Testing and Analysis

What material tests are typically performed to calibrate a hyperelastic material model?

The answer is:

B. Simple Tension, Planar Tension, Equal Biaxial Tension, and Volumetric Compression

Multiple experiments are desirable to fit the hyperelastic surface. And the experiments **need to put the elastomer into a known state of strain.**

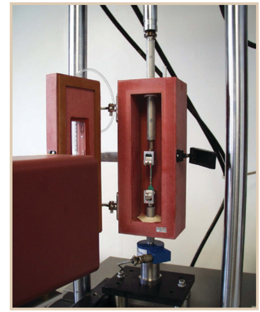

Figure 2, Simple (uniaxial) Tension

The answer is not:

A. Simple Tension, Simple Compression

Simple compression is generally undesirable because during the compression experiment, surface friction strains create an undefined strain state.

C. Simple Compression and Planar Tension

Simple compression is generally undesirable because during the compression experiment, surface friction strains create an undefined strain state.

Figure 3, Equal Biaxial Tension

D. Simple Shear and Poisson's Ratio

Poisson's ratio is not measured with sufficient precision to be a meaningful measurement for elastomers.

Please see the back side for further explanations.

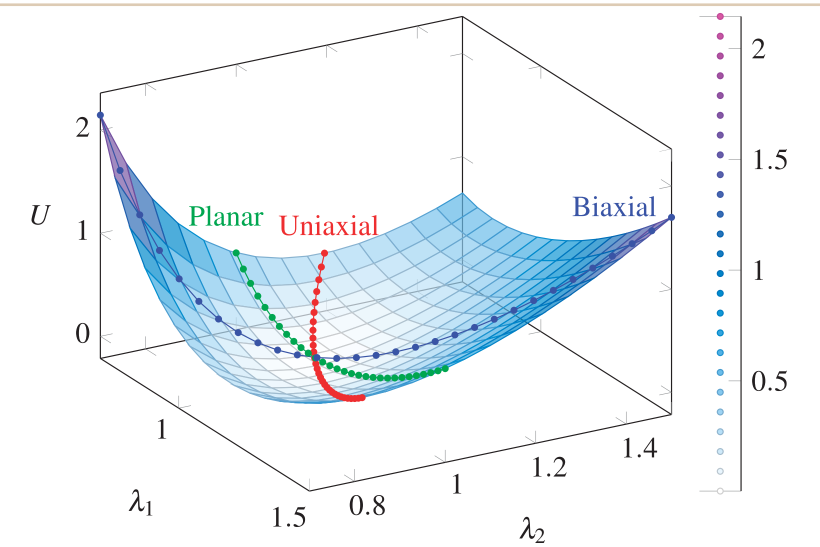

Figure 1: Hyperelastic energy surface, $U = \frac{G}{2}(\lambda_1^2 + \lambda_2^2 + \lambda_3^2 - 3)$, with three testing paths.

Figure 4, Planar Tension

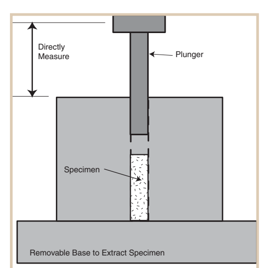

Figure 5, Volumetric Compression

Discussion:

Hyperelastic material models are used to define elastomers. Elastomers are materials that exhibit nearly incompressible behavior and often experience high strains in service. Because of their nearly incompressible nature, the states of strain in an elastomeric part are usually complex. They are a mixture of tension, compression and shear and a very small amount of volume change.

Hyperelastic material models may be thought of as a surface which contains the stress response to all of the various combinations of strains. When we calibrate the material model, we define the surface. We do this by performing individual experiments where each experiment (such as a tensile test) defines a line on the surface. To adequately define the entire surface, we perform experiments in several strain states so as to crisscross the surface and force it to represent the actual material.

The experiments used to calibrate the material model must put the material in a known state of strain so that we know exactly what the test data represents. A tension specimen must be long so that it is only in tension and there are no lateral constraints on the specimen. A compression test would seem like a good experiment because it is simple and elastomers are often used in compression. However, since even tiny amounts of friction between the test specimen and the contacting platen cause significant friction strains in the material, the overall strain state becomes unknown, making the compression test less desirable.

The nearly incompressible behavior of elastomers is such that the Poisson's ratio is nearly 0.5. If an elastomer is constrained in service, exactly how close to 0.5 it is may be critical to predicting stresses. Since we cannot measure Poisson's ratio in the lab with sufficient precision to extract this information, we perform a confined compression experiment to directly measure the bulk modulus.

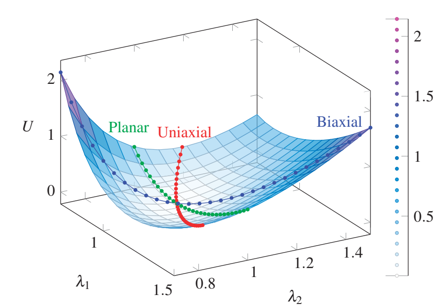

Figure 1: Hyperelastic energy surface, $U = \frac{G}{2}(\lambda_1^2 + \lambda_2^2 + \lambda_3^2 - 3)$, with three testing paths.

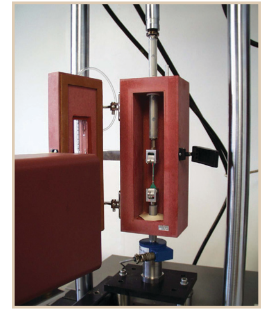

Figure 2, Simple (uniaxial) Tension

Figure 3, Equal Biaxial Tension

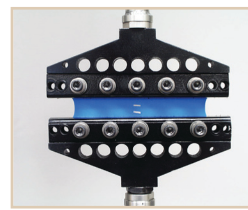

Figure 4, Planar Tension

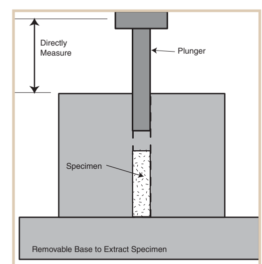

Figure 5, Volumetric Compression

For more information, visit www.axelproducts.com.

Axel Products provides physical testing services for engineers and analysts. The focus is on the characterization of nonlinear materials such as elastomers and plastics.

Axel Products, Inc.

2255 S Industrial
Ann Arbor MI 48104
Tel: 734 994 8308
Fax: 734 994 8309
info@axelproducts.com

axel
physical testing services