Background

- The mechanical behavior of elastomers is known to be rate-dependent and to exhibit hysteresis upon cyclic loading. Although these features of the material response are well-recognized and important to its function, few models attempt to quantify these aspects of the mechanical response.
- For this reason we have developed a new advanced user-material subroutine [1-6] that accurately predicts the large strain-, time- and temperature dependent behavior of both filled and unfilled elastomer-like materials.
- The foundation of the model is that the mechanical behavior can be decomposed into two parts: an equilibrium network corresponding to the state that is approached in long time stress relaxation tests; and a second network capturing the non-linear rate-dependent deviation from the equilibrium state. The time-dependence of the second network is further assumed to be governed by the reptational motion of molecules having the ability to significantly change conformation, thereby relaxing the overall stress state.

Key Features of the User Material Model

- The user material model has been tested on a number of different elastomers (e.g. natural rubber, chloroprene rubber, NBR, ABR, EPDM, FKM, Viton, and Silicone rubber) and soft biological tissues. The material model has also been tested on elastomeric material with different types and amounts of filler particles.
- The material model contains 8 material constants that can be determined from uniaxial testing results.

Once the material model has been calibrated, the user material subroutine can be used to simulate arbitrary geometries and thermomechanical loading conditions. The influence of different amounts of filler particles is also directly obtained.

The user material subroutine is easy to use and numerically stable. The subroutine is provided as a shared library with an annual license agreement. The subroutine has been designed to work with the commercial finite element packages ABAQUS/Standard, ABAQUS/Explicit (HKS, Inc.), and LS-DYNA (Livermore Software Technology Corp). The subroutine can be modified to work with other finite element packages.
Case Study 1: Time-Dependent Behavior of Filled Chloroprene Rubber

The mechanical response of chloroprene rubber is characterized by hysteresis and time-dependence that increases with filler particle concentration. This behavior is seen in most elastomers and, as shown in the figure to the right, can be captured by the user-material subroutine. In this case the material parameters were found for one concentration of filler particles and the influence of the filler particles was separately determined by examining the change in equilibrium stress with fillers.

Case Study 2: Modeling of Soft Biological Tissues

The user-material model has also been shown to capture the mechanical behavior of different soft biological tissues [1]. The figure to the right shows the cyclic shear response of rat septal myocardium at a shear strain rate of 0.067/s. The figure shows that the predicted response is in good agreement with the experimental data.

References


