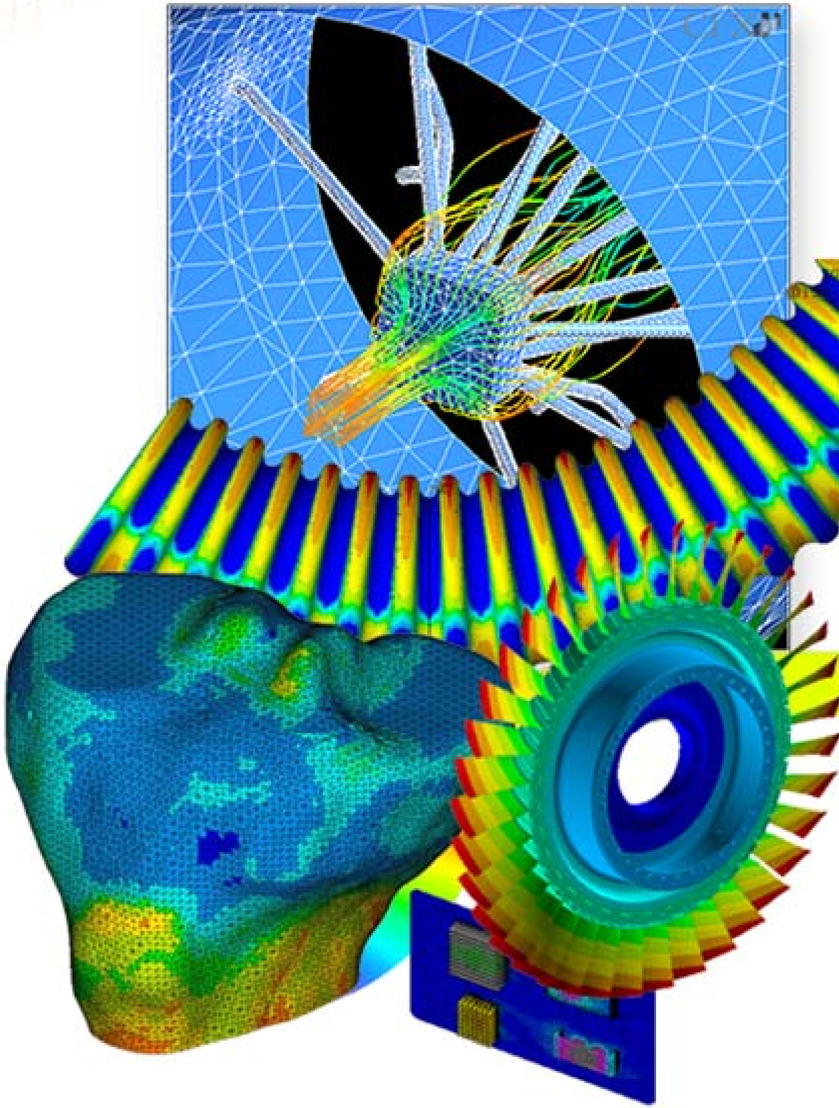
ENGINEERING ADVANTAGE

Damping in ANSYS/LS-Dyna



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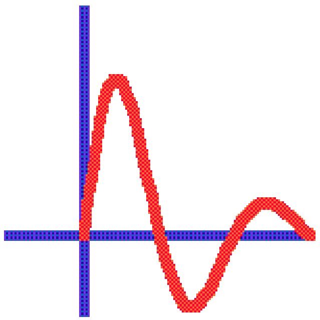
- ANSYS/LS-Dyna allows Rayleigh damping constants α and β only.

