/MAT/LAW38 (VISC_TAB)

Block Format Keyword

This law describes the visco-elastic foam tabulated material and can only be used with solid elements.

Format

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
/MAT/LAW38/*mat_ID*/*unit_ID* or /MAT/VISC_TAB/*mat_ID*/*unit_ID*									
mat_title									
ρ_i									
E_0		ν_t		ν_c		R_ν		*Iflag*	*Itota*
β		H		R_D		K_R	K_D	θ	
K_{air}	fct_ID_p	$Fscale_P$							
P_0		R_P		P_{max}		Φ			
fct_ID_{uL}		$Fscale_{unLoad}$		$\dot{\varepsilon}_{\text{unload}}$		a		b	
N_{funct}		*CUToff*		I_{insta}					
E_{final}		ε_{final}		λ		*Visc*		*Tol*	
$Fscale_1$		$Fscale_2$		$Fscale_3$		$Fscale_4$		$Fscale_5$	
$\dot{\varepsilon}_1$		$\dot{\varepsilon}_2$		$\dot{\varepsilon}_3$		$\dot{\varepsilon}_4$		$\dot{\varepsilon}_5$	
fct_ID_{1L}	fct_ID_{2L}	fct_ID_{3L}	fct_ID_{4L}	fct_ID_{5L}					
fct_ID_{1uL}	fct_ID_{2uL}	fct_ID_{3uL}	fct_ID_{4uL}	fct_ID_{5uL}					

Definitions

Field	Contents	SI Unit Example
mat_ID	Material identifier (Integer, maximum 10 digits)	

`unit_ID`	Unit Identifier (Integer, maximum 10 digits)	
`mat_title`	Material title (Character, maximum 100 characters)	
ρ_i	Initial density (Real)	$\left[\frac{\text{kg}}{\text{m}^3}\right]$
E_0	Minimum tension modulus, used for interface and time step computation (Real)	$[\text{Pa}]$
ν_t	Maximum Poisson's ratio in tension Default = 10^{-30} (Real)	
ν_c	Maximum Poisson's ratio in compression (Real)	
R_ν	Exponent for Poisson's ratio computation (Real)	
`Iflag`	Analysis formulation type flag [4] **= 0** viscoelasticity is computed in each principal stress direction **= 1** behavior is linear in both tension and compression (Integer)	
`Itota`	Incremental formulation flag (Integer) Total: 0 or 1 **= 0 (Default)** behavior in tension is linear **=1** behavior in tension is read from stress curves INCREMENTAL: 2 or 3 **= 2** behavior in tension is linear (obsolete) **= 3** behavior in tension is read from stress curves (obsolete)	

β	Relaxation rate for unloading Default = 10^{-30} (Real)	
H	Hysteresis coefficient for unloading Default = 1.0 (Real)	
R_D	Damping factor on strain rate Default = 0.5 (Real)	
K_R	Recovery model flag for unloading (hysteresis loop) (Integer) **= 0 (Default)** No stress recovery on unloading (unloading curve=loading curve) **= 1** Stress recovery on unloading is computed as: $\sigma = \sigma \cdot H \cdot \min\left(1, 1 - e^{-\beta\varepsilon(t)}\right)$ **= 2** Stress recovery on unloading is computed as: $\sigma = \sigma \cdot \left\{1 - H \cdot \left[1 - \left(\frac{E^{\text{int}}}{E^{\text{int}}_{\max}}\right)^{\beta}\right]\right\}$ Where, E^{int} and $E^{\text{int}}_{\max}$ are current internal energy and maximum internal energy, respectively. [6]	
K_D	Decay model flag, hysteresis type (Integer) **= 0 (Default)** Decay is active during loading and unloading **= 1** Decay is only active during loading **= 2** Decay is active during unloading	
θ	Integration coefficient for instantaneous module update Default = 0.67 (Real)	

K_{air}	Air content computation flag [7] (Integer) **= 0 (Default)** No confined air content **= 1** Confined air content computation active **= 2** Read hydrostatic curve (function identifier defined by fct_ID_p). The difference between pure compression and hydrostatic are taken into account.	
fct_ID_p	Pressure curve identifier (pressure vs. relative volume) (Integer)	
$Fscale_P$	Pressure curve scale factor (Real)	$[\mathrm{Pa}]$
P_0	Atmospheric pressure (Real)	$[\mathrm{Pa}]$
R_P	Relaxation rate of pressure Default = 10^{-30} (Real)	
P_{max}	Maximum air pressure Default = 10^{30} (Real)	$[\mathrm{Pa}]$
Φ	Porosity (density of foam/density of polymer) (Real)	
fct_ID_{uL}	Unloading function identifier > 0: when unloading strain rate is equal to the static one, unloading will use only the function fct_ID_{uL}. (Integer)	
$Fscale_{unLoad}$	Unloading function scale factor Default = 1.0 (Real)	$[\mathrm{Pa}]$
$\dot{\varepsilon}_{unload}$	Unloading strain rate (must be greater than $\dot{\varepsilon}_1$) (Real)	$\left[\frac{1}{\mathrm{s}}\right]$
a	Exponent for stress interpolation Default = 1.0 (Real)	
b	Exponent for stress interpolation Default = 1.0 (Real)	

