In tensile and compression directions and in a- as well as in b- direction, different failure surfaces can be assumed. The damage values, however, increase only when the loading direction changes.

Special control of shear behavior of fabrics

For fabric materials a nonlinear stress strain curve for the shear part of failure surface FS=-1 can be assumed as given below. This is not possible for other values of FS.
The curve, shown in Figure 19.58.1, is defined by three points:

a) the origin (0,0) is assumed,
b) the limit of the first slightly nonlinear part (must be input), stress (TAU1) and strain (GAMMA1), see below.
c) the shear strength at failure and shear strain at failure.

In addition a stress limiter can be used to keep the stress constant via the *SLIMS* parameter. This value must be less than or equal to 1.0 and positive, which leads to an elastoplastic behavior for the shear part. The default is 1.0E-08, assuming almost brittle failure once the strength limit SC is reached.

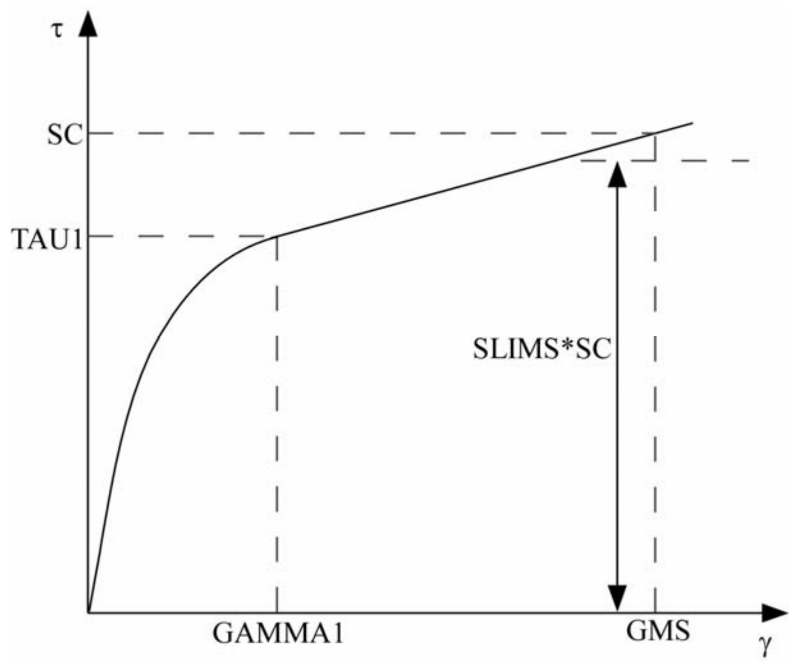

Figure 19.58.1. Stress-strain diagram for shear.

Material Type 60: Elastic With Viscosity

This material model was developed to simulate the forming of glass products (e.g., car windshields) at high temperatures. Deformation is by viscous flow but elastic deformations can also be large. The material model, in which the viscosity may vary with temperature, is suitable for treating a wide range of viscous flow problems and is implemented for brick and shell elements.

Volumetric behavior is treated as linear elastic. The deviatoric strain rate is considered to be the sum of elastic and viscous strain rates:

$$\dot{\underset{\sim}{\varepsilon}}'_{total} = \dot{\underset{\sim}{\varepsilon}}'_{elastic} + \dot{\underset{\sim}{\varepsilon}}'_{viscous} = \frac{\dot{\underset{\sim}{\sigma}}'}{2G} + \frac{\dot{\underset{\sim}{\sigma}}'}{2\nu} \tag{19.60.1}$$

where G is the elastic shear modulus, ν is the viscosity coefficient, and ~ indicates a tensor. The stress increment over one time step dt is

$$d\underset{\sim}{\sigma}' = 2G\dot{\underset{\sim}{\varepsilon}}'_{total}dt - \frac{G}{\upsilon}dt\underset{\sim}{\sigma}' \tag{19.60.2}$$

The stress before the update is used for $\underset{\sim}{\sigma}'$. For shell elements, the through-thickness strain rate is calculated as follows

$$d\sigma_{33} = 0 = K\left(\dot{\varepsilon}_{11} + \dot{\varepsilon}_{22} + \dot{\varepsilon}_{33}\right)dt + 2G\dot{\varepsilon}'_{33}\,dt - \frac{G}{\upsilon}dt\sigma'_{33} \tag{19.60.3}$$

where the subscript *ij=33* denotes the through-thickness direction and K is the elastic bulk modulus. This leads to:

$$\dot{\varepsilon}_{33} = -a\left(\dot{\varepsilon}_{11} + \dot{\varepsilon}_{22}\right) + bp \tag{19.60.4}$$

$$a = \frac{\left(K - \frac{2}{3}G\right)}{\left(K + \frac{4}{3}G\right)} \tag{19.60.5}$$

$$b = \frac{Gdt}{\upsilon\left(K + \frac{4}{3}G\right)} \tag{19.60.6}$$

in which p is the pressure defined as the negative of the hydrostatic stress.

Material Model 61: Maxwell/Kelvin Viscoelastic with Maximum Strain

The shear relaxation behavior is described for the Maxwell model by:

$$G(t) = G_\infty + (G_0 - G_\infty)e^{-\beta t}. \tag{19.61.1}$$

A Jaumann rate formulation is used

$$\overset{\nabla}{s}'_{ij} = 2\int_0^t G\left(t-\tau\right)\dot{\varepsilon}'_{ij}\left(\tau\right)dt \tag{19.61.2}$$