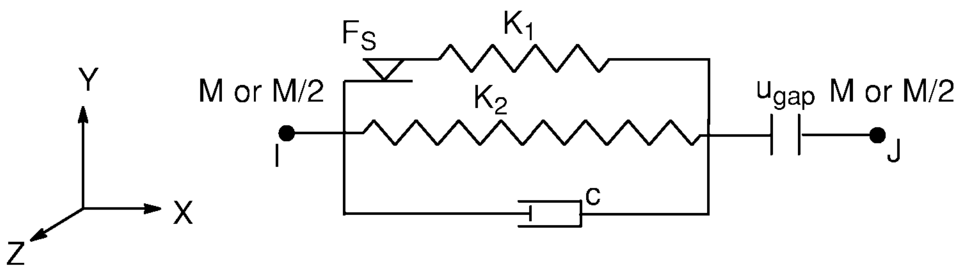
14.40 COMBIN40 — Combination



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

14.40.1 Characteristics of the Element

The force–deflection relationship for the combination element under initial loading is as shown in Figure 14.40–1 (for no damping).

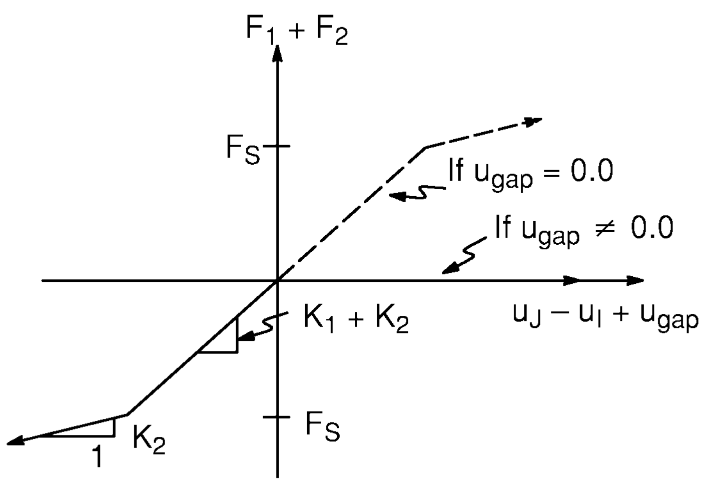


Figure 14.40–1 Force–Deflection Relationship

where: F_1 = force in spring 1 (output quantity F1)

F_2	=	force in spring 2 (output quantity F2)
K_1	=	stiffness of spring 1 (input quantity K1 on **R** command)
K_2	=	stiffness of spring 2 (input quantity K2 on **R** command)
u_{gap}	=	initial gap size (input quantity GAP on **R** command) (if zero, gap capability removed)
u_I	=	displacement at node I
u_J	=	displacement at node J
F_S	=	force required in spring 1 to cause sliding (input quantity FSLIDE on **R** command)

14.40.2 Element Matrices for Structural Applications

The element mass matrix is:

$$[M_e] = M \begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix} \text{ if KEYOPT(6) } = 0 \tag{14.40–1}$$

$$[M_e] = \frac{M}{2} \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \text{ if KEYOPT(6) } = 1 \tag{14.40–2}$$

$$[M_e] = M \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix} \text{ if KEYOPT(6) } = 2 \tag{14.40–3}$$

where: M = element mass (input quantity M on **R** command)

If the gap is open during the previous iteration, all other matrices and load vectors are null vectors. Otherwise, the element damping matrix is:

$$[C_e] = c \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} \tag{14.40–4}$$

where: c = damping constant (input quantity C on **R** command)

The element stiffness matrix is:

$$[K_e] = k \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} \tag{14.40–5}$$

where:

$$k = \begin{cases} K_1 + K_2 & \text{if slider was not sliding in previous iteration} \\ K_2 & \text{if slider was sliding in previous iteration} \end{cases}$$

and the element Newton–Raphson load vector is:

$$\{F_c^{nr}\} = (F_1 + F_2)\begin{Bmatrix} -1 \\ 1 \end{Bmatrix} \quad (14.40\text{–}6)$$

F_1 and F_2 are the current forces in the element.

14.40.3 Determination of F_1 and F_2 for Structural Applications

1. If the gap is open,

$$F_1 + F_2 = 0.0 \quad (14.40\text{–}7)$$

If no sliding has taken place, $F_1 = F_2 = 0.0$. However, if sliding has taken place during unidirectional motion,

$$F_1 = \frac{u_s K_1 K_2}{K_1 + K_2} \quad (14.40\text{–}8)$$

and thus

$$F_2 = -F_1 \quad (14.40\text{–}9)$$

where: u_s = amount of sliding (output quantity SLIDE)

2. If the gap is closed and the slider is sliding,

$$F_1 = \pm F_S \quad (14.40\text{–}10)$$

and

$$F_2 = K_2 u_2 \quad (14.40\text{–}11)$$

where: u_2 = $u_J - u_I + u_{gap}$ = output quantity STR2

3. If the gap is closed and the slider is not sliding, but had slid before,

$$F_1 = K_1 u_1 \quad (14.40\text{–}12)$$

where: u_1 = $u_2 - u_s$ = output quantity STR1

and

$$F_2 = K_2 u_2 \quad (14.40\text{–}13)$$

14.40.4 Thermal Analysis

The description above refers to structural analysis only. When this element is used in a thermal analysis, the conductivity matrix is $[K_e]$, the specific heat matrix is $[C_e]$ (based on input quantity M) and the Newton–Raphson load vector is $\{f_e^{nr}\}$, where F_1 and F_2 represent heat flow. Input quantity C is not used. The gap size u_{gap} is the temperature difference. Sliding, F_{slide}, is the element heat flow limit for conductor K_1.