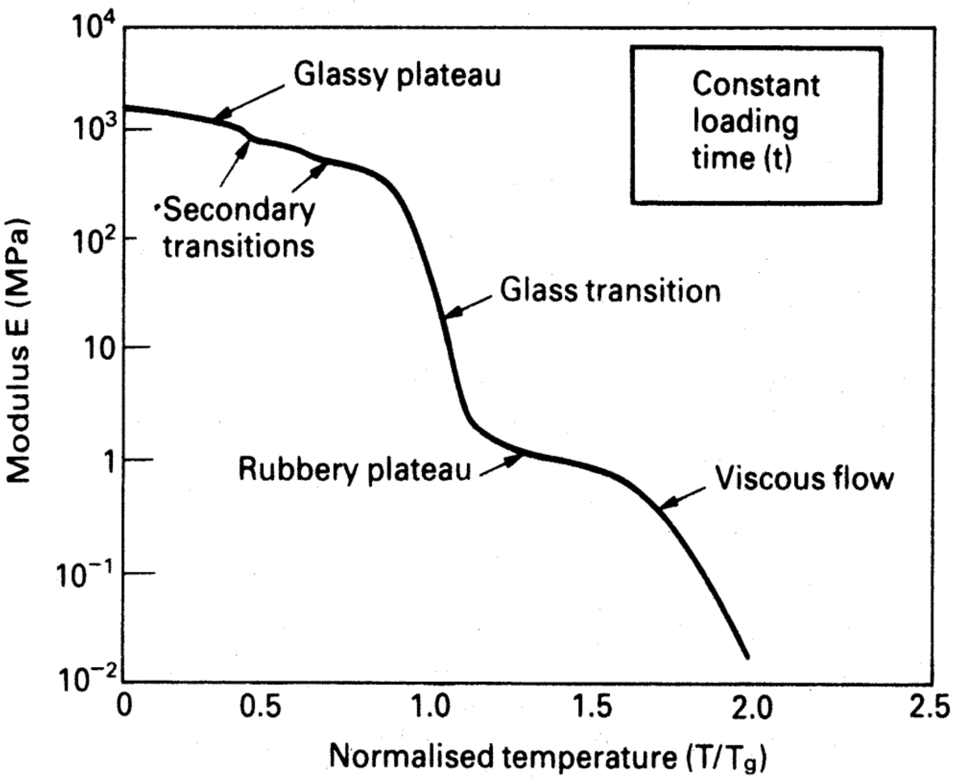
Thermal Effects

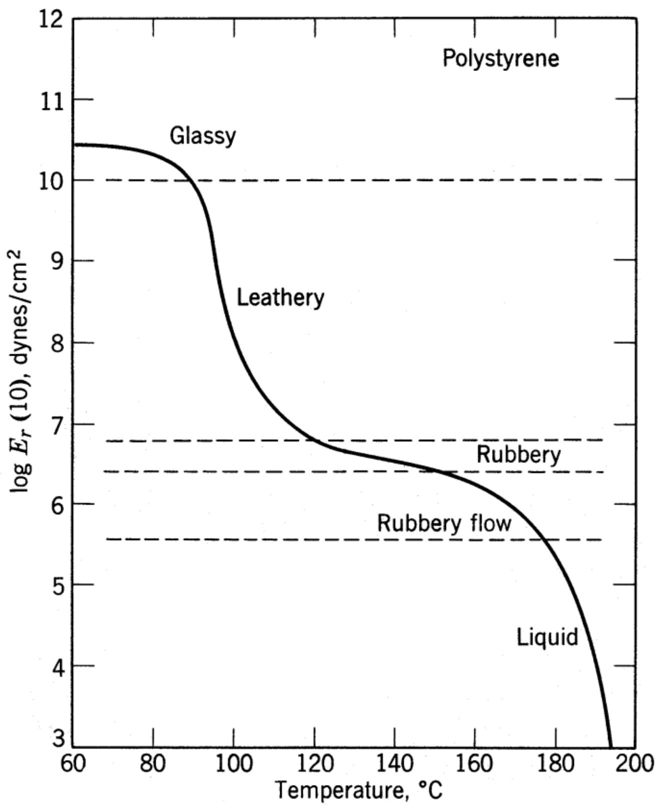
1. Cold and Hot
2. Thermal Conductivity
3. Thermal Expansion



Cold and Hot

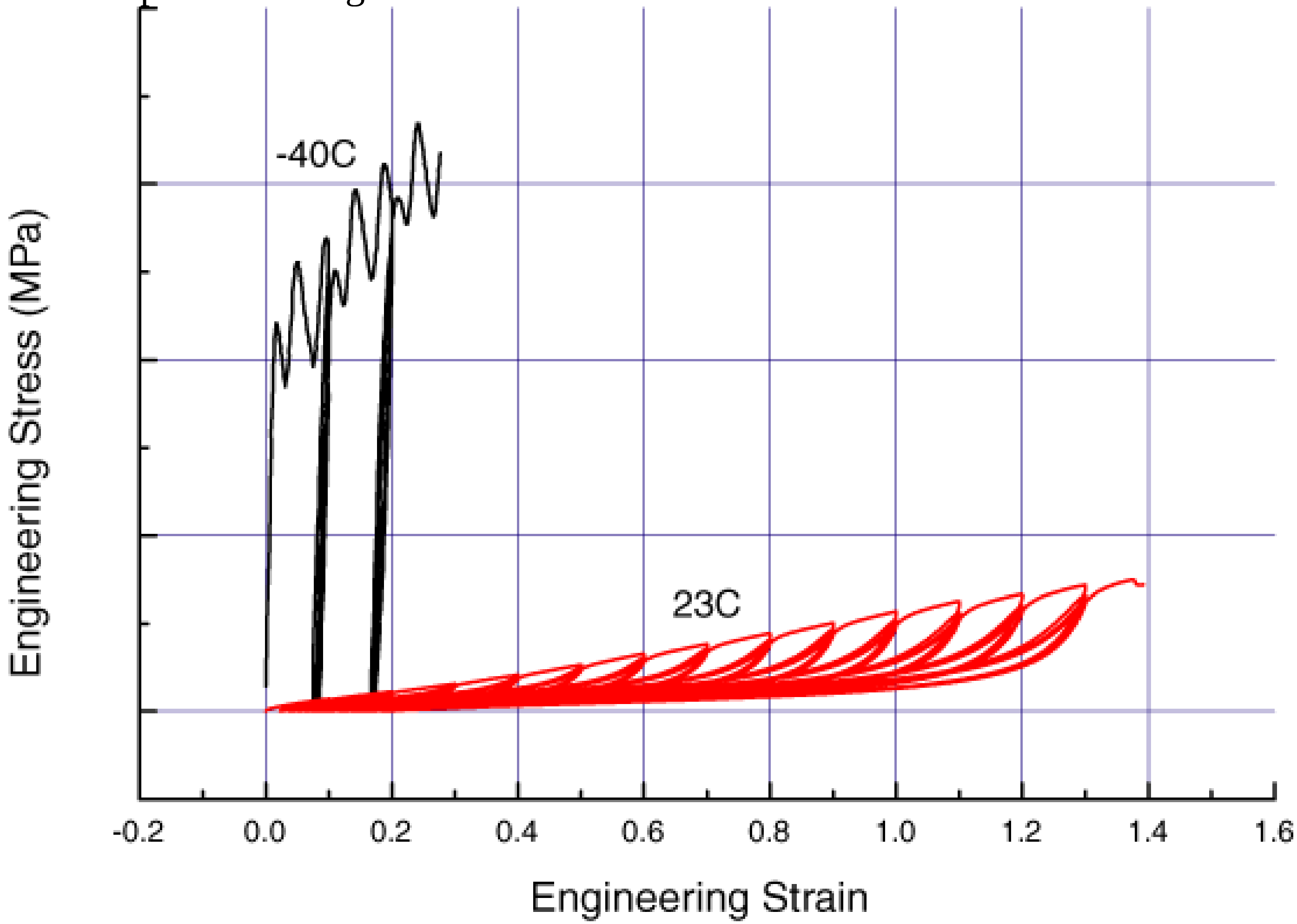
Typical $\mathbf{T_G}$ diagrams for polymer materials