<u>What is damping?</u>

- The energy dissipation mechanism that causes vibrations to diminish over time and eventually stop.
- Amount of damping mainly depends on the material, velocity of motion, and frequency of vibration.
- Can be classified as:
  - Viscous damping
    - Damping ratio ξ
    - Rayleigh mass-weighted damping constant α
  - Hysteresis or solid damping
    - Rayleigh stiffness-weighted damping constant β



Damping

- Most damping in an ANSYS dynamics analysis is approximated as some form of viscous damping:

$$F = C\dot{x}$$

- The proportionality constant c is called the *damping constant*.
- The amount of damping is usually described using a quantity called the *damping ratio* ξ (ratio of damping constant c to critical damping constant c_c*).
- Critical damping is defined as the threshold between oscillatory and non-oscillatory behavior, where damping ratio = 1.0.

*For a single-DOF spring mass system of mass m and frequency ω, $c_c = 2m\omega$

Damping

- Rayleigh damping constants α and β
  - Used as multipliers of [M] and [K] to calculate [C]:

    $$[C] = \alpha[M] + \beta[K]$$
    $$\alpha/2\omega + \beta\omega/2 = \xi$$

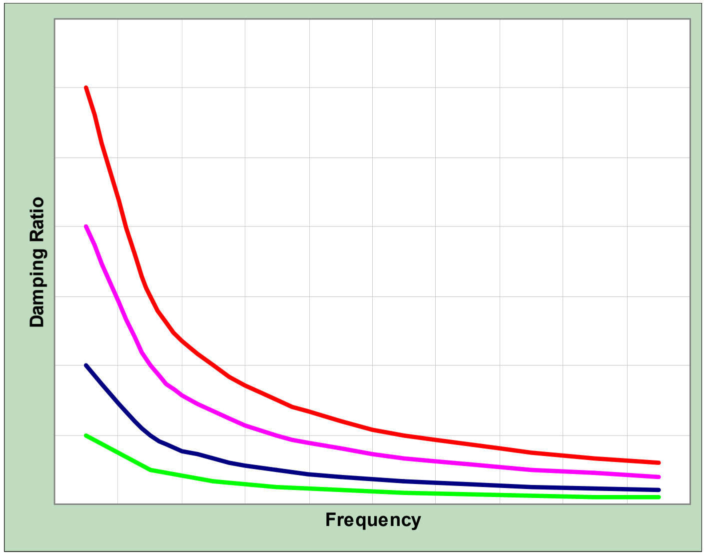
    - Where ω is the frequency, and ξ is the damping ratio.
- Needed in situations where damping ratio ξ cannot be specified.
- Alpha is the viscous damping component, and Beta is the hysteresis or solid or *stiffness* damping component.

Alpha Damping

- Also known as *mass damping.*
- Good for damping out low-frequency system-level oscillations (typically high amplitude).
- If beta damping is ignored, α can be calculated from a known value of ξ (damping ratio) and a known frequency ω:

$$\alpha = 2\xi\omega$$

  - Only one value of alpha is allowed, so pick the most dominant response frequency to calculate α.

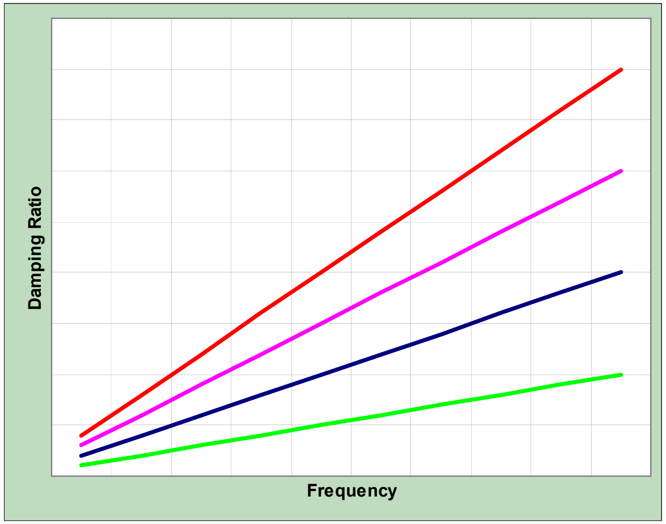


Beta Damping

- Also known as *structural* or *stiffness* damping.
- Good for damping out high-frequency component-level oscillations (typically low amplitude).
- Inherent property of most materials.
- If alpha damping is ignored, β can be calculated from a known value of ξ (damping ratio) and a known frequency ω:

$$\beta = 2\xi/\omega$$

  - Pick the most dominant response frequency to calculate β.



