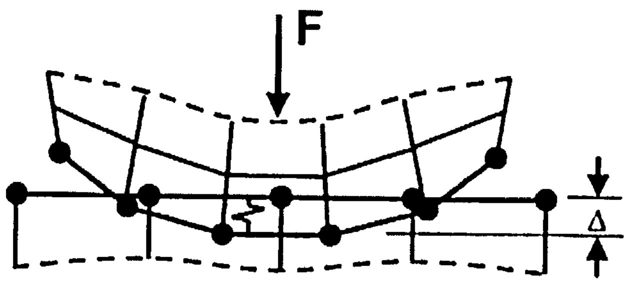
A. Basic Concepts

Review:

- Recall that all ANSYS contact elements use a penalty stiffness (contact stiffness) to help enforce compatibility at the contact interface.



The contact spring will deflect an amount Δ, such that equilibrium is satisfied:

$$F = k\,\Delta$$

where k is the contact stiffness.

- Some finite amount of penetration, $\Delta > 0$, is required mathematically to maintain equilibrium.
- However, physical contacting bodies do not interpenetrate ($\Delta = 0$).

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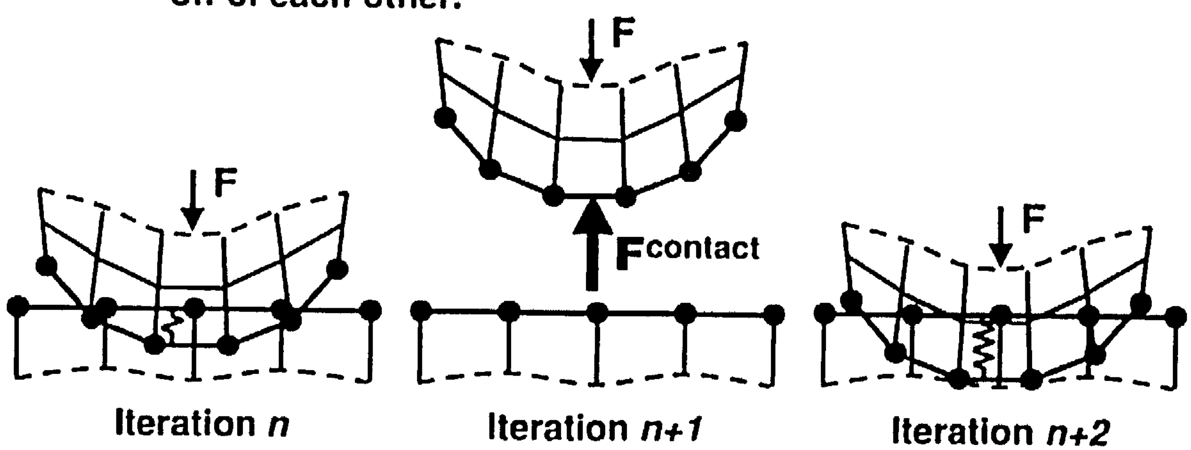
... Basic Concepts

- As an analyst, you face a dilemma:
  - Minimum penetration gives best accuracy.
    - Therefore, the contact stiffness should be very great.
  - However, too stiff a value causes convergence difficulties.
    - The model can oscillate, with contacting surfaces bouncing off of each other.



Contact Stiffness

... *Determining a value*

- As a practical matter, a good first trial value for bulky contact stiffness would be $k_{contact} = f_{bulk} \times k_{Hertz}$, where f_{bulk} is a factor usually between 0.1 and 10 for bulky solids.
  - Because the starting estimated value of f_{bulk} ranges over at least two orders of magnitude, and because $k_{contact}$ will be adjusted by trial-and-error anyway, it is usually not justifiable to worry about the element's size when estimating the penalty stiffness.
- *For bulky solids*, simply estimate the penalty stiffness by

$$k = f_{bulk} \times E$$

  - where the factor f_{bulk} is usually between 0.1 and 10, and a good starting value for f_{bulk} is often $f_{bulk} = 1.0$.
  - This estimate assumes an approximate "unit" element size; for very large or very small elements, you might need to adjust the starting value of f_{bulk} accordingly.

... Determining a value

- Determining a good stiffness value usually requires some experimentation. The following procedure may be used as a guideline:
  - 1. Use a low value of stiffness to start.
  - 2. Run the analysis to a fraction of the final load.
  - 3. Check the penetration and number of equilibrium iterations used in each substep.
    - As a rough, quick check, if you can visually detect penetration in a true-scale displaced plot of the entire model, the penetration is probably excessive. Increase the stiffness and restart.
    - If many iterations are needed for convergence (or if convergence is never achieved), reduce the stiffness and restart.
  - *Note: Penalty stiffness can be modified from one load step to another, and can be adjusted in a restart.*

