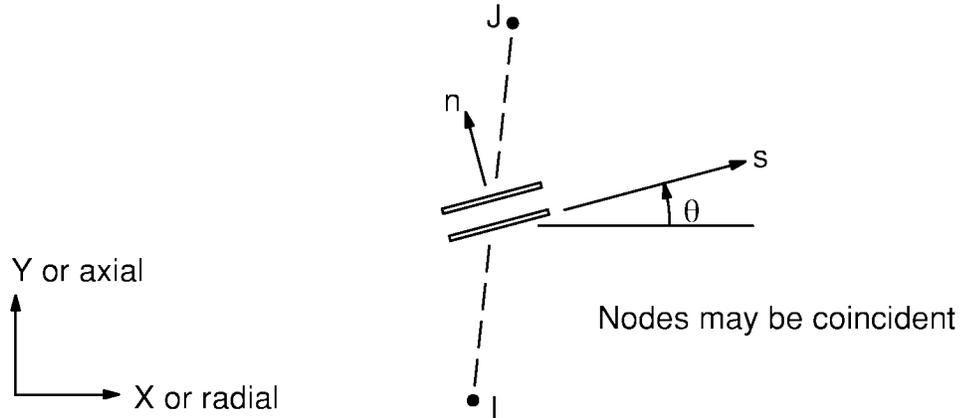


14.12 CONTACT12 — 2-D Point-to-Point Contact



Matrix or Vector	Shape Functions	Integration Points
Stiffness Matrix	None (nodes may be coincident)	None

Load Type	Distribution
Element Temperature	None – average used for material property evaluation
Nodal Temperature	None – average used for material property evaluation

14.12.1 Element Matrices

CONTACT12 may have one of three conditions if the elastic Coulomb friction option (KEYOPT(1) = 0) is used: closed and stuck, closed and sliding, or open. The following matrices are derived assuming that θ is input as 0.0.

1. Closed and stuck. This occurs if:

$$\mu |F_n| > |F_s| \tag{14.12-1}$$

where:

- μ = coefficient of friction (input as MU on **MP** command)
- F_n = normal force across gap
- F_s = sliding force parallel to gap

The normal force is:

$$F_n = k_n (u_{n,J} - u_{n,I} - \Delta) \quad (14.12-2)$$

where:

- k_n = normal stiffness (input as KN on **R** command)
- $u_{n,I}$ = displacement of node I in normal direction
- $u_{n,J}$ = displacement of node J in normal direction
- Δ = interference $\left\{ \begin{array}{l} \text{input as INTF on } \mathbf{R} \text{ command} \\ \text{if KEYOPT(4) = 0} \\ = -d \text{ if KEYOPT(4) = 1} \end{array} \right.$
- d = distance between nodes

The sliding force is:

$$F_s = k_s (u_{s,J} - u_{s,I} - u_o) \quad (14.12-3)$$

where:

- k_s = sticking stiffness (input as KS on **R** command)
- $u_{s,I}$ = displacement of node I in sliding direction
- $u_{s,J}$ = displacement of node J in sliding direction
- u_o = distance that nodes I and J have slid with respect to each other

The resulting element stiffness matrix (in element coordinates) is:

$$[K_\ell] = \begin{bmatrix} k_s & 0 & -k_s & 0 \\ 0 & k_n & 0 & -k_n \\ -k_s & 0 & k_s & 0 \\ 0 & -k_n & 0 & k_n \end{bmatrix} \quad (14.12-4)$$

and the Newton–Raphson load vector (in element coordinates) is:

$$\{F_\ell^{nr}\} = \begin{Bmatrix} F_s \\ F_n \\ -F_s \\ -F_n \end{Bmatrix} \quad (14.12-5)$$

2. Closed and sliding. This occurs if:

$$\mu F_n \leq F_s \quad (14.12-6)$$

In this case, the element stiffness matrix (in element coordinates) is:

$$[K_\ell] = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & k_n & 0 & -k_n \\ 0 & 0 & 0 & 0 \\ 0 & -k_n & 0 & k_n \end{bmatrix} \quad (14.12-7)$$

and the Newton–Raphson load vector is the same as in equation (14.12–5). If the unsymmetric option is chosen (KEYOPT(11) = 1), then the stiffness matrix includes the coupling between the normal and sliding directions; which for STAT = 2 is:

$$[K_\ell] = \begin{bmatrix} 0 & -\mu k_n & 0 & \mu k_n \\ 0 & k_n & 0 & -k_n \\ 0 & \mu k_n & 0 & -\mu k_n \\ 0 & -k_n & 0 & k_n \end{bmatrix} \quad (14.12-8)$$

3. Open — When there is no contact between nodes I and J. There is no stiffness matrix or load vector.

Figure 14.12–1 shows the force–deflection relationships for this element. It may be seen in these figures that the element is nonlinear and therefore needs to be solved iteratively. Further, since energy lost in the slider cannot be recovered, the load needs to be applied gradually.

