Testing and Analysis

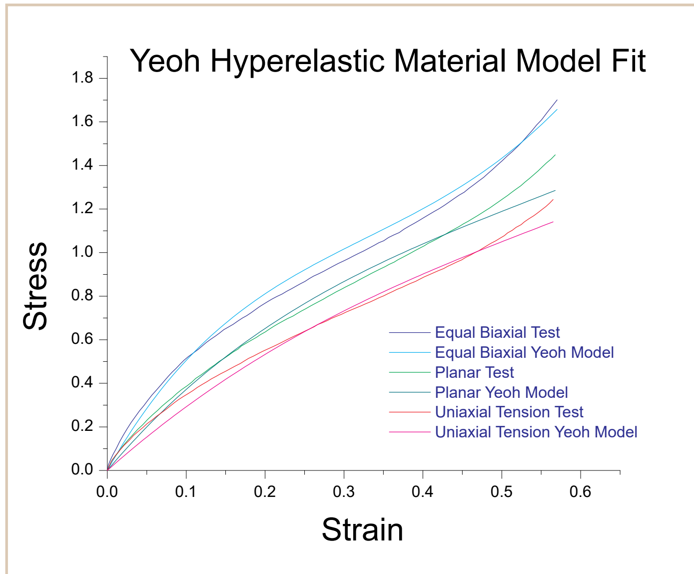
Fitting a Hyperelastic Material Model for a Stabilized-Loading Application

Objective

A material model is needed to describe the behavior of an elastomeric bushing in service.

Introduction

At Axel, we fit material models based on the needs of the simulation, the capabilities of the finite-element software being used and the behavior of the material. In this case, the material will be compressed and somewhat confined in a metal housing. A hyperelastic model is selected to capture the incompressible material behavior during use to describe the complex strain field and predict the performance of the part.

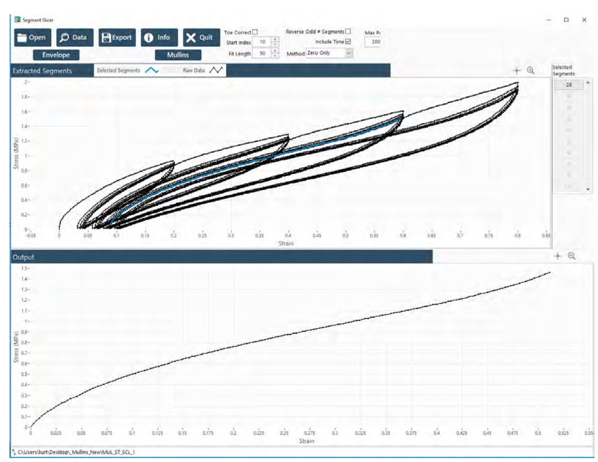


Yeoh Hyperelastic Material Model Fit to Experimental Data

Testing and Modeling Effort

Physical experiments are performed in multiple strain states so that the calibrated hyperelastic model describes the material behavior during its complex deformation. Multiple models are reviewed and the simplest math model with the best fit is selected. Models considered include Mooney-Rivlin, Neo-Hookean, Yeoh, Ogden, Gent, and Arruda-Boyce. The experiments run are the three classic experiments: uniaxial tension, planar tension (pure shear), and equal biaxial extension. Because the bushing will experience significant confinement, a volumetric-compression experiment is performed to capture the bulk behavior. Uniaxial compression is avoided because of adverse friction effects during the experiment.

The experiments were run using a slow cyclic time-strain loading-unloading pattern. The test specimens were stretched from zero stress to 20% strain and unloaded to zero stress 5 times and then strained to 40% strain and unloaded to zero stress 5 times and then on to 60% and to 100% levels. This loading pattern allows us to observe the effects of Mullins softening on the material stiffness and it also allows us to observe any plastic-strain accumulation. For this application, the plastic-strain accumulation was not considered to be significant and a stabilized 60% loading was picked to be typical of the part loading condition.

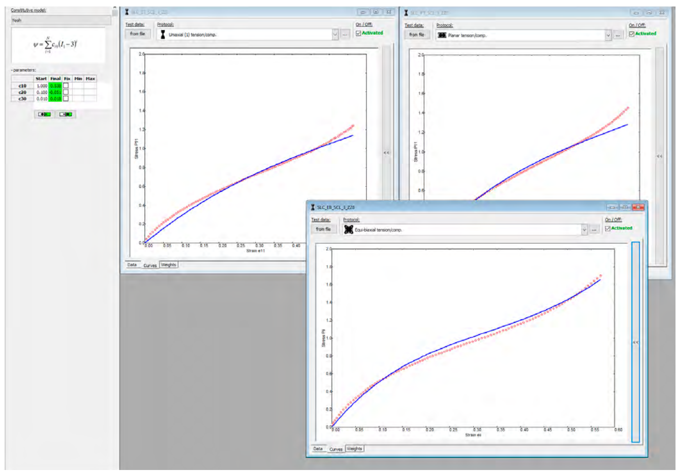


The stabilized 5th stretch to 60% strain is sliced out and shifted to zero.