Cold and Hot

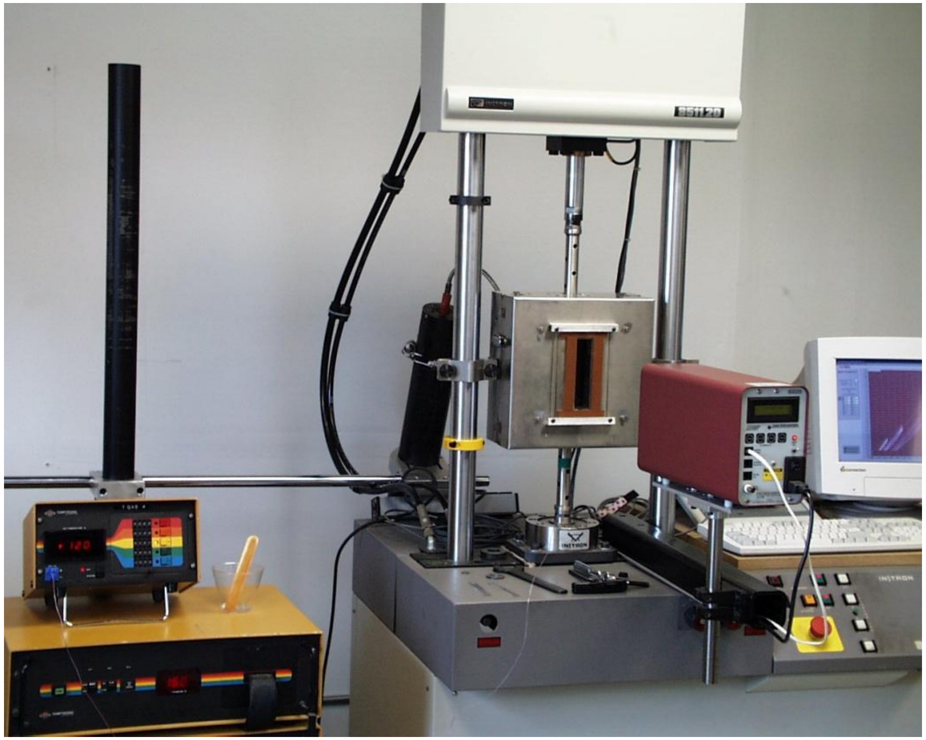
Elastomers Properties Can Change by Orders of Magnitude in the Application Temperature Range.

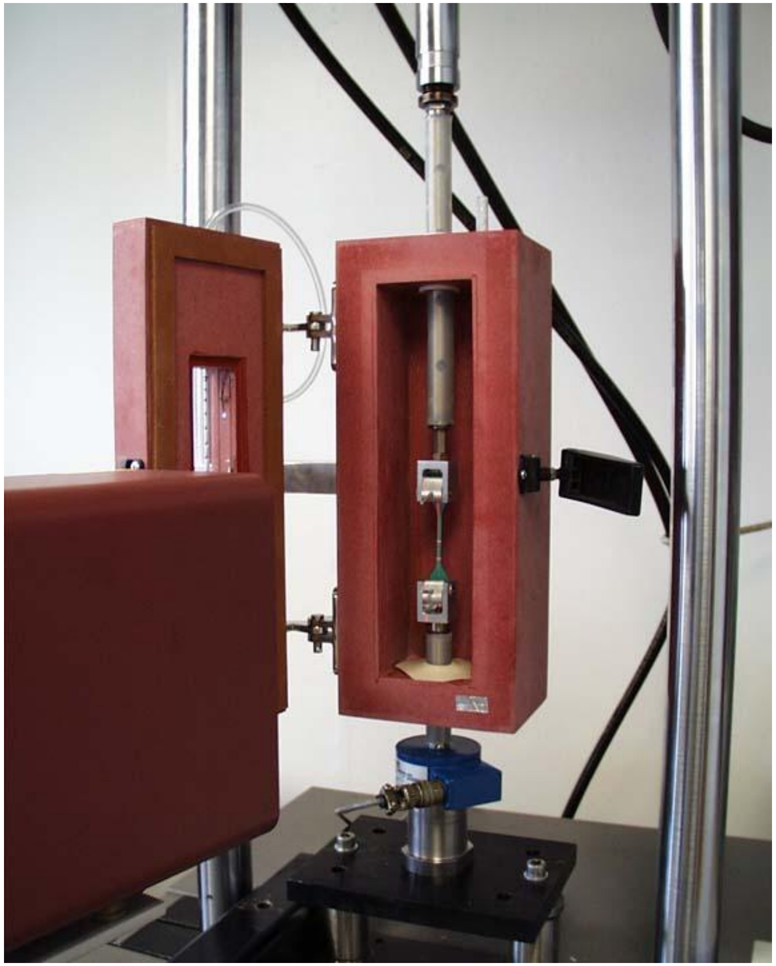


Cold and Hot

Testing at the Application Temperature

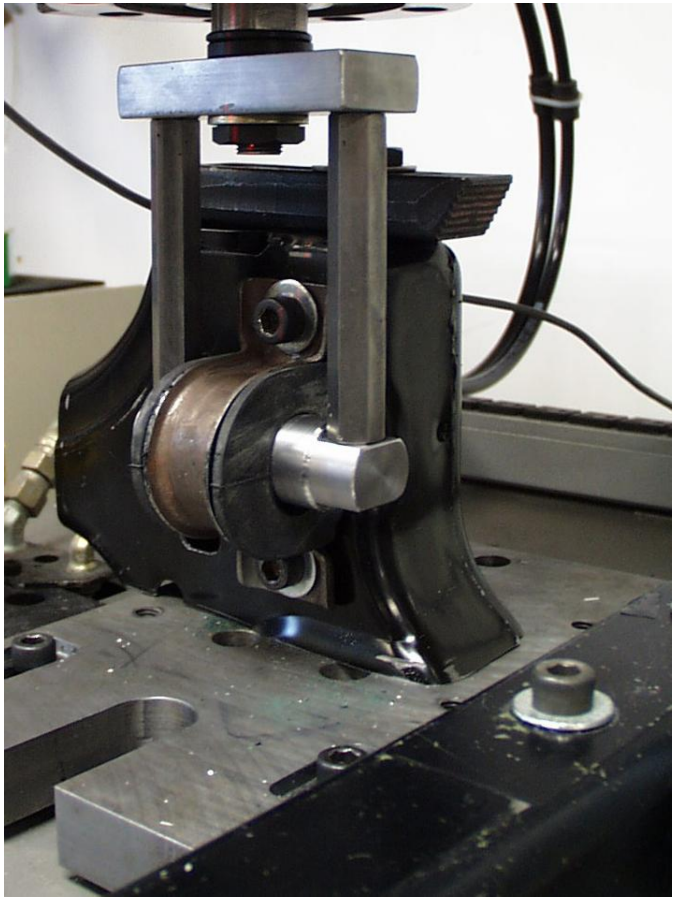
1. Measure Strain at the Right Location
2. Perform Realistic Loadings