To specify both α and β damping:

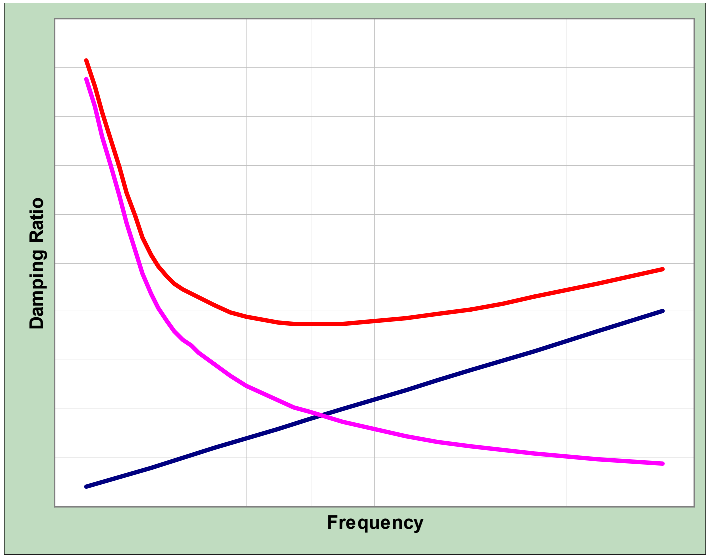
- Use the relation

$$\alpha/2\omega + \beta\omega/2 = \xi$$

- Since there are two unknowns, assume that the sum of alpha and beta damping gives a constant damping ratio ξ over the frequency range ω_1 to ω_2. This gives two simultaneous equations from which you can solve for α and β.

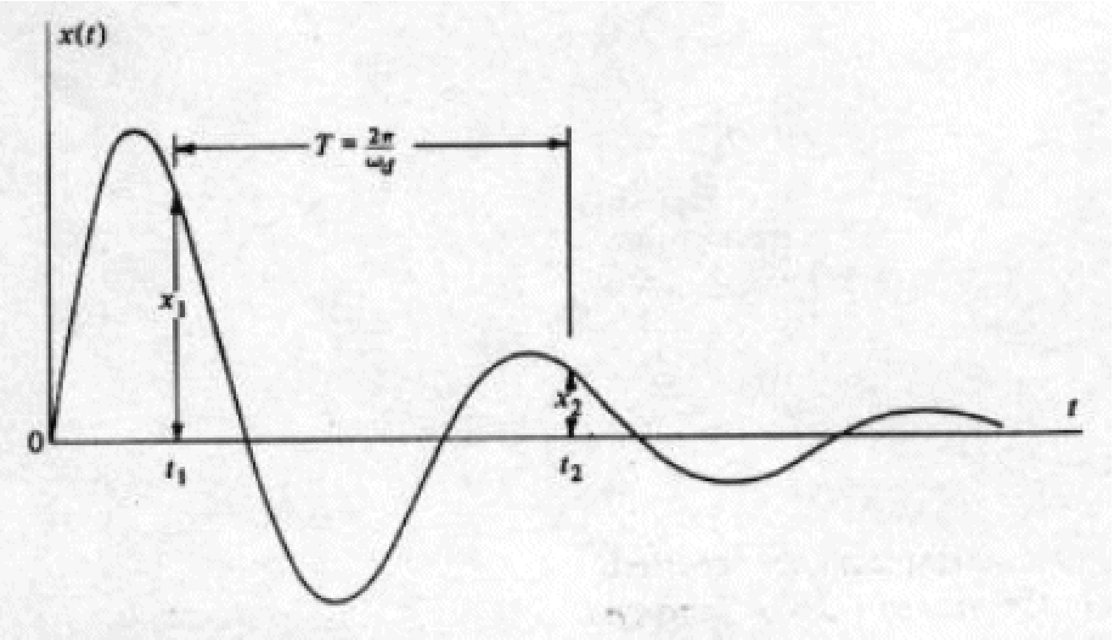
$$\xi = \alpha/2\omega_1 + \beta\omega_1/2$$

$$\xi = \alpha/2\omega_2 + \beta\omega_2/2$$



Damping

- The damping ratio, ξ, can be obtained from test data as follows



- Calculate the logarithmic decrement, δ, as follows:

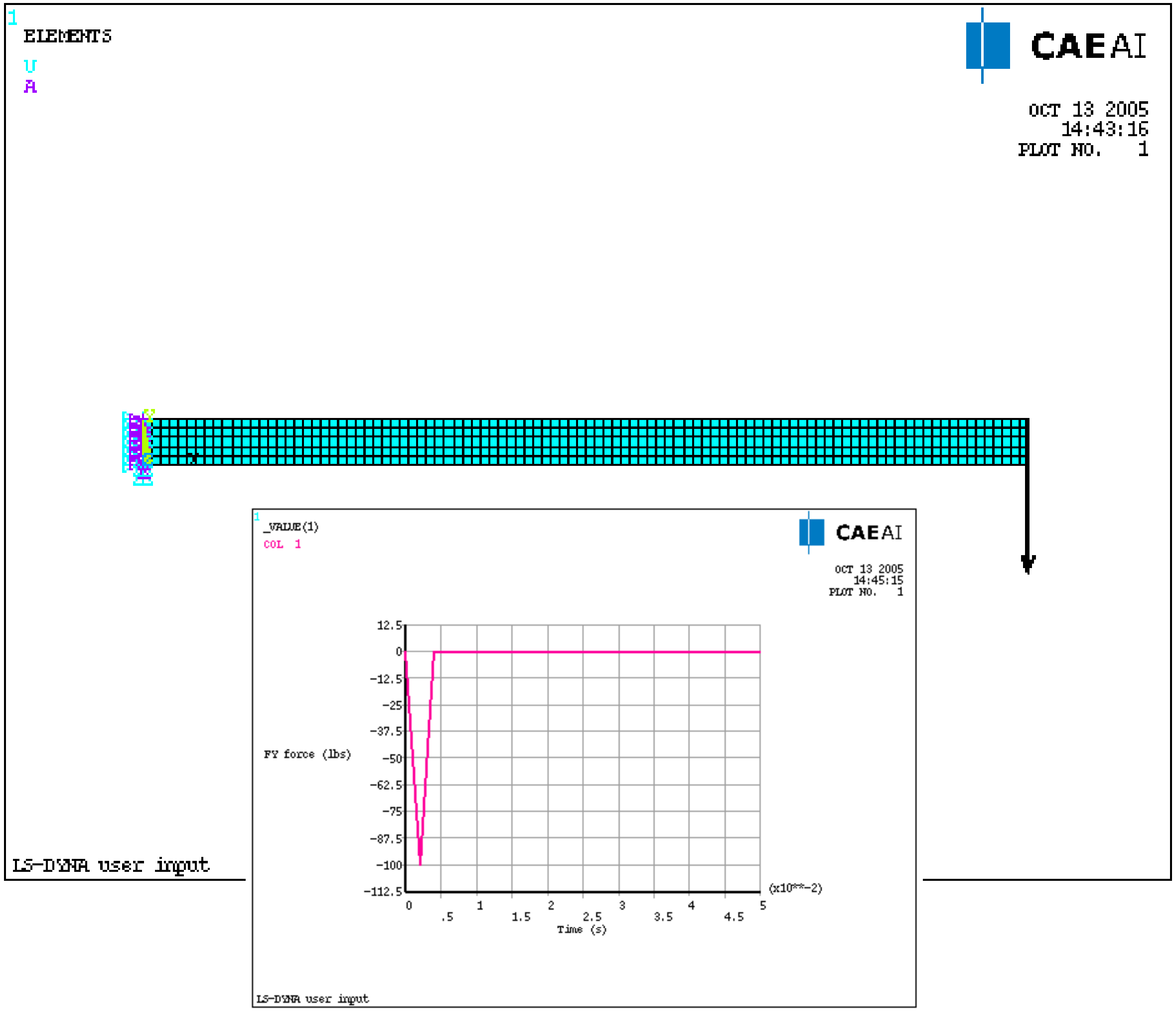
$$\delta = \ln(x1/x2)$$

- X1 and X2 are two consecutive displacements, one cycle apart.

Damping

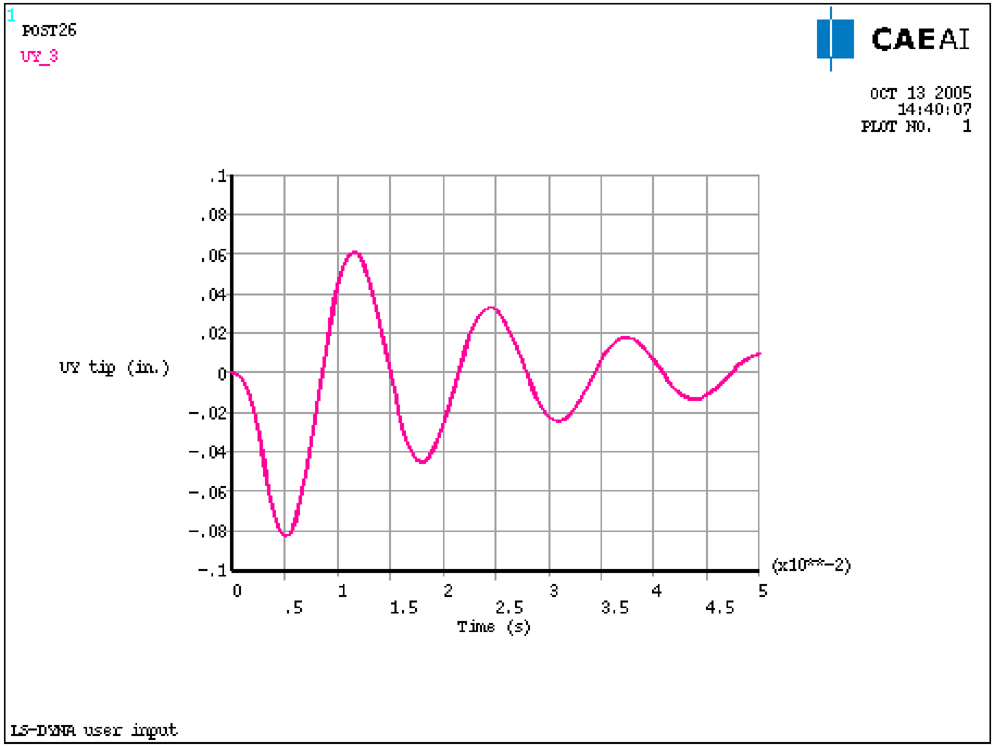
$$\xi = \frac{\delta}{\sqrt{(2\pi)^2 + \delta^2}}$$