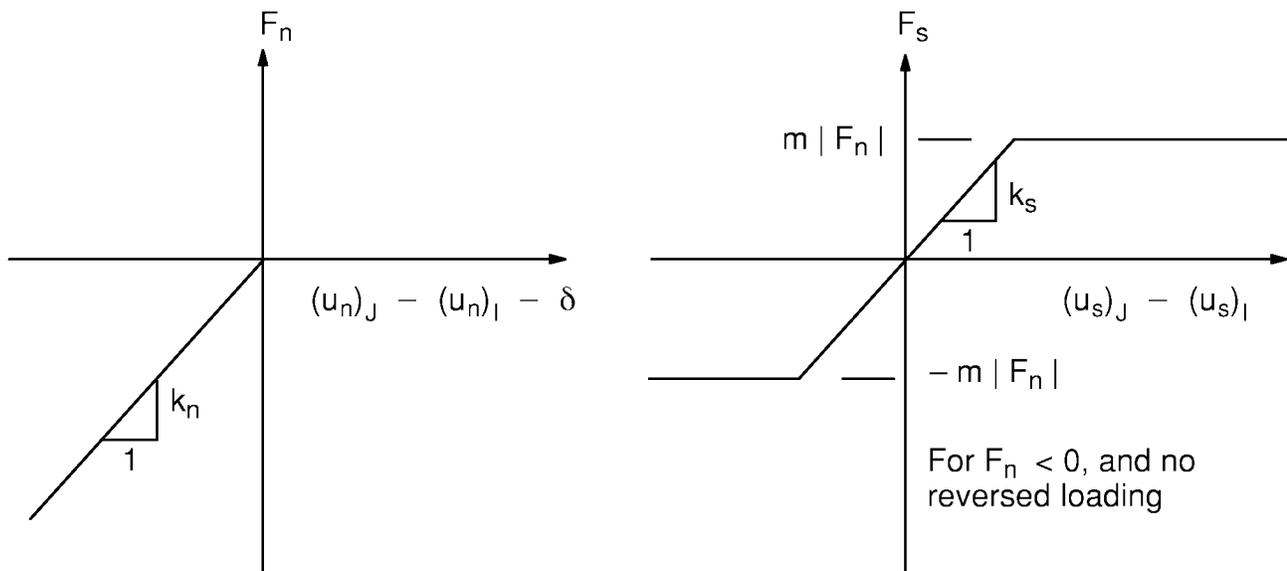


Figure 14.12–1 Force–Deflection Relations for Standard Case

14.12.2 Orientation of the Element

The element is normally oriented based on θ (input as THETA on **R** command). If KEYOPT(2) = 1, however, θ is not used. Rather, the first iteration has θ equal to zero, and all subsequent iterations have the orientation of the element based on the displacements of the previous iteration. In no case does the element use its nodal coordinates.

14.12.3 Rigid Coulomb Friction

If the user knows that a gap element will be in sliding status for the life of the problem, and that the relative displacement of the two nodes will be monotonically increasing, the rigid Coulomb friction option (KEYOPT(1) = 1) can be used to avoid convergence problems. This option removes the stiffness in the sliding direction, as shown in Figure 14.12–2. It should be noted that if the relative displacement does not increase monotonically, the convergence characteristics of KEYOPT(1) = 1 will be worse than for KEYOPT(1) = 0.

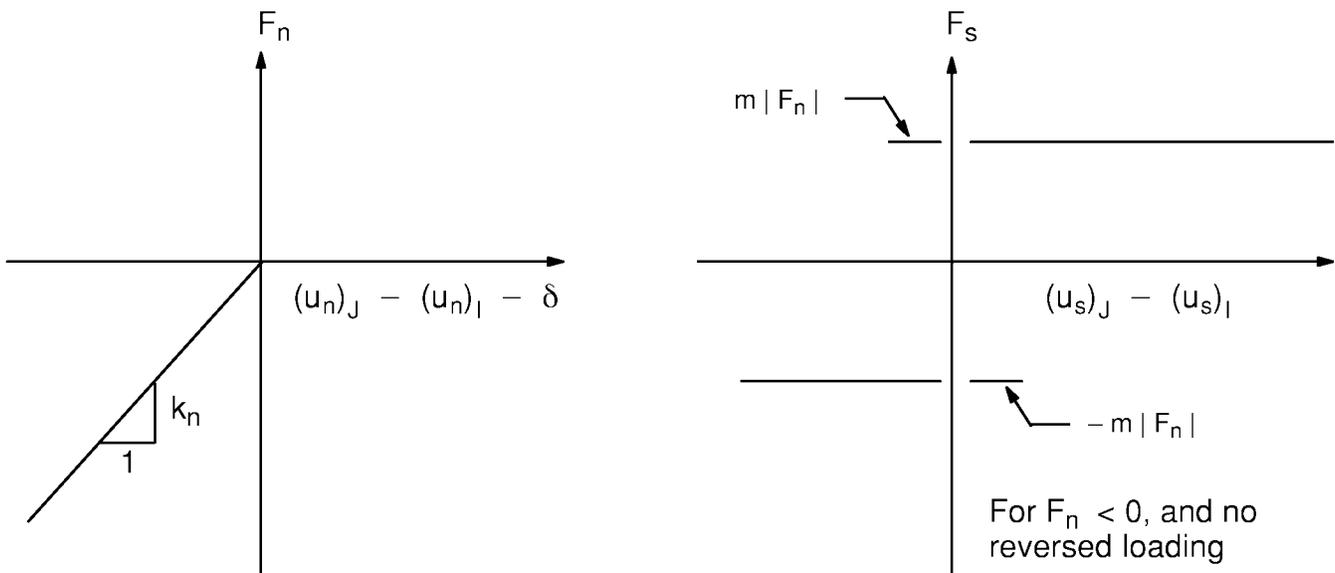


Figure 14.12–2 Force–Deflection Relations for Rigid Coulomb Option