*MAT_COHESIVE_TH

This is Material Type 185. It is a cohesive model by Tvergaard and Hutchinson [1992] for use with cohesive element fomulations; see the variable ELFORM in *SECTION_SOLID and *SECTION_SHELL. The implementation is based on the description of the implementation in the Sandia National Laboratory code, Tahoe [2003].

Card 1	1	2	3	4	5	6	7	8
Variable	MID	RO	ROFLG	INTFAIL	SIGMAX	NLS	TLS	
Type	A8	F	F	F	F	F	F	

Card 2	1	2	3	4	5	6	7	8
Variable	LAMDA1	LAMDA2	LAMDAF	STFSF				
Type	F	F	F	F				

VARIABLE	DESCRIPTION
MID	Material identification. A unique number or label not exceeding 8 characters must be specified.
RO	Mass density
ROFLG	Flag for whether density is specified per unit area or volume. ROFLG = 0 specified density per unit volume (default), and ROFLG = 1 specifies the density is per unit area for controlling the mass of cohesive elements with an initial volume of zero.
INTFAIL	The number of integration points required for the cohesive element to be deleted. If it is zero, the element won't be deleted even if it satisfies the failure criterion. The value of INTFAIL may range from 1 to 4, with 1 the recommended value.
SIGMAX	Peak traction.
NLS	Length scale (maximum separation) in the normal direction.
TLS	Length scale (maximum separation) in the tangential direction.
LAMDA1	Scaled distance to peak traction (Λ_1).

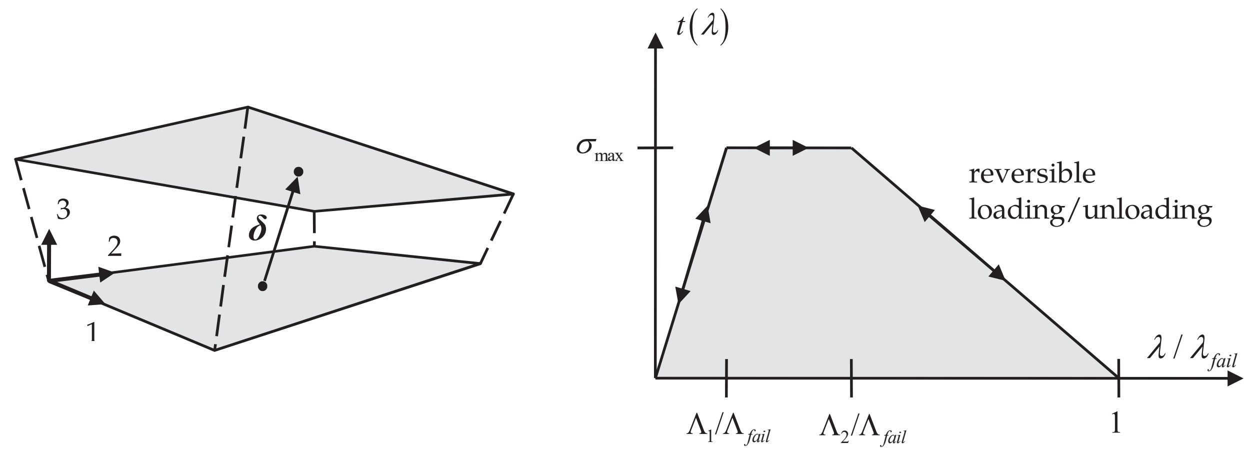

Figure M185-1. Relative displacement and trilinear traction-separation law

VARIABLE	DESCRIPTION
LAMDA2	Scaled distance to beginning of softening (Λ_2).
LAMDAF	Scaled distance for failure (Λ_{fail}).
STFSF	Penetration stiffness multiplier. The penetration stiffness, *PS*, in terms of input parameters becomes: $$\mathrm{PS} = \frac{\mathrm{STFSF} \times \mathrm{SIGMAX}}{\mathrm{NLS} \times \left(\frac{\mathrm{LAMDA1}}{\mathrm{LAMDAF}}\right)}$$

Remarks:

In this cohesive material model, a dimensionless separation measure λ is used, which grasps for the interaction between relative displacements in normal (δ_3 - mode I) and tangential (δ_1, δ_2 - mode II) directions (see Figure M185-1 left):

$$\lambda = \sqrt{\left(\frac{\delta_1}{\mathrm{TLS}}\right)^2 + \left(\frac{\delta_2}{\mathrm{TLS}}\right)^2 + \left(\frac{\langle \delta_3 \rangle}{\mathrm{NLS}}\right)^2}$$

where the Mc-Cauley bracket is used to distinguish between tension ($\delta_3 \geq 0$) and compression ($\delta_3 < 0$). NLS and TLS are critical values, representing the maximum separations in the interface in normal and tangential direction. For stress calculation, a trilinear traction-separation law is used, which is given by (see Figure M185-1 right):

$$t(\lambda) = \begin{cases} \sigma_{\max}\dfrac{\lambda}{\Lambda_1/\Lambda_{\text{fail}}} & \lambda < \Lambda_1/\Lambda_{\text{fail}} \\ \sigma_{\max} & \Lambda_1/\Lambda_{\text{fail}} < \lambda < \Lambda_2/\Lambda_{\text{fail}} \\ \sigma_{\max}\dfrac{1-\lambda}{1-\Lambda_2/\Lambda_{\text{fail}}} & \Lambda_2/\Lambda_{\text{fail}} < \lambda < 1 \end{cases}$$

With these definitions, the traction drops to zero when $\lambda = 1$. Then, a potential ϕ is defined as:

$$\phi(\delta_1, \delta_2, \delta_3) = \text{NLS} \times \int_0^{\lambda} t(\bar{\lambda})\ d\bar{\lambda}$$

Finally, tangential components (t_1, t_2) and normal component (t_3) of the traction acting on the interface in the fracture process zone are given by:

$$t_{1,2} = \frac{\partial \phi}{\partial \delta_{1,2}} = \frac{t(\lambda)}{\lambda}\frac{\delta_{1,2}}{\text{TLS}}\frac{\text{NLS}}{\text{TLS}}, \qquad t_3 = \frac{\partial \phi}{\partial \delta_3} = \frac{t(\lambda)}{\lambda}\frac{\delta_3}{\text{NLS}}$$

which in matrix notation is

$$\begin{bmatrix} t_1 \\ t_2 \\ t_3 \end{bmatrix} = \frac{t(\lambda)}{\lambda}\begin{bmatrix} \dfrac{\text{NLS}}{\text{TLS}^2} & 0 & 0 \\ 0 & \dfrac{\text{NLS}}{\text{TLS}^2} & 0 \\ 0 & 0 & \dfrac{1}{\text{NLS}} \end{bmatrix}\begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \end{bmatrix}$$

In case of compression ($\delta_3 < 0$), penetration is avoided by:

$$t_3 = \frac{\text{STFSF} \times \sigma_{\max}}{\text{NLS} \times \Lambda_1/\Lambda_{\text{fail}}}\delta_3$$

Loading and unloading follows the same path, i.e. this model is completely reversible.

This cohesive material model outputs three tractions having units of force per unit area into the D3PLOT database rather than the usual six stress components. The in plane shear traction t_1 along the 1-2 edge replaces the x-stress, the orthogonal in plane shear traction t_2 replaces the y-stress, and the traction in the normal direction t_3 replaces the z-stress.