Background

- Polymeric foams play an important role in many structural and commercial applications. The mechanical behavior of polymeric foams is very different from solid polymers, and to a first order, is dominated by deformation and distortion of the microstructure. It is well known, however, that polymeric foams also exhibit time-dependence and hysteresis. These characteristic behaviors are mainly controlled by the deformation of the solid polymer that makes up the microstructure.

- There currently are very few models that attempt to predict the large deformation, time-dependent behavior of polymeric foams, and none of these models can accurately quantify the non-linear behavior that is observed for many foams. For this reason we have developed a new material subroutine [1] that accurately predict the large strain, time- and temperature dependent behavior of polymeric foams at different reduced densities.

- The foundation of the new model is a generalization of currently available hyperfoam models, which are known to predict the equilibrium response of foams, but are unable of predicting time-dependence, hysteresis, and permanent set. In the new user material model the mechanical behavior is conceptually 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.

The user material subroutine can be used to simulate different types of polymeric foam components subjected to different loading conditions. The foam density is an input parameter to the model.

Key Features of the User Material Model

- The user material model has been tested on different polymeric foams with different reduced densities. The predicted behavior of the model has been shown to be more accurate than hyperviscoelastic models currently used.

- The material model supports both traditional I₁-based and principal stretch based hyperfoam models and contains 3 material constants to characterize the time-dependence of the foam.
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: Time-Dependent Behavior of EPDM Foam

The stiffness of EPDM foam as a function of reduced density is shown in the figure below. This figure also shows the predictions of the Garboczi and Day [2] model which has been shown to accurately captures the influence of reduced density on the stiffness. This representation is also used in the advanced foam model to capture the dependence on the reduced density.

The large strain behavior of the foam in uniaxial compression, confined compression, and simple shear is shown in the figure below. In this figure, the shear data (at two different strain rates) is plotted with positive values, and the uniaxial compression and confined compression data are plotted with negative stress and strain values. In the figure is also shown the predicted response from the user material subroutine. The figure shows that the model accurately captures the behavior in the different loading modes and also the time-dependence and hysteresis.

References