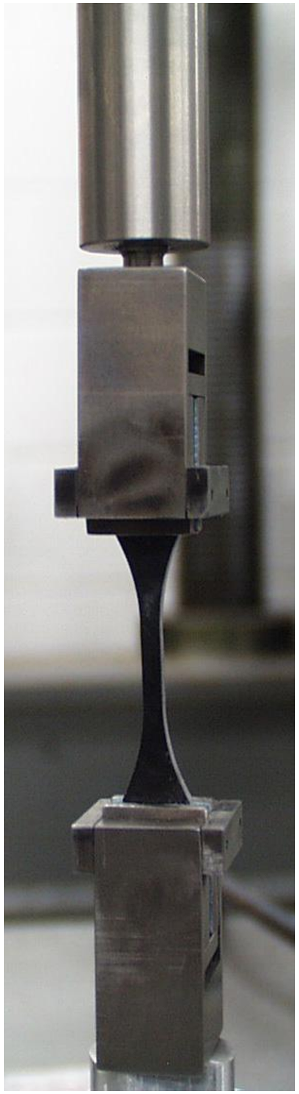


Dynamic Properties

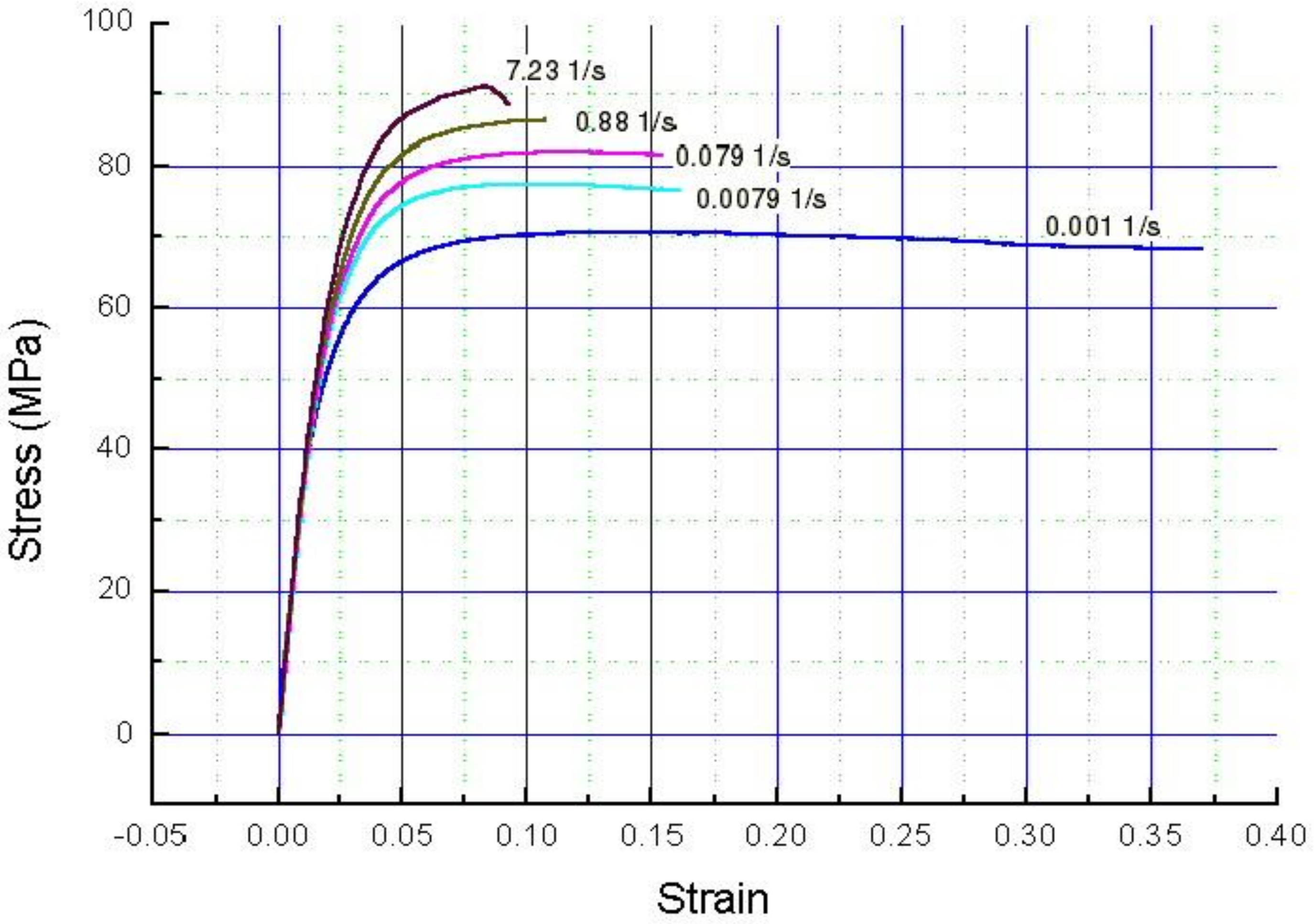
1. Loading Rates
2. Vibrations
3. High Frequency Vibrations