- Cantilever beam with an impulse load applied to the tip



Damping Example

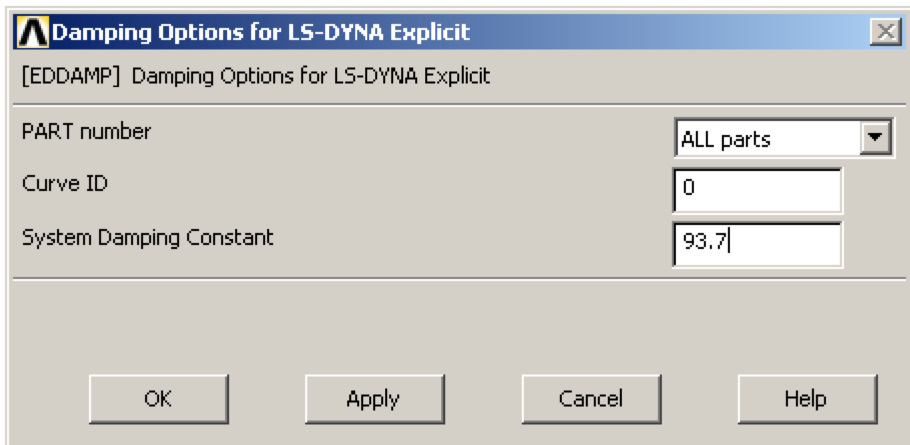
- Tip deflection: ω = 76.9 cycles/s = 483 rad/s



- $\delta = \ln(0.061/0.033) = 0.614$
- $\xi = 0.097$
- $\alpha = 2\xi\omega = 93.7\ s^{-1}$ **or** $\beta = 2\xi/\omega = 0.0004$ s