VM73: Free Vibration with Coulomb Damping

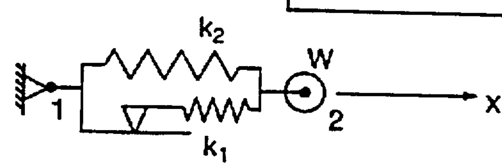
Reference: Tse (Ref. 12), Page 175, Case 1
Analysis Type(s): Full transient dynamic analysis (ANTYPE=4)
Element Type(s): Combination elements (COMBIN40)

Test Case

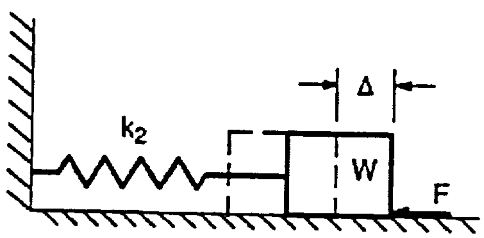
A spring–mass system with coulomb damping is displaced a distance Δ and released. Dry friction is assumed to act as a limiting sliding force F between the sliding mass and the surface. Determine the displacement u at various times t.

Material Properties
W = 10 lb
k_2 = 30 lb/in
m = W/g

Loading
Δ = −1 in
F = 1.875 lb



Representative Finite Element Model



Problem Sketch

	X	$\dot{X}$
t = 0	−1.	0.

Initial Conditions

Analysis Assumptions and Modeling Notes

One combination element is used with the slider in parallel with the spring. The slider spring constant (k_1 = 10,000 lb/in) is arbitrarily selected high enough to minimize the elastic contact effect but low enough to also allow a practical integration time step size. The integration time step (0.2025/405 = 0.0005 sec) is based on ≃1/Nf where N=20 and f is the system natural frequency. At release, the mass acceleration is not necessarily zero. Therefore, a load step with a small time period is used to ramp up to the appropriate acceleration while maintaining an essentially zero velocity. The final time of 0.2025 sec allows one full cycle of motion. POST26 is used to postprocess results from the solution phase.

VM73: Free Vibration with Coulomb Damping (continued)

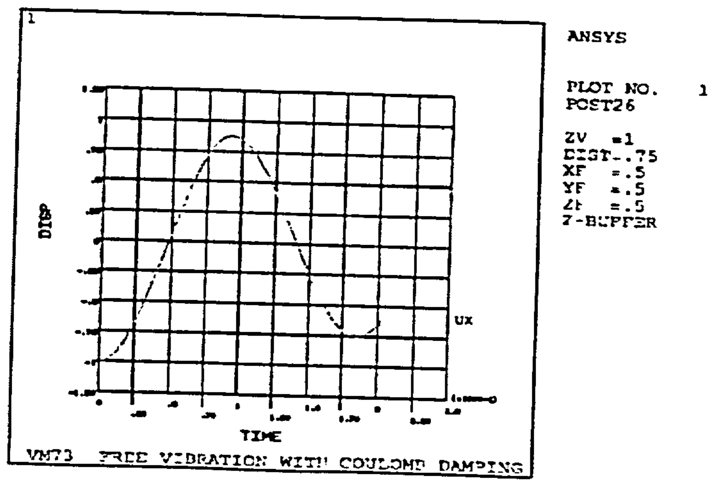
ANSYS

Results Comparison

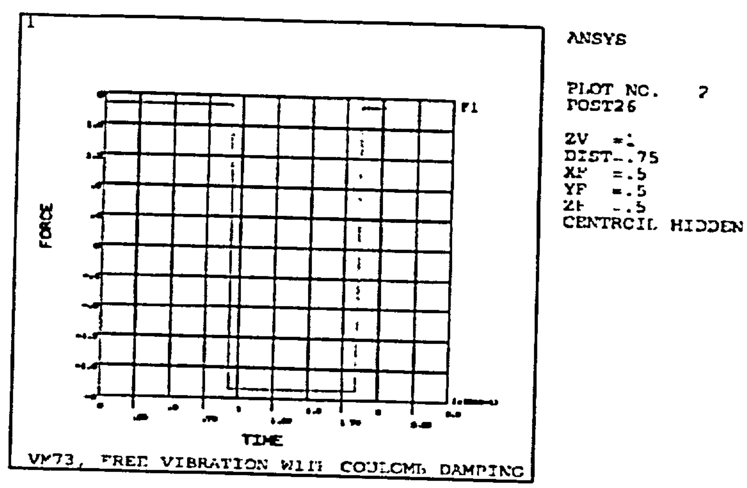
	Target	ANSYS	Ratio
u, in (t = 0.09 sec)	0.87208	0.87205	1.000
u, in (t = 0.102 sec)	0.83132	0.83018	0.999
u, in (t = 0.183 sec)	−0.74874	−0.74875	1.000

VM73: Free Vibration with Coulomb Damping (continued)

ANSYS



VM73 – Displacement vs. Time Display



VM73 – Sliding Force vs Time Display