N_{funct}	Number of functions defining rate dependency (five or less) (Integer)	
$CUToff$	Tension cutoff stress. The element is deleted when one element integration point exceeds the tension cutoff stress value. Default = 10^{30} (Real)	$[\mathrm{Pa}]$
I_{insta}	Material instability control flag (Integer) **= 0 (Default)** No material instability control **= 1** Material instability control	
E_{final}	Maximum tension modulus Default = E_0 (Real)	$[\mathrm{Pa}]$
ε_{final}	Absolute value of strain at final modulus Default = 1.0 (Real)	
λ	Modulus interpolation coefficient Default = 1.0 (Real)	
$Visc$	Maximum viscosity [10] Default = 10^{30} (Real)	$[\mathrm{Pa}]$
Tol	Tolerance on principal direction update Default = 1.0 (Real)	
$Fscale_i$	Scale factor for curve i (Real)	$[\mathrm{Pa}]$
$\dot{\varepsilon}_i$	Engineering strain rate for curve i (Real)	$\left[\frac{1}{\mathrm{s}}\right]$
fct_ID_{iL}	Loading function identifier for curve i (Integer)	
fct_ID_{iuL}	Unloading function identifier for curve i (Integer)	

Example (Foam)

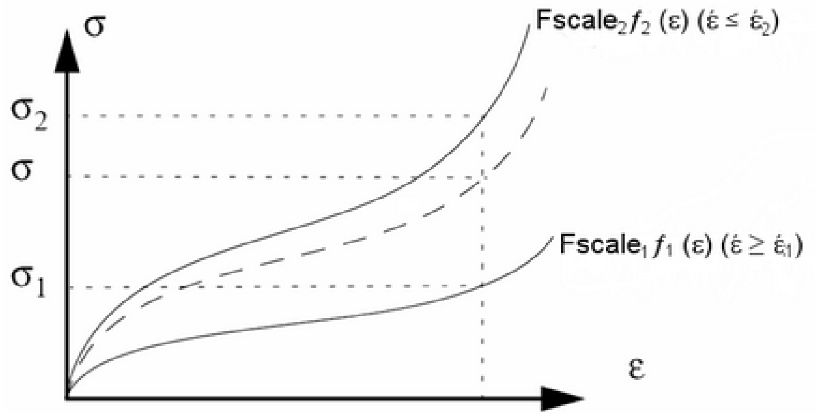
```
#RADIOSS STARTER
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
/UNIT/1
unit for mat
                  Mg                  mm                   s
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
#-  2. MATERIALS:
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
/MAT/VISC_TAB/1/1
Foam
#              RHO_I
               2E-10
#                E_0                nu_t                nu_c                 R_V     Iflag     Itota
                 200                   0                   0                   0         0         0
#               Beta                   H                 R_D       K_R       K_D                Teta
                   0                   0                   0         0         0                   0
#    K_air  fct_ID_p            Fscale_P
         0         0                   1
#                 P0                  Rp                Pmax                 Phi
                   0                   0                   0                   0
#funID_unl                 Fscale_unload        Eps_._unload                   a                   b
         0                             0                   0                   0                   0
#  N_funct                       CUT_off   I_insta
         1                             0         0
#            E_final           Eps_final              Lambda                Visc                 Tol
                   0                   0                   0                   0                   0
#      Fscale_i
                   1
#      Eps_._i
                   0
#    func_ID_iload
         4
#    func_ID_iunload
         0
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
#-  3. FUNCTIONS:
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
/FUNCT/4
function_4
#                  X                   Y
                  -1                -200
                   1                 200
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
#ENDDATA
/END
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
```

Comments

1. Engineering stress versus engineering strain can be input as functions for different strain rates. The stress and strain is positive in compression and negative in tension. By default ($Itota$=0), the tension behavior is linear elastic using Young's modulus, E_0. If $Itota$=1, the engineering stress strain behavior should be input using the functions, fct_ID_{iL}, with the stress strain curve defined both in compression and tension
2. When stress strain functions are defined at different strain rates, the stresses are computed by interpolation from input functions: $\sigma = f(\varepsilon, \dot{\varepsilon})$

   for given $\dot{\varepsilon}$, read two values of function at ε for the two immediately lower and higher strain rates.

Figure 1. Two Strain Rate Curves (up to five may be input)



with

EQ. 2.

$$\sigma = \sigma_2 + (\sigma_1 - \sigma_2)\left[1 - \left(\frac{\dot\varepsilon - \dot\varepsilon_1}{\dot\varepsilon_2 - \dot\varepsilon_1}\right)^a\right]^b$$

The parameters a and b define the shape of the interpolation function within each interval. If a = b = 1, the interpolation is linear.