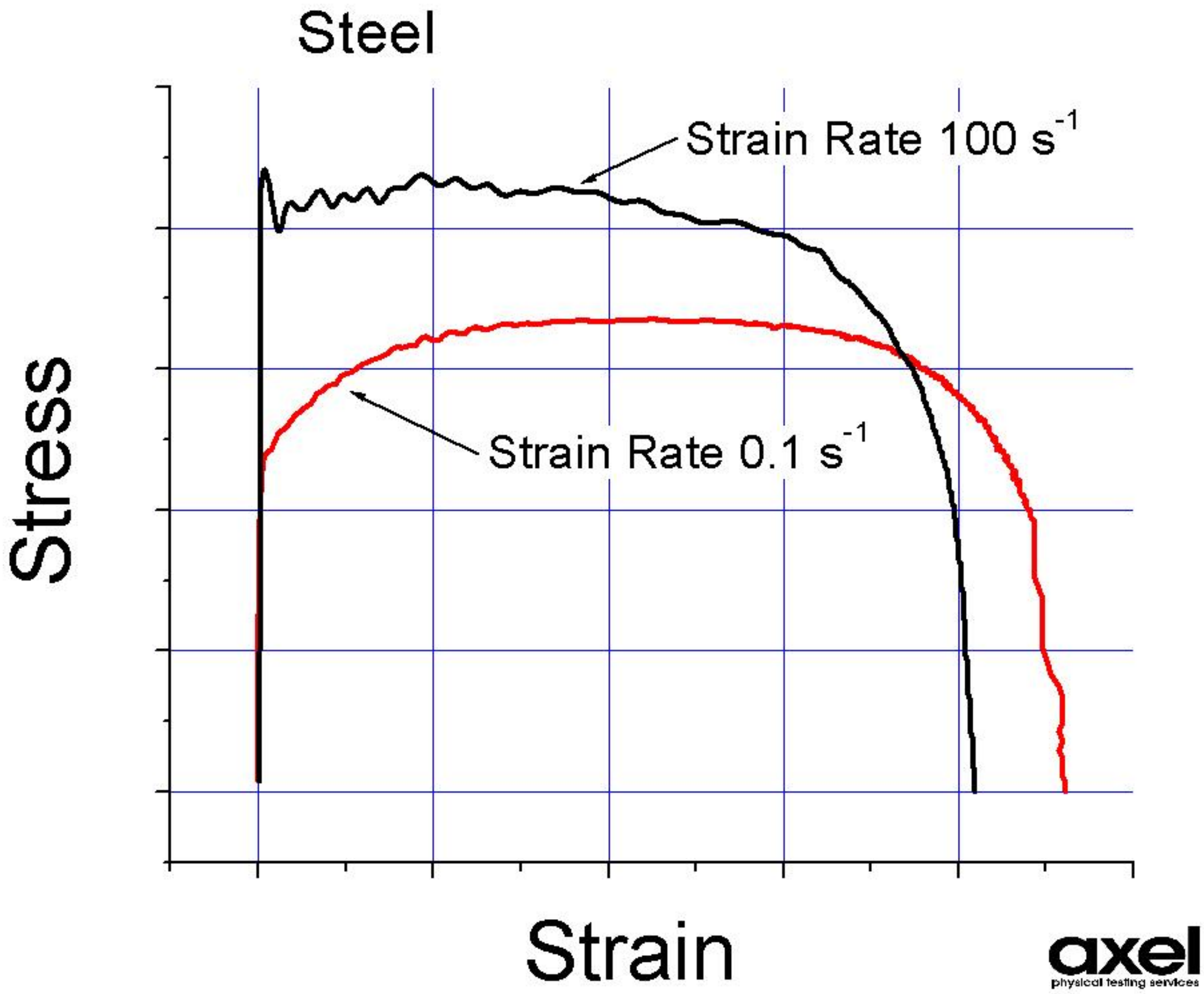
Loading Rates



Loading Rates

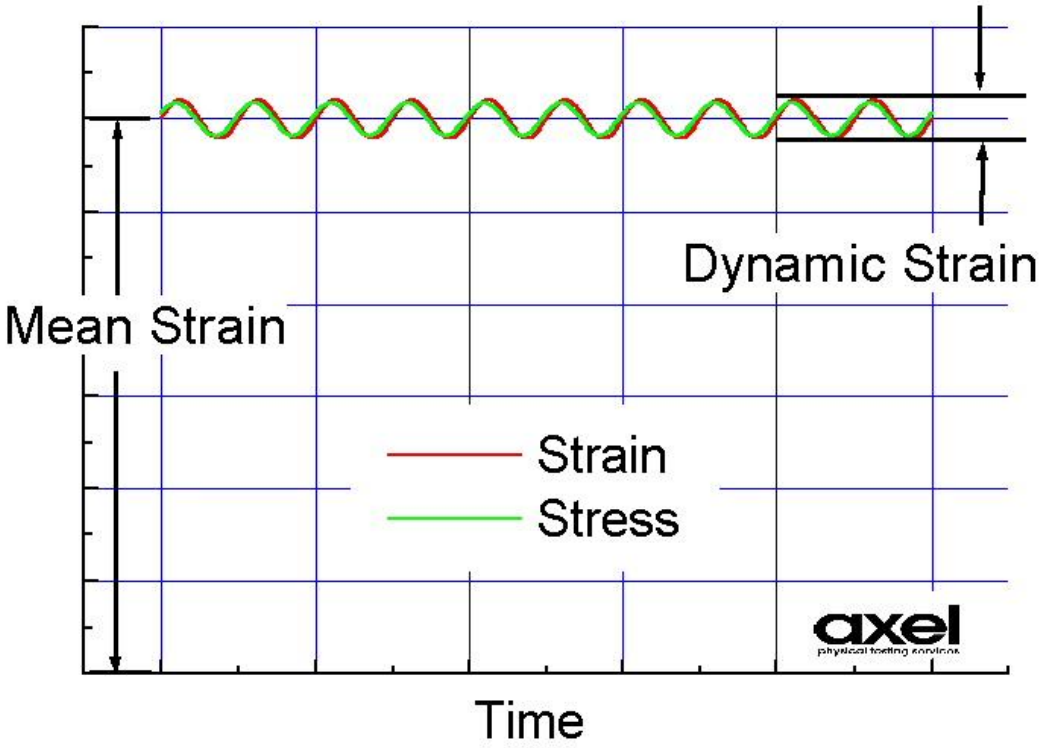


Loading Rates

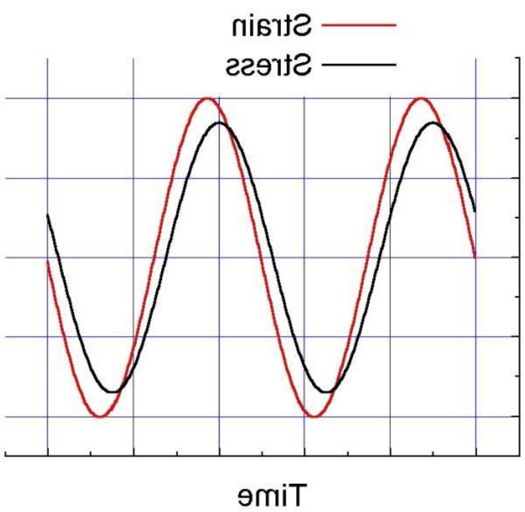


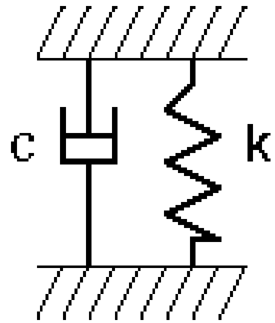
Vibrations

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



Vibrations





No inertia effect

Long Wave Length vs Measurement

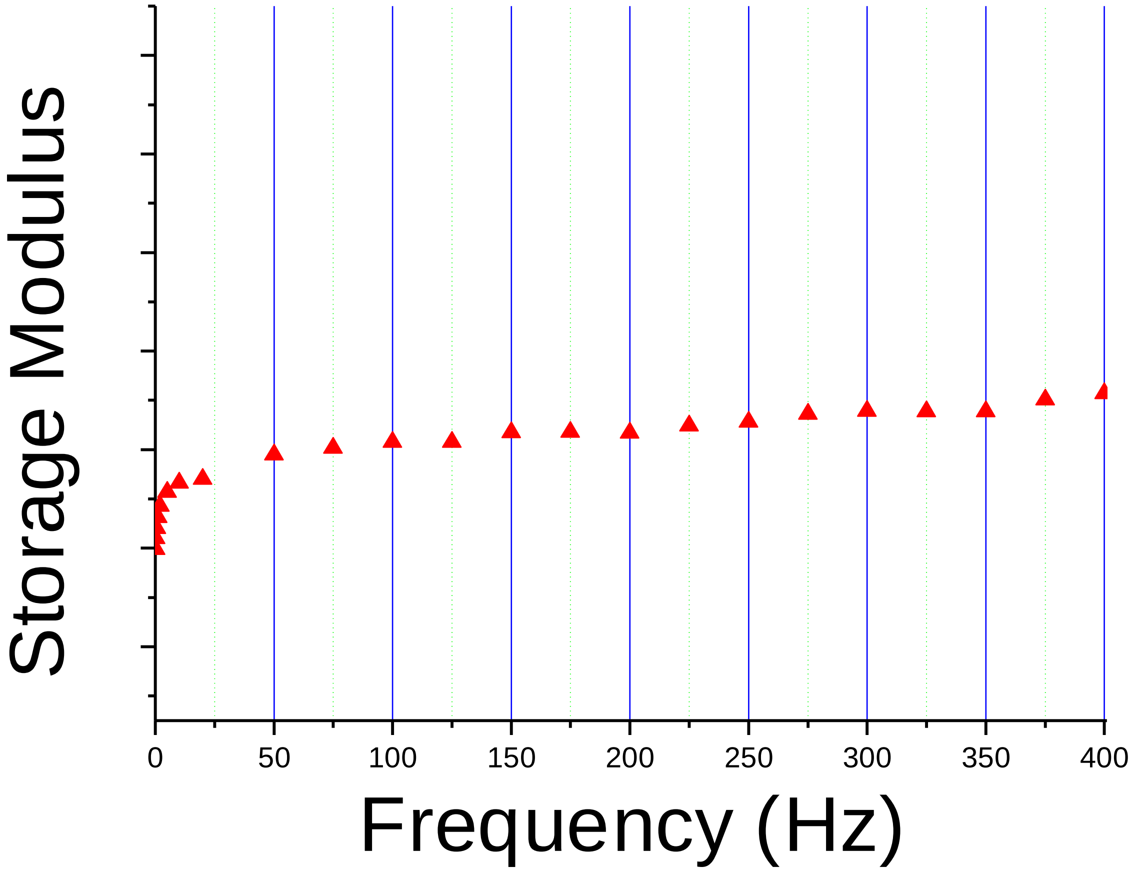
Dynamic Modulus = Peak Stress/ Peak Strain