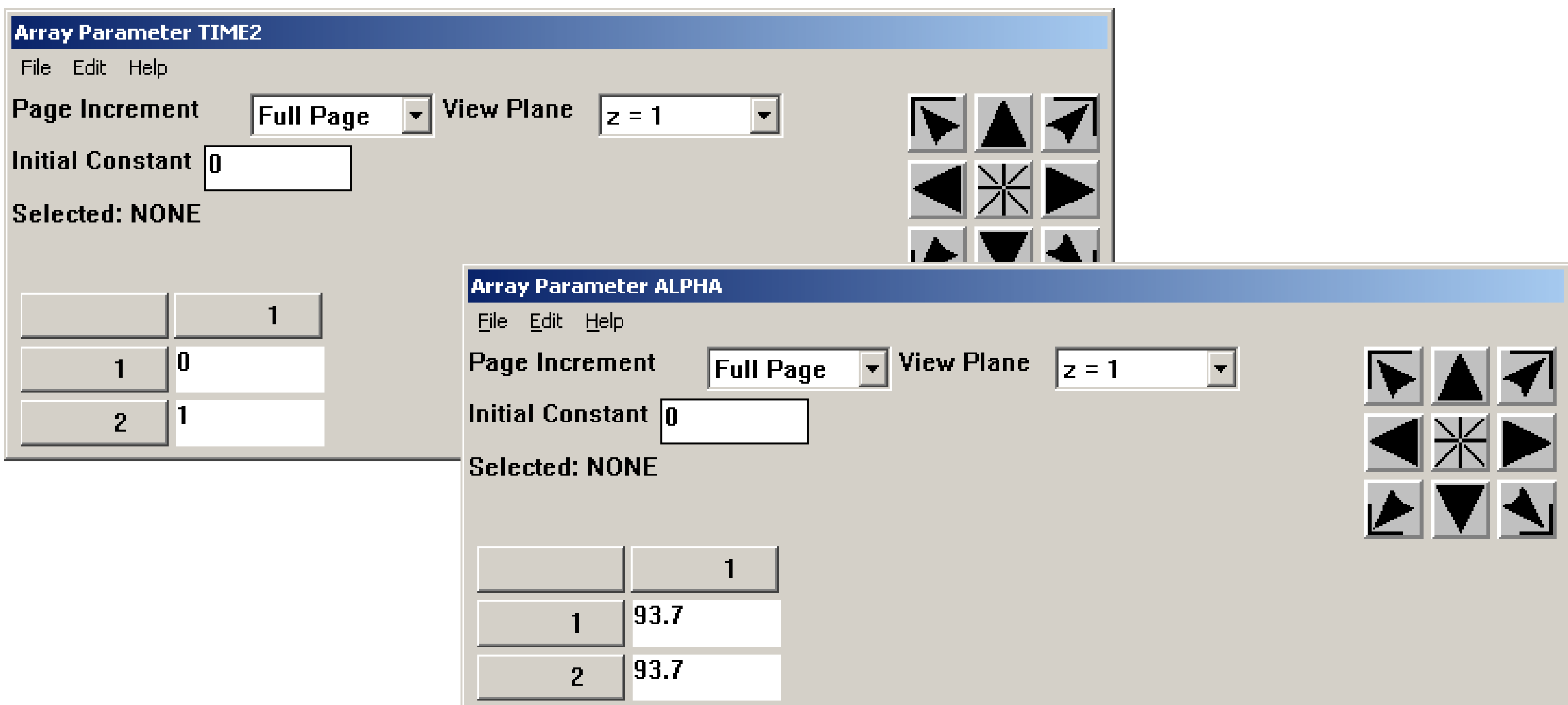
Damping Example

- Alpha damping
  - Same alpha damping applied to all parts
    - Preprocessor > Material Props > Damping
    - Set the part number to All parts and do not specify a curve ID



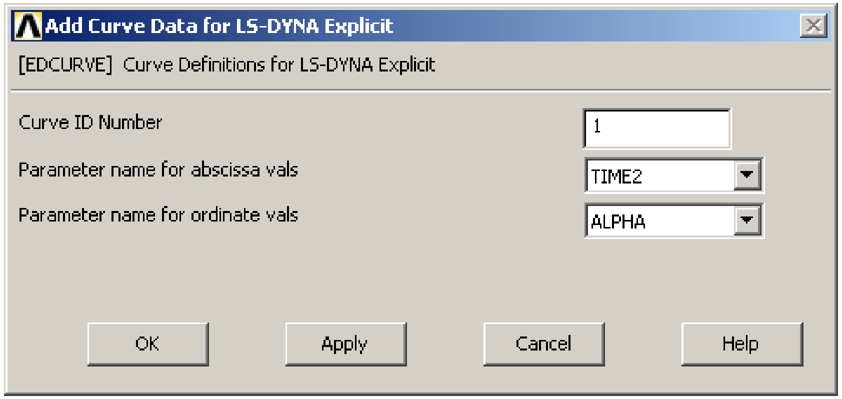
Damping Example

- Alpha damping
  - Time-varying alpha damping applied to a specific part
    - Create a curve ID for alpha damping vs. time and identify it in the damping input window.
    - Utility Menu > Parameters > Array Parameters > Define/Edit