The 5th loading of each experiment to 60% strain was “sliced out” of the larger data set, shifted to zero stress and strain, and used as a set of experiments to fit a material model.

We used a commercial fitting tool, Hyperfit, to do the fitting operation. The same data-handling tasks would be applicable using other fitting tools.

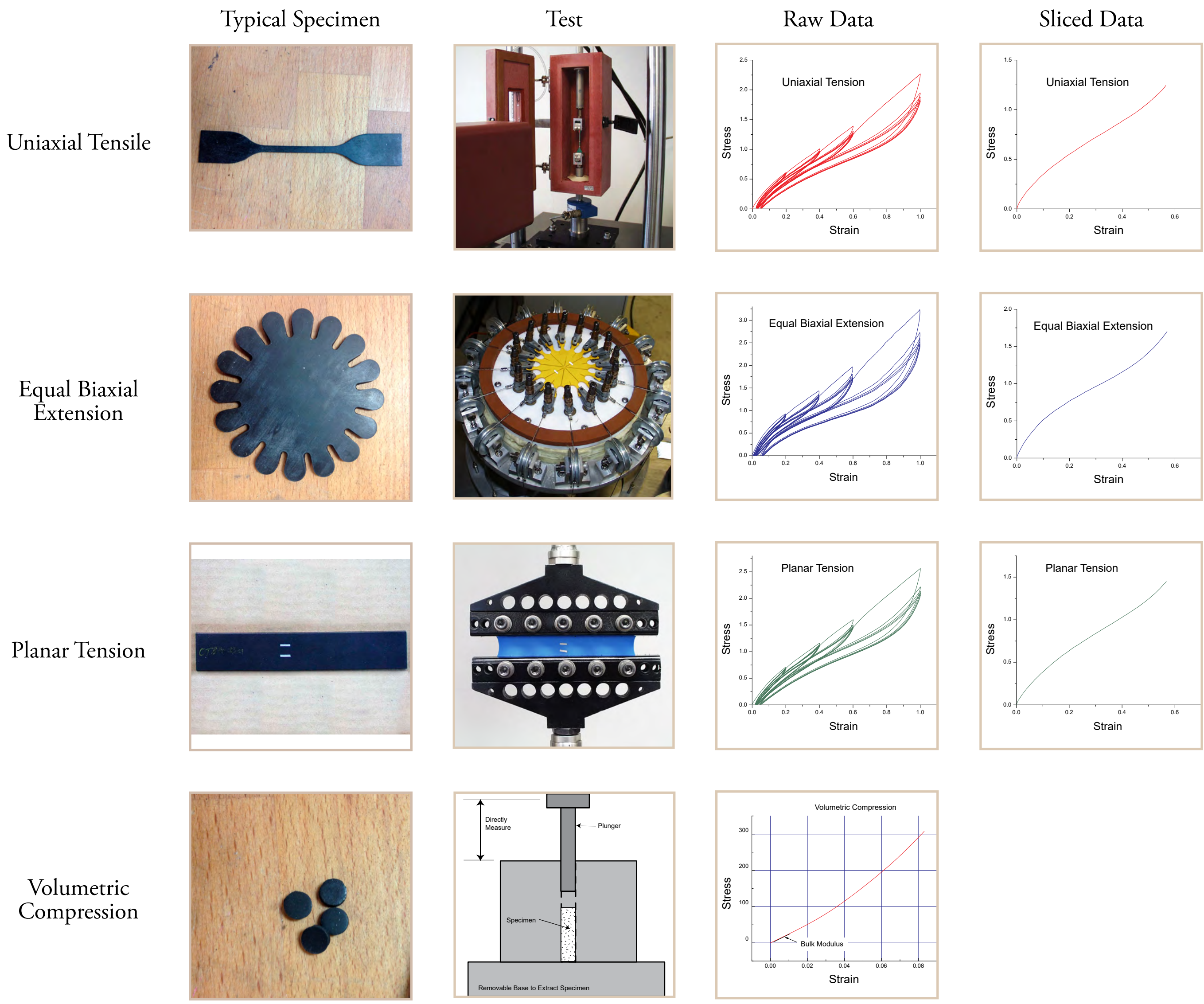
The last step is to run single-element models to verify that the material model performs as expected in the simulation software under the loading conditions of the experiments. This step must happen. In this case, we ran Abaqus single-element simulations in uniaxial tension, planar tension, and equal biaxial extension and compared these results to the experimental data to which the model had been calibrated. Any time fitting tools external to the simulation software are used, verification must take place because simple or extreme errors may appear.



Hyperfit fitting utility used to find Hyperelastic coefficients.

Test Plan Summary:
Uniaxial Tension Test, Slow Cyclic Loading, 23C
Planar Tension Test, Slow Cyclic Loading, 23C
Uniaxial Tension Test, Slow Cyclic Loading, 23C
Volumetric Compression, 23C

Analysis Tools Summary:
Axel Internal Data Handling Tools
Hyperfit fitting utility
Simulia Abaqus for Single Element Verification



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

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