14.37   COMBIN37 — Control

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

14.37.1   Element Characteristics

COMBIN37 is a nonlinear, 1–D element with two active nodes and one or two control nodes. The element has spring–damper–sliding capability similar to COMBIN40. The degree of freedom (DOF) for the active nodes is selected using KEYOPT(3) and the DOF for the control nodes is selected using KEYOPT(2).

The action of the element in the structure is based upon the value of the control parameter (P_{cn}) (explained later), O_n and O_f (input quantities ONVAL and OFFVAL on **R** command), and the behavior switches KEYOPT(4) and (5). Figure 14.37–1 illustrates the behavior of one of the more common modes of operation of the element. It is analogous to the normal home thermostat during the winter.

The behavior of all possible combinations of KEYOPT(4) and (5) values is summarized in Figure 14.37–2 through Figure 14.37–7. Figure 14.37–5 is analogous to Figure 14.37–1. P_{cn} represents the control parameter (output quantity CONTROL PARAM). The element is active where the figure indicates on, and inactive where it indicates off. For some options, the element may be either on or off for P_{cn} between O_n and O_f, depending upon the last status change.
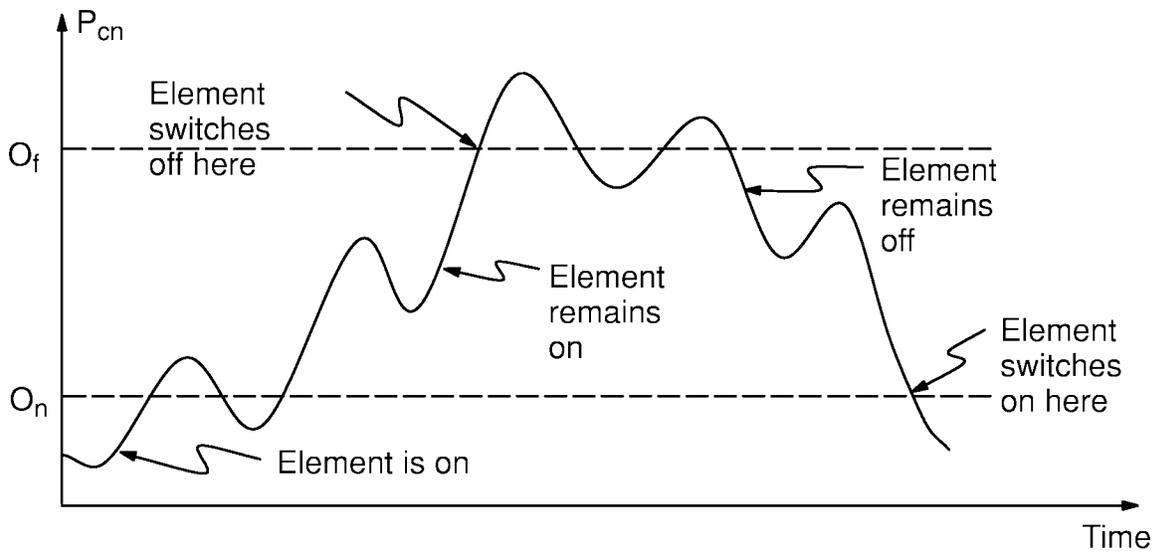
**Figure 14.37–1 Element Behavior with KEYOPT(4) = 0,
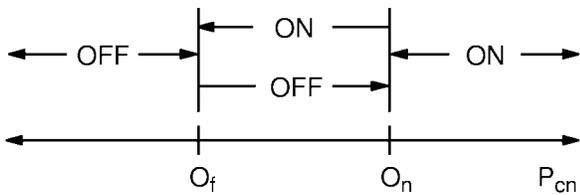KEYOPT(5) = 1, and $O_f > O_n$**

**Figure 14.37–2 Element Behavior
with KEYOPT(4) = 0,
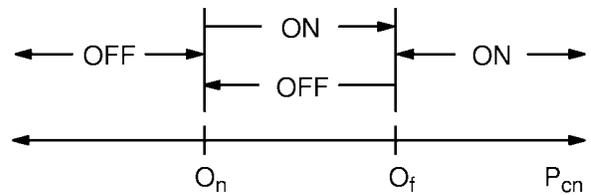KEYOPT(5) = 0, and $O_f \leq O_n$**

**Figure 14.37–3 Element Behavior
with KEYOPT(4) = 0,
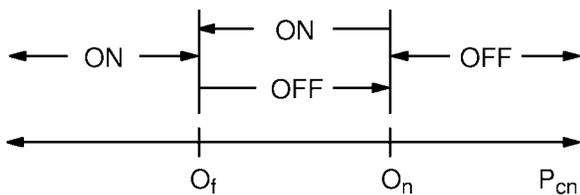KEYOPT(5) = 0, and $O_f > O_n$**

**Figure 14.37–4 Element Behavior
with KEYOPT(4) = 0,
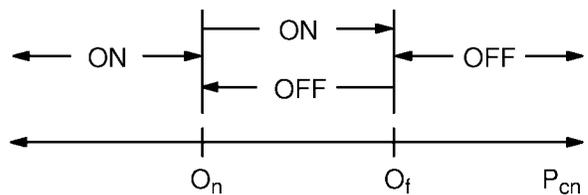KEYOPT(5) = 1, and $O_f \leq O_n$**