    - Dimension and fill the time and alpha vectors

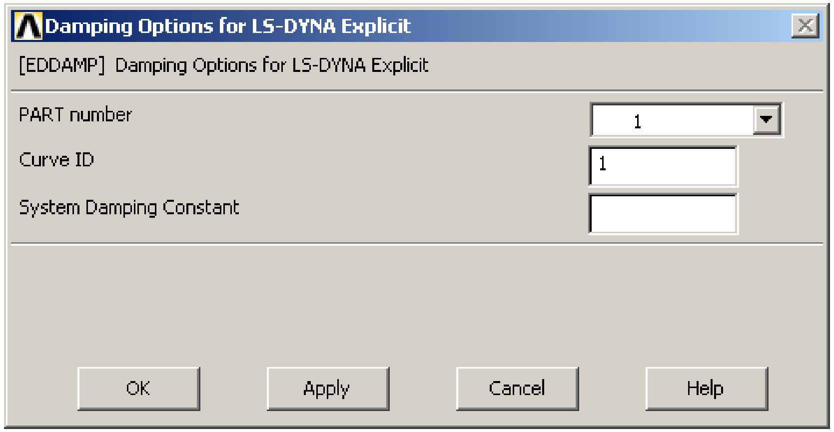


Damping Example

- Generate a curve that relates the alpha to time
  - Preprocessor > LS-Dyna Options > Loading Options > Curve Options > Add Curve



- Assign the curve to the appropriate part
  - Preprocessor > Material Props > Damping



Damping Example

- Beta damping
  - Constant beta damping applied to a specific part
    - Preprocessor > Material Props > Damping
    - Use a specific part number and do not specify a curve ID