Storage Modulus = E*cosδ

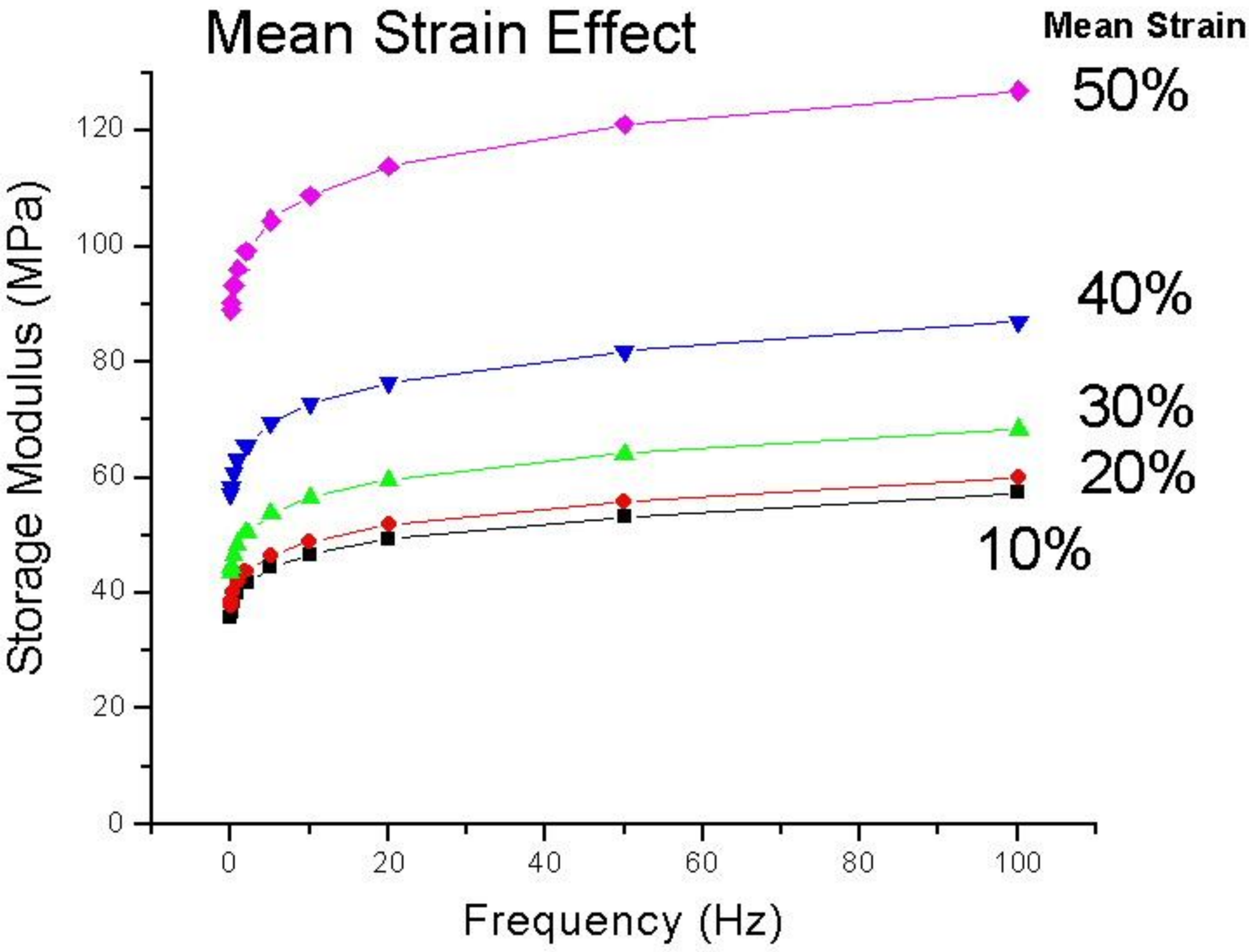
Loss Modulus = E*sinδ

Vibrations

Data at 30%
Mean Strain

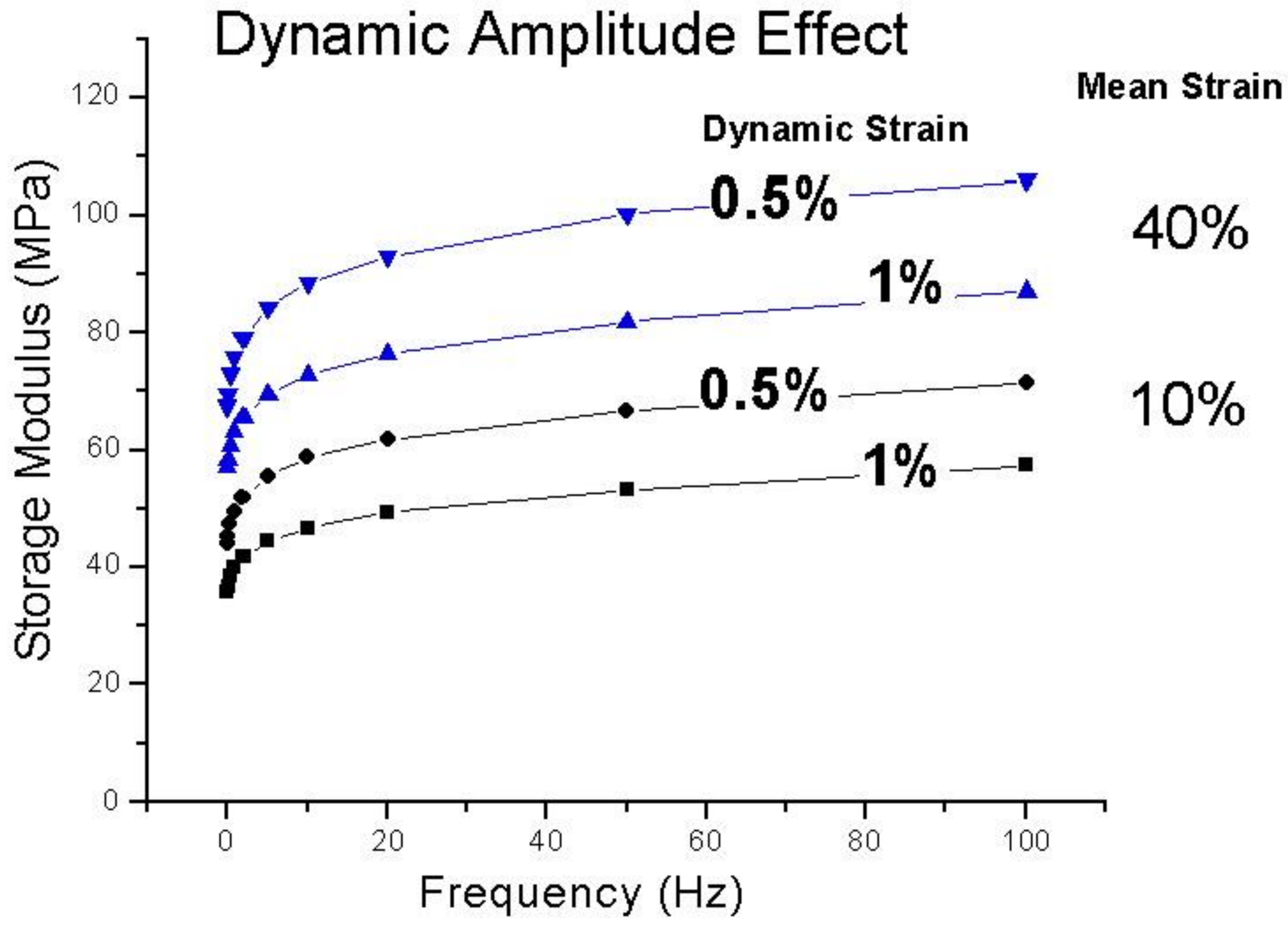


Vibrations



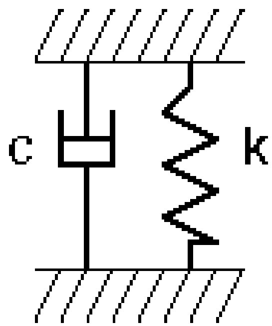
Mean Strain Effect
Mean Strain
50%
40%
30%
20%
10%
Storage Modulus (MPa)
0
20
40
60
80
100
120
0
20
40
60
80
100
Frequency (Hz)

