used 800 history variables would be stored. Not only is memory much less for this model, but the CPU time required is also considerably reduced.

Material Model 117-118: Composite Matrix

This material is used for modeling the elastic responses of composites where pre-integration, which is done outside of LS-DYNA unlike the lay-up option above, is used to compute the extensional, bending, and coupling stiffness coefficients for use with the Belytschko-Tsay and the assumed strain resultant shell formulations. Since the stresses are not computed in the resultant formulation, the stresses output to the binary databases for the resultant elements are zero.

The calculation of the force, N_{ij}, and moment, M_{ij}, stress resultants is given in terms of the membrane strains, ε_i^0, and shell curvatures, κ_i, as:

$$\begin{Bmatrix} N_x \\ N_y \\ N_{xy} \\ M_x \\ M_y \\ M_{xy} \end{Bmatrix} = \begin{bmatrix} C_{11} & C_{12} & C_{13} & C_{14} & C_{15} & C_{16} \\ C_{21} & C_{22} & C_{23} & C_{24} & C_{25} & C_{26} \\ C_{31} & C_{32} & C_{33} & C_{34} & C_{35} & C_{36} \\ C_{41} & C_{42} & C_{43} & C_{44} & C_{45} & C_{46} \\ C_{51} & C_{52} & C_{53} & C_{54} & C_{55} & C_{56} \\ C_{61} & C_{62} & C_{63} & C_{64} & C_{65} & C_{66} \end{bmatrix} \begin{Bmatrix} \varepsilon_x^0 \\ \varepsilon_y^0 \\ \varepsilon_z^0 \\ \kappa_x \\ \kappa_y \\ \kappa_{xy} \end{Bmatrix} \tag{19.117.1}$$

where $C_{ij} = C_{ji}$.. In this model this symmetric matrix is transformed into the element local system and the coefficients are stored as element history variables.

In a variation of this model, *MAT_COMPOSITE_DIRECT, the resultants are already assumed to be given in the element local system which reduces the storage since the 21 coefficients are not stored as history variables as part of the element data. The shell thickness is built into the coefficient matrix and, consequently, within the part ID, which references this material ID, the thickness must be uniform.

Material Model 119: General Nonlinear 6DOF Discrete Beam

Catastrophic failure, which is based on displacement resultants, occurs if either of the following inequalities are satisfied:

$$\left(\frac{u_r}{u_r^{tfail}}\right)^2 + \left(\frac{u_s}{u_s^{tfail}}\right)^2 + \left(\frac{u_t}{u_t^{tfail}}\right)^2 + \left(\frac{\theta_r}{\theta_r^{tfail}}\right)^2 + \left(\frac{\theta_s}{\theta_s^{tfail}}\right)^2 + \left(\frac{\theta_t}{\theta_t^{tfail}}\right)^2 - 1. \geq 0$$

$$\left(\frac{u_r}{u_r^{cfail}}\right)^2 + \left(\frac{u_s}{u_s^{cfail}}\right)^2 + \left(\frac{u_t}{u_t^{cfail}}\right)^2 + \left(\frac{\theta_r}{\theta_r^{cfail}}\right)^2 + \left(\frac{\theta_s}{\theta_s^{cfail}}\right)^2 + \left(\frac{\theta_t}{\theta_t^{cfail}}\right)^2 - 1. \geq 0 \tag{19.119.1}$$

After failure the discrete element is deleted. If failure is included either the tension failure or the compression failure or both may be used.

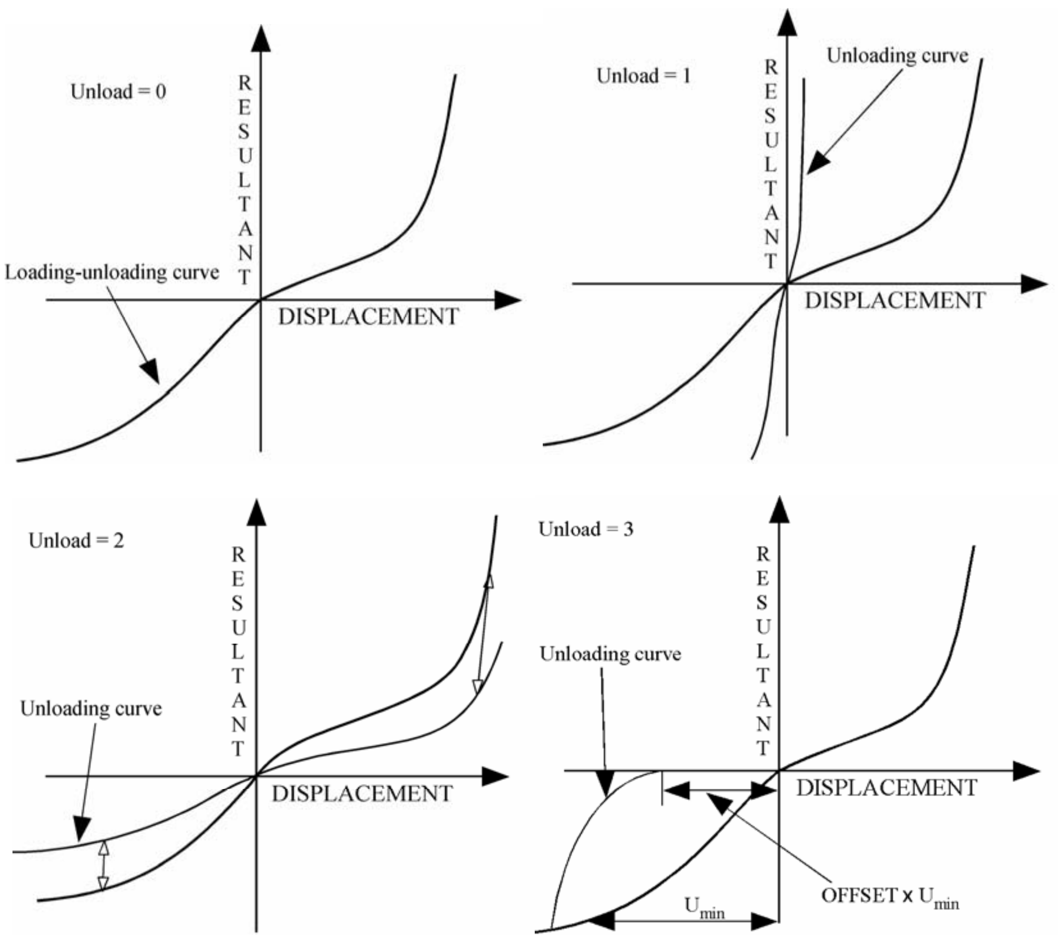

Figure 19.119.1. Load and unloading behavior.

Material Model 120: Gurson

The Gurson flow function is defined as:

$$\Phi = \frac{\sigma_M^2}{\sigma_Y^2} + 2q_1 f^* \cosh\left(\frac{3q_2\sigma_H}{2\sigma_Y}\right) - 1 - \left(q_1 f^*\right)^2 = 0 \tag{19.120.1}$$

where σ_M is the equivalent von Mises stress, σ_Y is the Yield stress, σ_H is the mean hydrostatic stress. The effective void volume fraction is defined as

$$f^*(f) = \begin{cases} f & f \le f_c \\ f_c + \dfrac{1/q_1 - f_c}{f_F - f_c}(f - f_c) & f > f_c \end{cases} \tag{19.120.2}$$

The growth of void volume fraction is defined as

$$\dot{f} = \dot{f}_G + \dot{f}_N \tag{19.120.3}$$