**Figure 14.37–5 Element Behavior
with KEYOPT(4) = 0,
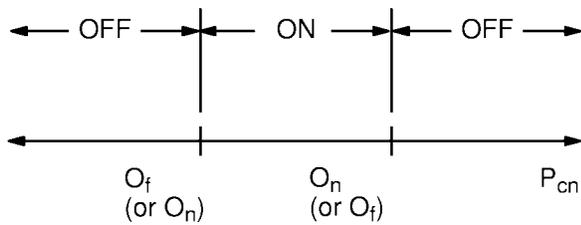KEYOPT(5) = 1, and $O_f > O_n$**

Figure 14.37–6 Element Behavior with KEYOPT(4) = 1 and and KEYOPT(5) = 0
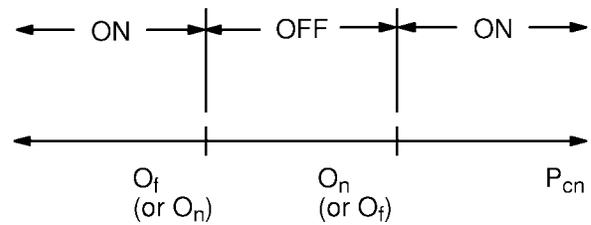
Figure 14.37–7 Element Behavior with KEYOPT(4) = 1 and KEYOPT(5) = 1

14.37.2 Element Matrices

When the element status is ON, the element matrices are:

$$[K_e] = k_o \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} \tag{14.37-1}$$

$$[M_e] = \begin{bmatrix} M_I & 0 \\ 0 & M_J \end{bmatrix} \tag{14.37-2}$$

$$[C_e] = C_o \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} \tag{14.37-3}$$

where: k_o = stiffness (input quantity STIF on **R** command)

M_I = mass at node I (input quantity MASI on **R** command)

M_J = mass at node J (input quantity MASJ on **R** command)

C_o = damping constant (input quantity DAMP on **R** command)

When the element status is OFF, all element matrices are set to zero.

14.37.3 Adjustment of Real Constants

If KEYOPT(6) > 0, a real constant is to be adjusted as a function of the control parameter as well as other real constants. Specifically,

$$\text{if KEYOPT(6)} = 0 \text{ or } 1, \ k_o' = k_o + D \tag{14.37-4}$$

$$\text{if KEYOPT(6)} = 2, \ C_o' = C_o + D \tag{14.37-5}$$

$$\text{if KEYOPT(6) = 3,} \quad M_J' = M_J + D \tag{14.37-6}$$

$$\text{if KEYOPT(6) = 4,} \quad O_n' = O_n + D \tag{14.37-7}$$

$$\text{if KEYOPT(6) = 5,} \quad O_f' = O_f + D \tag{14.37-8}$$

$$\text{if KEYOPT(6) = 6,} \quad F_A' = F_A + D \tag{14.37-9}$$

$$\text{if KEYOPT(6) = 7,} \quad M_I' = M_I + D \tag{14.37-10}$$

$$\text{or, if KEYOPT(6) = 8,} \quad F_S' = F_S + D \tag{14.37-11}$$

where:

$$D = \begin{cases} C_1 \, |P_{cn}|^{C_2} + C_3 \, |P_{cn}|^{C_4} & \text{if KEYOPT(9) = 0} \\ f_1 \left(C_1, \ C_2, \ C_3, \ C_4, \ P_{cn} \right) & \text{if KEYOPT(9) = 1} \end{cases}$$

F_A = input quantity AFORCE ON **R** command

F_S = input quantity FSLIDE on **RMORE** command

C_1, C_2, C_3, C_4 = input quantities C1, C2, C3, and C4 on **RMORE** command

P_{cn} = control parameter (defined below)

f_1 = function defined by subroutine USERRC

If F_S' (or F_S, if KEYOPT(6) $\neq$ 8) is less than zero, it is reset to zero.

14.37.4   Evaluation of Control Parameter

The control parameter is defined as:

$$P_{cn} = \begin{cases} V & \text{if KEYOPT(1) = 0 or 1} \\[2ex] \dfrac{dV}{dt} & \text{if KEYOPT(1) = 2} \\[2ex] \dfrac{d^2V}{dt^2} & \text{if KEYOPT(1) = 3} \\[2ex] \displaystyle\int_0^t V dt & \text{if KEYOPT(1) = 4} \\[2ex] t & \text{if KEYOPT(1) = 5} \end{cases}$$

(14.37–12)

where:

$$V = \begin{cases} u(K) - u(L) & \text{if node L is defined} \\ u(K) & \text{if node L is not defined} \end{cases}$$

t = time (input on **TIME** command)

u = degree of freedom as selected by KEYOPT(2)

The assumed value of the control parameter for the first iteration (P_{cn}^1) is defined as:

$$P_{cn}^1 = \begin{cases} \dfrac{O_n + O_f}{2} & \text{if } S^t = 1 \text{ or} -1 \\[1ex] \text{or} \\[1ex] T_{UNIF} & \text{if } S^t = 0 \text{ and KEYOPT(2) = 8} \\[1ex] \text{or} \\[1ex] 0 & \text{all other cases} \end{cases}$$

(14.37–13)

where:

S^t = input as START on **R** command defining starting status
where: 1 means ON, –1 means OFF

T_{UNIF} = uniform temperature (input on **BFUNIF** command)