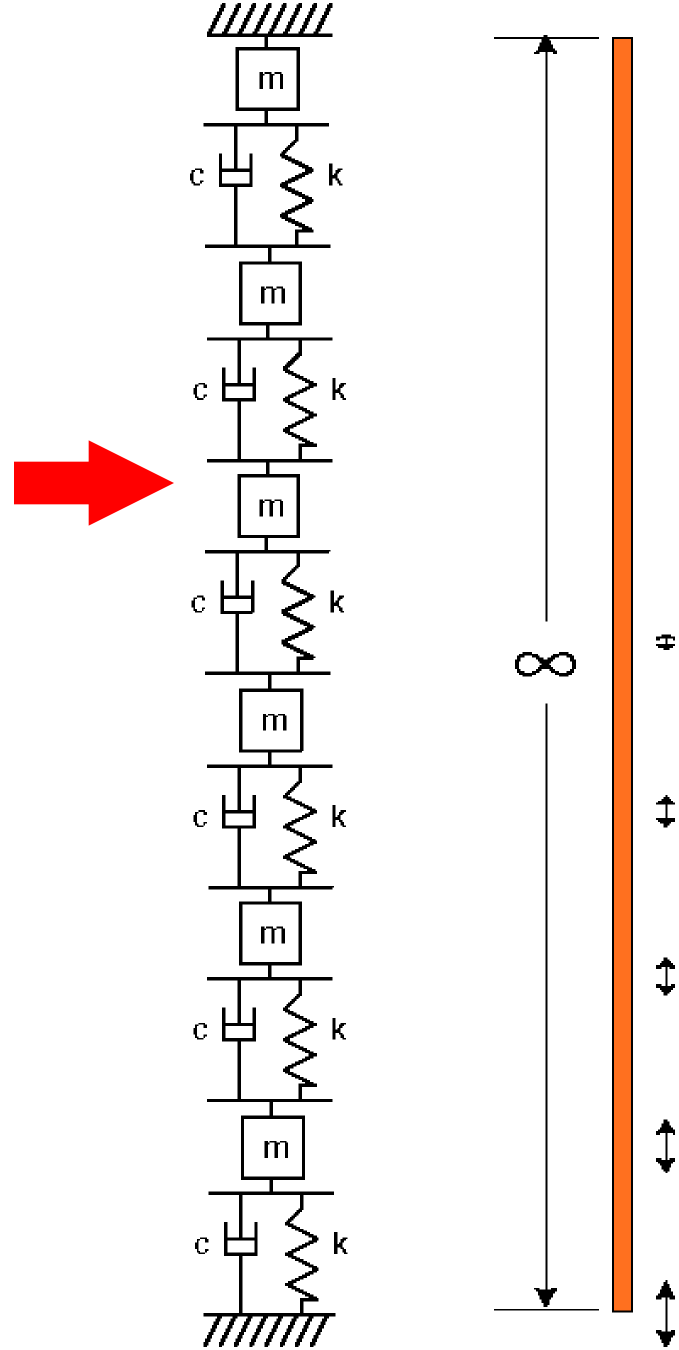
Vibrations



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

High Frequency Dynamics





Wave Propagation

Inertial effect is Significant

Wave Length is Small

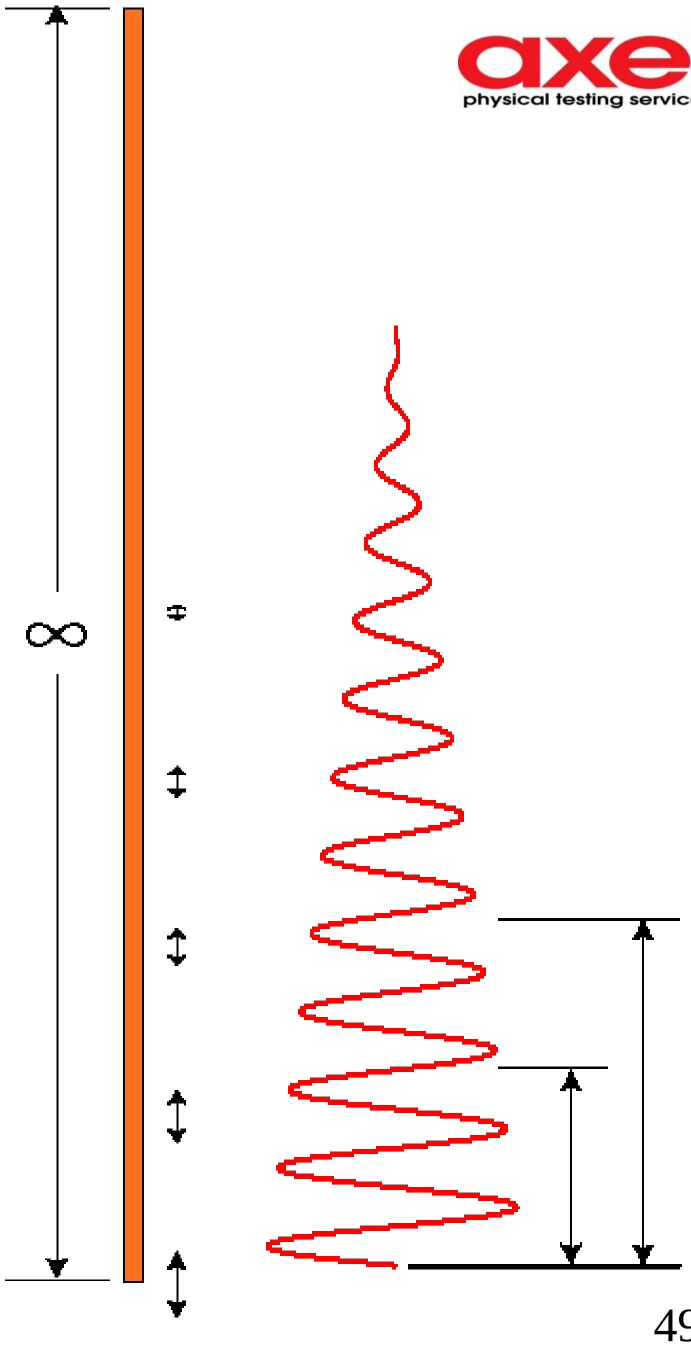
100 - 10,000 Hz.