3. A "coupled" set of principal nominal stresses is computed with anisotropic Poisson's ratios:

   $\nu_{ij} = \nu_c + (\nu_t - \nu_c)\left(1 - \exp\left(-R_v\left|\varepsilon_{ij}\right|\right)\right)$ in tension ($\varepsilon_{ij} \ge 0$)

   $\nu_{ij} = \nu_c$ in compression.

   Where,

   EQ. 3.

   $$\varepsilon_{ij} = \frac{(\varepsilon_i + \varepsilon_j)}{2}$$

   EQ. 4.

   $$\varepsilon_{ij} \ge 0$$

4. Analysis formulation type *Iflag*.

   Iflag=0: corresponds to the visco-elastic foam tabulated material (visco-elasticity is computed in each principal stress direction).

   Iflag=1: behavior will be linear in both tension and compression, following Hook's relations.

   For compression, Young Modulus E_0 and Poisson's ratio ν_c are used.

   In tension, the instantaneous Young's modulus ratio E_t is used.

   The instantaneous Young’s modulus is updated using:

   EQ. 5.

   $$E_t = E_{final} + \left(E_0 - E_{final}\right)\left[1 - e^{-\lambda\left(V_R - 1 + \varepsilon_{final}\right)}\right]$$

   with

EQ. 6.

$$E_0 < E < E_{final}$$

Where,

E_0	Minimum tension modulus
E_{final}	Maximum tension modulus
V_R	Relative volume computed in RADIOSS
ε_{final}	Absolute value of the strain corresponding to the maximum compression modulus.

The instantaneous modulus is only used for tension.

5. For stability, $\dot{\varepsilon}$ is filtered using:

EQ. 7.

$$\dot{\varepsilon}^{n}_{filt} = \dot{\varepsilon}^{n-1}_{filt} + R_D \left(\dot{\varepsilon}^{n} - \dot{\varepsilon}^{n-1}_{filt} \right)$$

6. Hysteresis is applied in linear tension case.

   If K_R=1, Hysteresis is only applied in compression.

   If K_R=2, Hysteresis is applied both in compression and in tension.

7. For air pressure P_{air} (when K_{air}=1)

   If $fct\_ID_p \neq 0$:

EQ. 8.

$$P_{air} = Fscale_p . \mathrm{f} \left(\frac{V}{V_0} \right)$$

Where, f refers to function number fct_ID_p.

If fct_ID_p=0:

EQ. 9.

$$P_{air} = P_0 \frac{\left(1 - \frac{V}{V_0} \right)}{\left(\frac{V}{V_0} - \Phi \right)}$$

Relaxation is applied as:

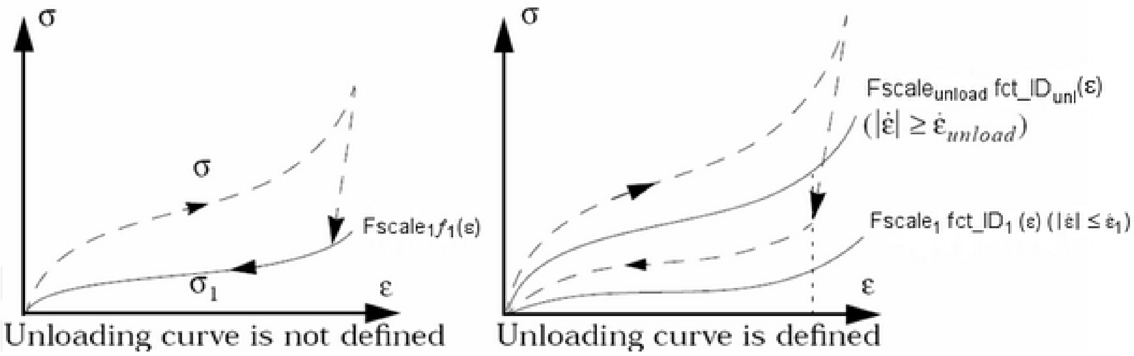
EQ. 10.

$$P_{air} = \min \left(P_{air}, P_{\max} \right) \exp \left(-R_p t \right)$$

Where, R_p is the relaxation rate of pressure and t is the time.

8. During unloading, without an unloading curve defined fct_ID_{iuL} = fct_ID_{uL}=0, σ is computed from the first loading curve, fct_ID_{1L}.

Figure 11.



If the unloading curve is defined, σ is interpolated between the first loading curve fct_ID_{1L} and the defined unloading curve fct_ID_{uL} or fct_ID_{iuL}. In this case, fct_ID_{1L} must correspond to a quasi-static state.

9. Unloading functions fct_ID_{iuL} (Line 12) are used only if the unloading curve fct_ID_{uL} is not defined.
10. If $Visc$ is input, interpolated stress will be limited by this value to have a larger timestep:

EQ. 12.

$$\sigma \leq \sigma_1 + Visc\left(\dot{\varepsilon} - \dot{\varepsilon}_1\right)$$

11. The behavior is strain rate independent when $\dot{\varepsilon} \leq \dot{\varepsilon}_1$.

See Also

Material Compatibility

Failure Models