Material Model 31: Slightly Compressible Rubber Model

This model implements a modified form of the hyperelastic constitutive law first described in [Kenchington 1988].

The strain energy functional, U, is defined in terms of the input constants as:

$$U = C_{100}\, I_1 + C_{200}\, I_1^{\,2} + C_{300}\, I_1^{\,3} + C_{400}\, I_1^{\,4} + C_{110} I_1 I_2 + C_{210} I_1^{\,2} I_2 + C_{010}\, I_2 + C_{020} I_2^{\,2} + f(J) \tag{19.31.1}$$

where the strain invariants can be expressed in terms of the deformation gradient matrix, F_{ij}, and the Green-St. Venant strain tensor, E_{ij}:

$$\begin{aligned} J &= \left|F_{ij}\right| \\ I_1 &= E_{ii} \\ I_2 &= \frac{1}{2!}\delta^{ij}_{pq} E_{pi} E_{qj} \end{aligned} \tag{19.31.2}$$

The derivative of U with respect to a component of strain gives the corresponding component of stress

$$S_{ij} = \frac{\partial U}{\partial E_{ij}} \tag{19.31.3}$$

where, S_{ij}, is the second Piola-Kirchhoff stress tensor which is transformed into the Cauchy stress tensor:

$$\sigma_{ij} = \frac{\rho}{\rho_0}\frac{\partial x_i}{\partial X_k}\frac{\partial x_j}{\partial X_l} S_{kl} \tag{19.31.4}$$

where ρ_0 and ρ are the initial and current density, respectively.

Material Model 32: Laminated Glass Model

This model is available for modeling safety glass. Safety glass is a layered material of glass bonded to a polymer material which can undergo large strains.

The glass layers are modeled by isotropic hardening plasticity with failure based on exceeding a specified level of plastic strain. Glass is quite brittle and cannot withstand large strains before failing. Plastic strain was chosen for failure since it increases monotonically and, therefore, is insensitive to spurious numerical noise in the solution.

The material to which the glass is bonded is assumed to stretch plastically without failure. The user defined integration rule option must be used with this material. The user defined rule specifies the thickness of the layers making up the safety glass. Each integration point is flagged with a zero if the layer is glass and with a one if the layer is polymer.

An iterative plane stress plasticity algorithm is used to enforce the plane stress condition.