Wave Propagation

$$E^* = \rho c^2$$

Measure:

- Density ρ
- Wave Speed c
- Wave Decay



$c = f\lambda$

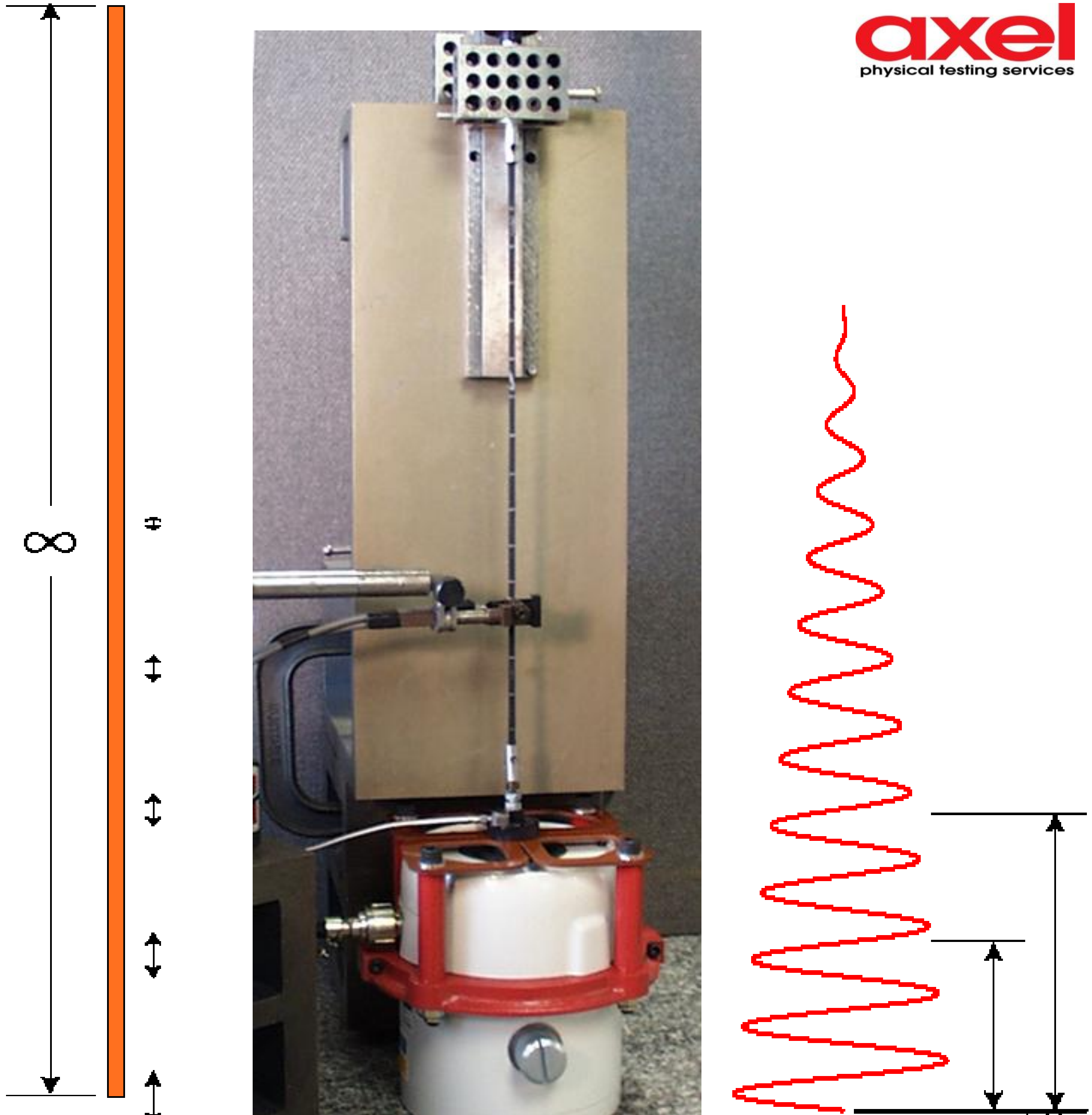
c speed of longitudinal wave

f excitation frequency

λ wave length

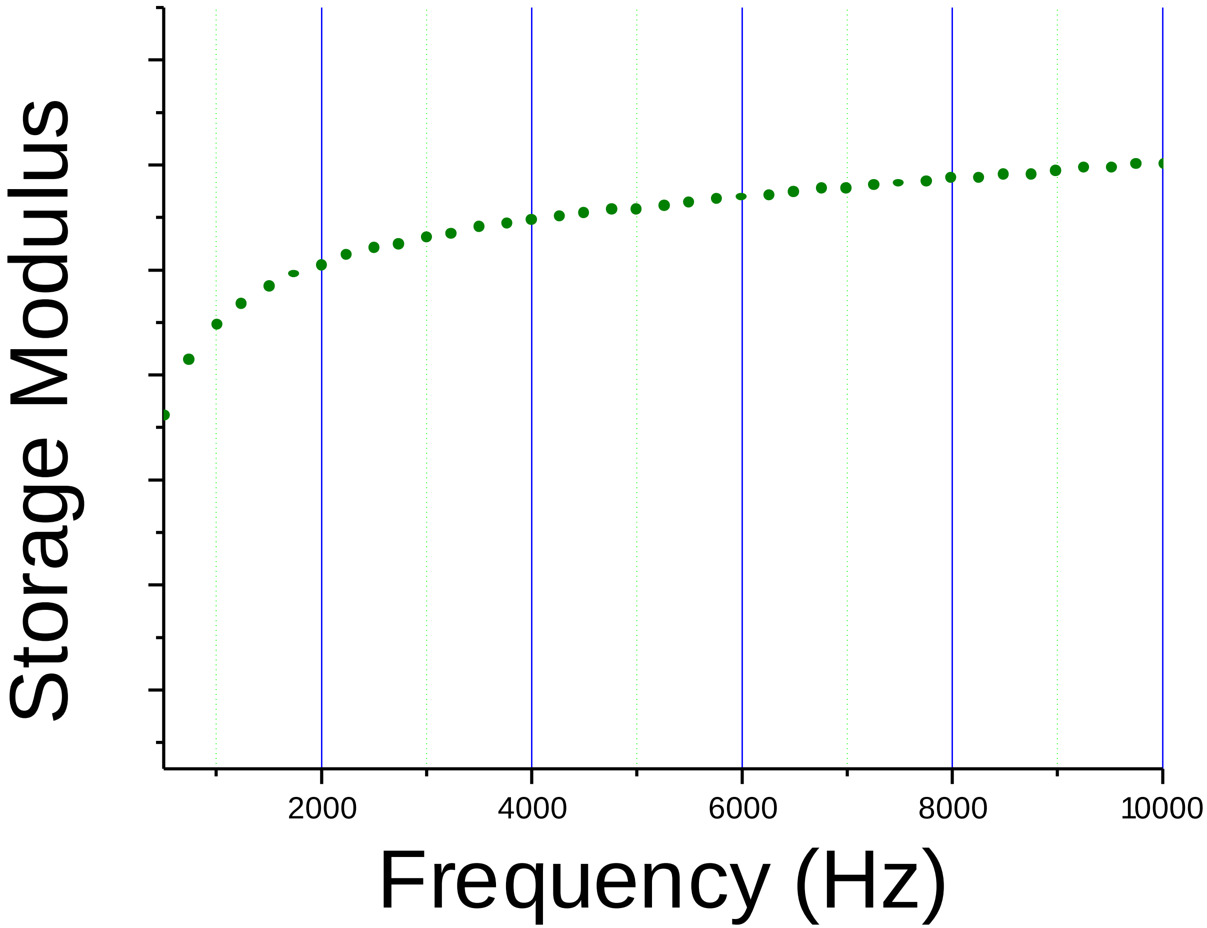
E* Dynamic Modulus

Wave Propagation



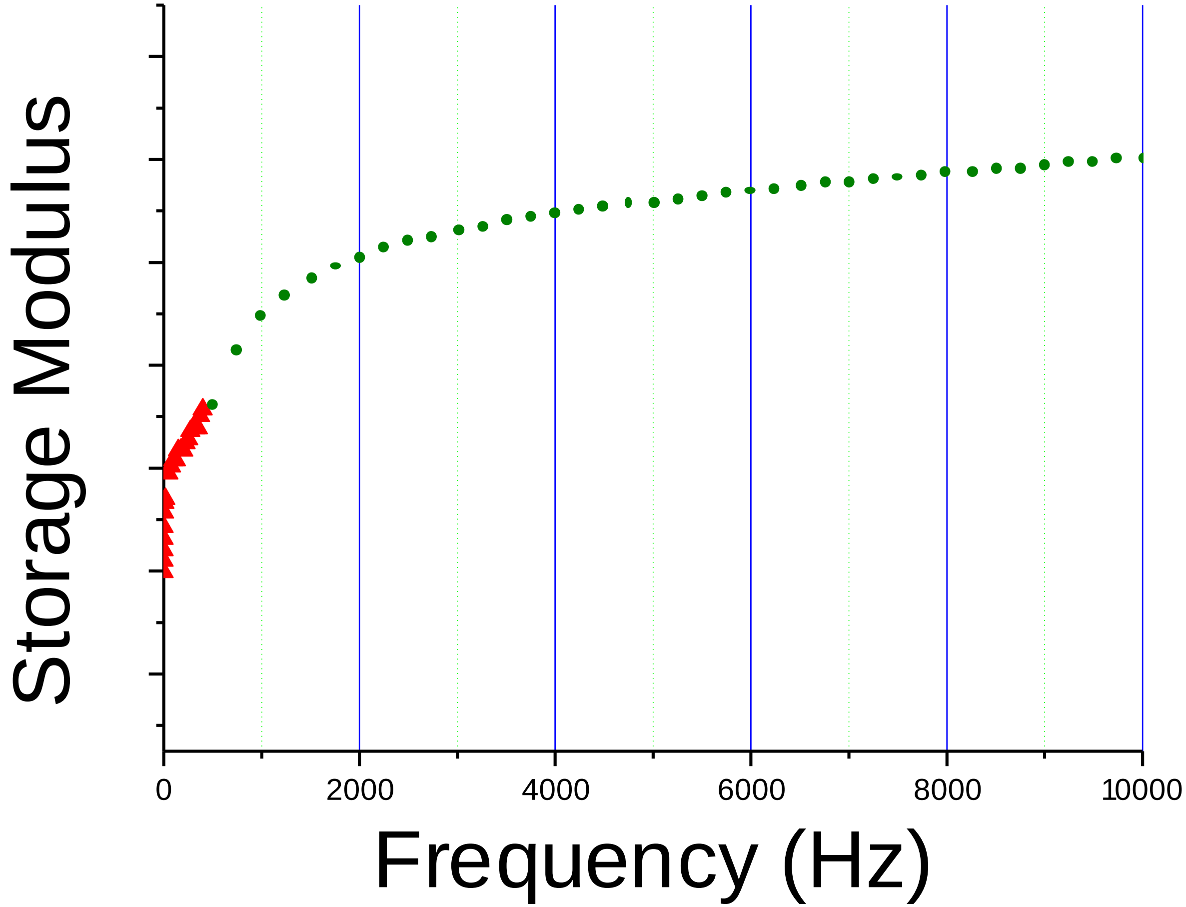
High Frequency Dynamics

Data at 30%
Mean Strain



Vibrations

Data at 30%
Mean Strain



Model Verification

Attributes of a Good Model Verification Experiment

