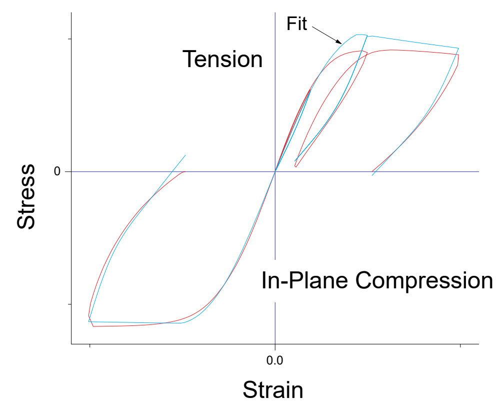
Combining Plastic and Hyperelastic Material Models to Describe Complex PEEK Thermoplastic Behavior

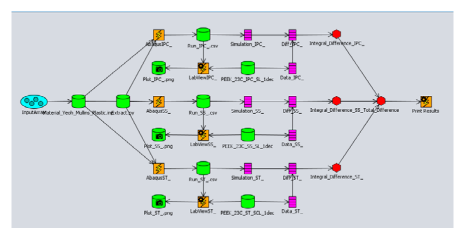
Objective
PEEK is the selected material in a bearing application where stresses are expected to cause plastic yielding.

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 support loads and undergo some localized plastic deformation. It is important to predict the plastic deformation and the resulting deflections under loading. There isn't a distinct yield point and the material has a changing loading slope with increasing strains. An isotropic plastic model with hyperelastic and Mullins softening is selected to capture the behavior.



Plastic-Yeoh-Mullins Fit to tension and compression test data

Testing and Modeling Effort
Often for thermoplastic models only tensile test data is used to calibrate the material model. Because the material model is somewhat complex and the application has a complex stress distribution, tensile data, tensile load-unload data, shear data, and in-plane compression data were collected.



Abaqus wrapped in Optimus optimization software

The tensile load-unload data to 2%, 5%, and 10% strain was used to make initial guesses for the isotropic plasticity parameters. A Yeoh model was selected using a hand-fitted modulus to guess at the first Yeoh term and the 2nd and 3rd parameters were made small. Mullins parameters were selected to make the Mullins effect small. We could have been more methodical about separating these effects and fitting them individually but the analyst was feeling lucky.

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**YEOH W/ MULLINS
*SOLID SECTION,ELSET=ONE,MATERIAL=YEOH_MULL_PLASTICITY
*MATERIAL,NAME=YEOH_MULL_PLASTICITY
*HYPERELASTIC, YEOH
**C10, C20,  C30,  D1,  D2,  D3 (if no VC, Ds are ZERO)
5.7845350000000e+002, -1.9704010000000e+004, 2.7214530000000e+005, 0.0, 0.0, 0.0
*MULLINS EFFECT
** R, M, BETA
1.9291200000000e+000, 1.9575400000000e+000, 9.8730000000000e-002
*PLASTIC, HARDENING=ISOTROPIC
**YIELD STRESS,PLASTIC STRAIN
8.2312880000000e+001,0.000
9.9286780000000e+001,1.8000000000000e-004
8.9440630000000e+001,1.4342000000000e-001
```

Final Abaqus Material Model

A single-element uniaxial tensile simulation was configured in Abaqus and wrapped and optimized with the Optimus optimization software until a reasonable solution was obtained.

The last step was 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 operation was performed with terrible results. The very good fit developed with the tensile data yielded very poor results in compression, the very load case that is most critical to this application.

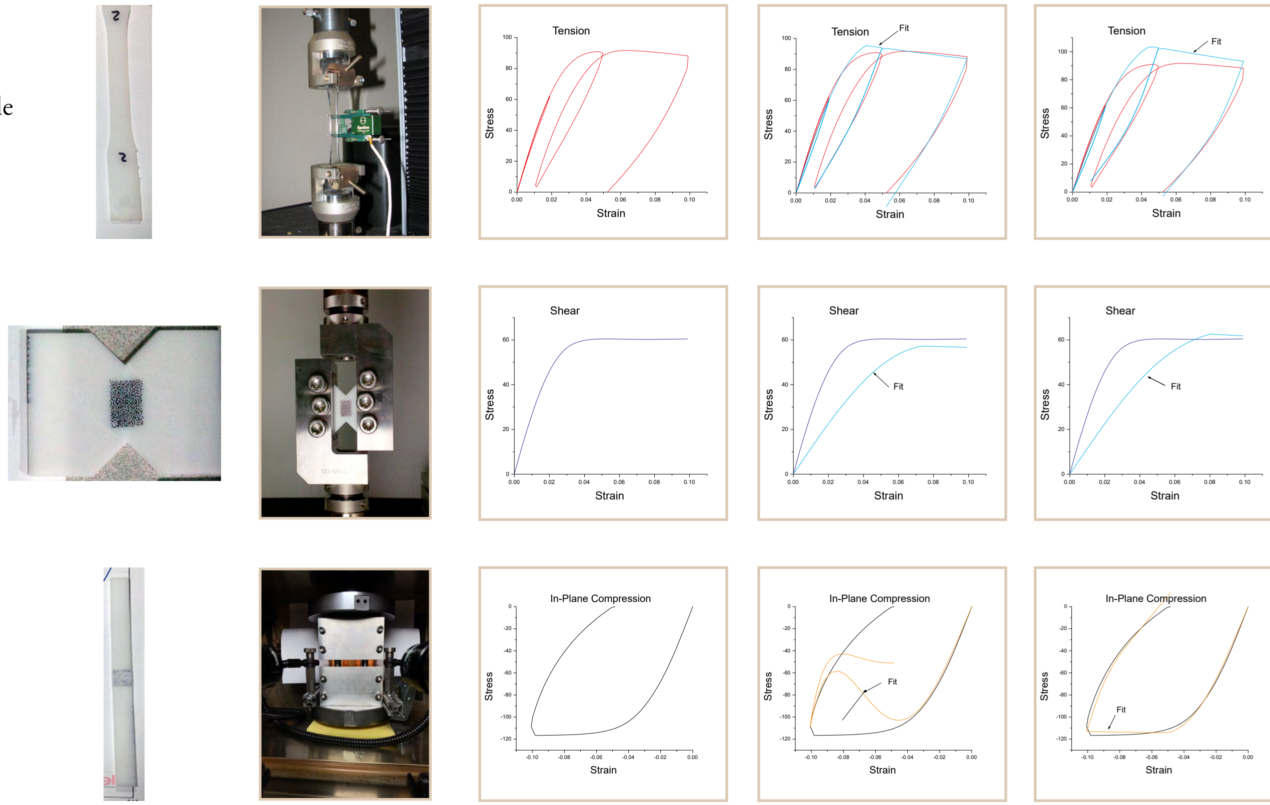
A new optimization tree was developed in the Optimus optimization software using Abaqus elements and tensile, shear, and in-plane-compression data sets using the previous optimization parameters as start values. This effort yielded much more acceptable results.

Typical Specimen | Test | Raw Data | First Fit | Final Fit

Uniaxial Tensile

Shear

In Plane Compression



Test Plan Summary:
Uniaxial Tension Test, Slow Cyclic Loading, 23C
Rail Shear Test, Slow Cyclic Loading, 23C
In-Plane Compression Test, Slow Cyclic Loading, 23C

Analysis Tools Summary:
Axel Internal Data Handling Tools
Optimus Optimization Software
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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