2.2 Damping Input

Damping is a mathematical approximation used to represent the energy dissipation observed in structures. Damping is difficult to model accurately since it is caused by many mechanisms including

- Viscous effects (dashpot, shock absorber)
- External friction (slippage in structural joints)
- Internal friction (characteristic of the material type)
- Structural nonlinearities (plasticity, gaps)

Because these effects are difficult to quantify, damping values are often computed based on the results of a dynamic test. Simple approximations are often justified because the damping values are low.

Two types of damping are generally used for linear-elastic materials: viscous and structural. The viscous damping force is proportional to velocity, and the structural damping force is proportional to displacement. Which type to use depends on the physics of the energy dissipation mechanism(s) and is sometimes dictated by regulatory standards.

The viscous damping force $f_v$ is proportional to velocity and is given by

$$f_v = b \dot{u} \quad (2-6)$$

where $b = \text{viscous damping coefficient}$

$\dot{u} = \text{velocity}$

The structural damping force $f_s$ is proportional to displacement and is given by

$$f_s = i \ast G \ast k \ast u \quad (2-7)$$

where $G = \text{structural damping coefficient}$

$k = \text{stiffness}$

$u = \text{displacement}$

$i = \sqrt{-1} \quad (\text{phase change of 90 degrees})$
For a sinusoidal displacement response of constant amplitude, the structural damping force is constant, and the viscous damping force is proportional to the forcing frequency. Figure 2-2 depicts this and also shows that for constant amplitude sinusoidal motion the two damping forces are equal at a single frequency. At this frequency,

\[ Gk = b \omega^* \text{ or } b = \frac{Gk}{\omega^*} \]  

(2-8)

where \( \omega^* \) is the frequency at which the structural and viscous damping forces are equal for a constant amplitude of sinusoidal motion.

![Image of damping forces](image)

**Figure 2-2. Structural Damping and Viscous Damping Forces for Constant Amplitude Sinusoidal Displacement.**

If the frequency \( \omega^* \) is the circular natural frequency \( \omega_n \), Eq. (2-8) becomes

\[ b = \frac{Gk}{\omega_n} = G \omega_n m \]  

(2-9)

Recall the definition of critical damping from Eq. (1-11)

\[ b_{cr} = 2\sqrt{km} = 2m\omega_n \]
Some equalities that are true at resonance ($\omega_n$) for constant amplitude sinusoidal displacement are

$$\frac{b}{b_{cr}} = \zeta = \frac{G}{2}$$  \hspace{1cm} (2-10)

and

$$Q = \frac{1}{2\zeta} = \frac{1}{G}$$  \hspace{1cm} (2-11)

where $Q$ is the quality or dynamic magnification factor, which is inversely proportional to the energy dissipated per cycle of vibration.

Damping is the result of many complicated mechanisms. The effect of damping on computed response depends on the type and loading duration of the dynamic analysis. Damping can often be ignored for short duration loadings, such as those resulting from a crash impulse or a shock blast, because the structure reaches its peak response before significant energy has had time to dissipate. Damping is important for long duration loadings (such as earthquakes), and is critical for loadings (such as rotating machinery) that continually add energy to the structure. The proper specification of the damping coefficients can be obtained from structural tests or from published literature that provides damping values for structures similar to yours.

As is discussed in detail in Chapters 5 and 6, certain solution methods allow specific forms of damping to be defined. The type of damping used in the analysis is controlled by both the solution being performed and the MSC/NASTRAN data entries. In transient response analysis, for example, structural damping must be converted to equivalent viscous damping.

Structural damping is specified on the MATi and PARAM,G Bulk Data entries. The GE field on the MATi entry is used to specify overall structural damping for the elements that reference this material entry. This definition is via the structural damping coefficient GE.

For example, the MAT1 entry:

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</tr>
</thead>
<tbody>
<tr>
<td>$$MAT1</td>
<td>MID</td>
<td>E</td>
<td>G</td>
<td>NU</td>
<td>RHO</td>
<td>A</td>
<td>TREF</td>
<td>GE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAT1</td>
<td>2</td>
<td>30.066</td>
<td>0.3</td>
<td>7.764E-4</td>
<td></td>
<td></td>
<td>0.10</td>
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specifies a structural damping coefficient of 0.1.

An alternate method for defining structural damping is through PARAM,G,r where r is the structural damping coefficient. This parameter multiplies the stiffness matrix to obtain the structural damping matrix. The default value for PARAM,G is 0.0. The default value causes this source of structural damping to be ignored. Two additional parameters are used in transient response analysis to convert structural damping to equivalent viscous damping: PARAM,W3 and PARAM,W4.
PARAM, G and GE can both be specified in the same analysis.

Viscous damping is defined by the following elements:

**CDAMP1 entry**  Scalar damper between two degrees of freedom (DOFs) with reference to a PDAMP property entry.

**CDAMP2 entry**  Scalar damper between two DOFs without reference to a property entry.

**CDAMP3 entry**  Scalar damper between two scalar points (SPOINTS) with reference to a PDAMP property entry.

**CDAMP4 entry**  Scalar damper between two scalar points (SPOINTS) without reference to a property entry.

**CVISC entry**  Element damper between two grid points with reference to a PVISC property entry.

Viscous damping for modal transient response and modal frequency response is specified with the TABDMP1 entry.

Note that GE and G by themselves are dimensionless; they are multipliers of the stiffness. The CDAMP1 and CVISC entries, however, have damping units.

Damping is further described in Chapters 5 and 6 as it pertains to frequency and transient response analyses.