The geometry is realistic.

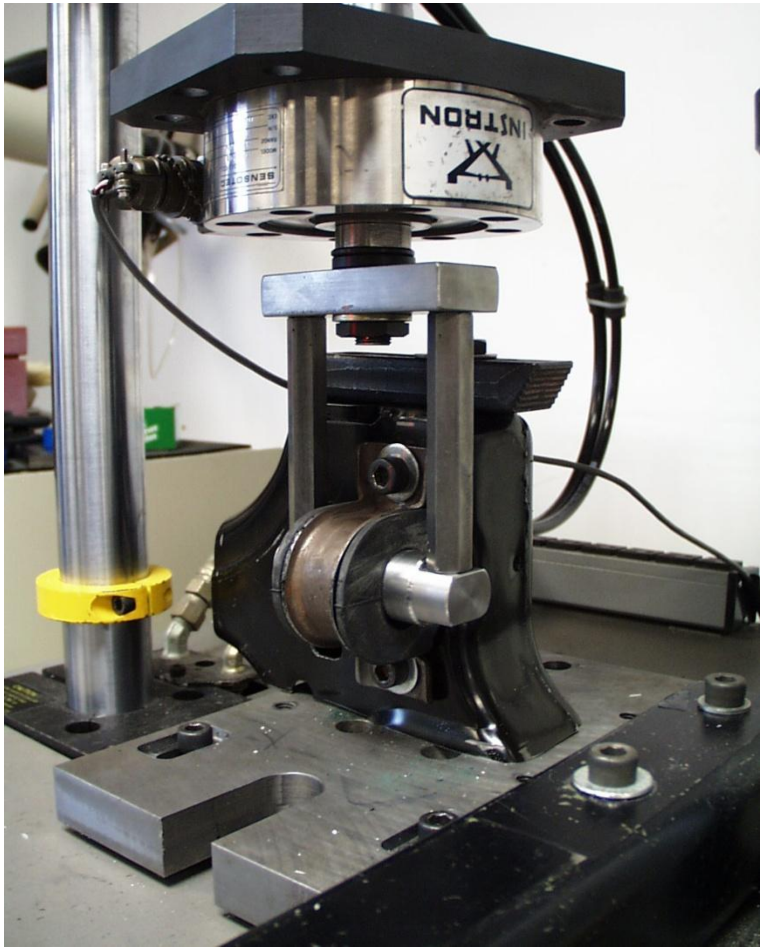
All Relevant Constraints are Measurable.

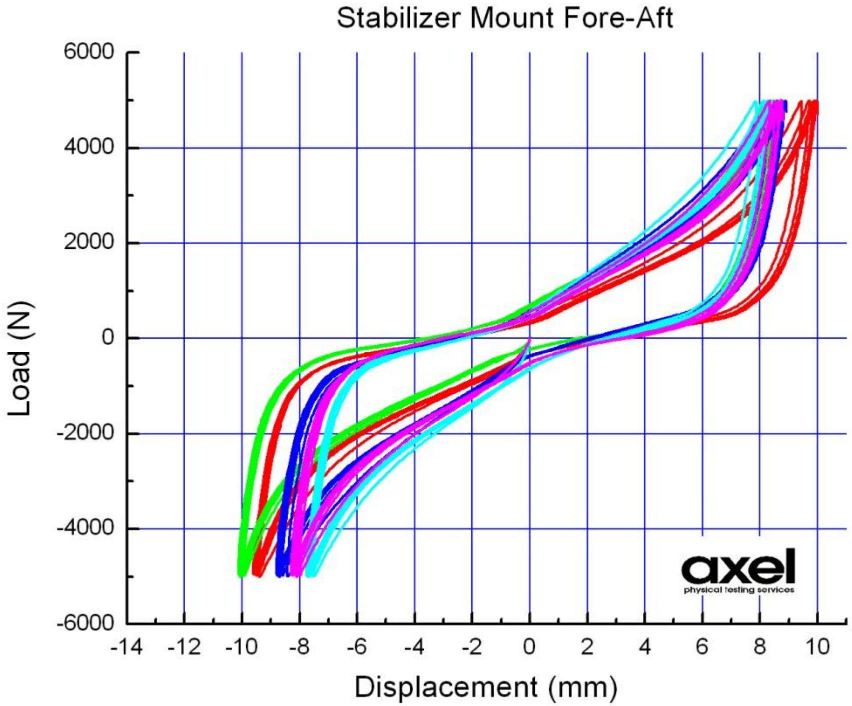
The Analytical Model is Well Understood

Model Verification

The Contribution of the Flashing on the Part was Unexpected, Initially Not Modeled, But Very Significant to the Actual Load Deflection

Model Verification





In Summary

We covered:

- General Strategy
- Basic Hyperelastic
- Basic Viscoelastic
- Thermal Effects
- Dynamic Measurements

Thank you!