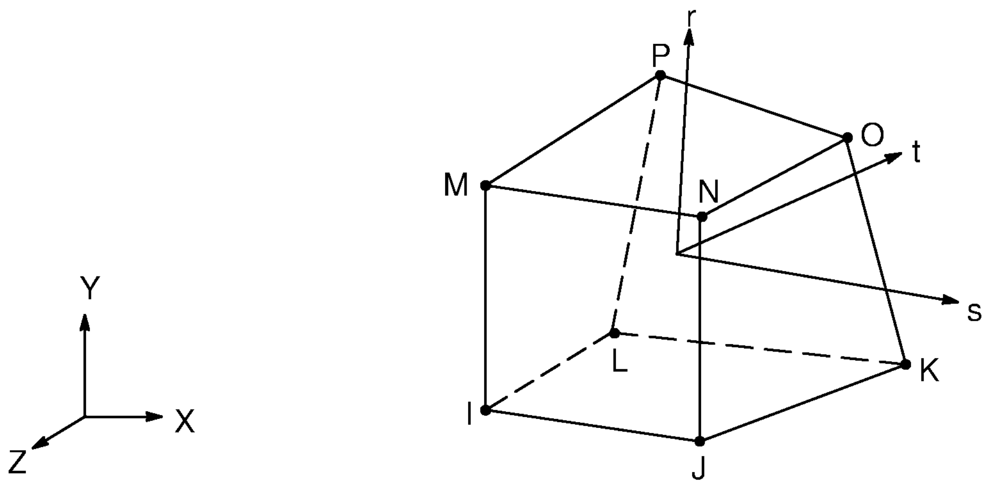
14.70 SOLID70 — 3–D Thermal Solid



Matrix or Vector	Shape Functions	Integration Points
Conductivity Matrix	Equation (12.8.18–20)	2 x 2 x 2
Specific Heat Matrix	Equation (12.8.18–20). Matrix is diagonalized as described in Section 13.2	Same as conductivity matrix
Heat Generation Load Vector	Equation (12.8.18–20)	2 x 2 x 2
Convection Surface Matrix and Load Vector	Equation (12.8.18–20) specialized to the face	2 x 2

14.70.1 Other Applicable Sections

Section 6.2 has a complete derivation of the matrices and load vectors of a general thermal analysis element. Section 13.1 describes integration point locations. Mass transport is discussed in Section 14.55.

14.70.2 Fluid Flow in a Porous Medium

An option (KEYOPT(7) = 1) is available to convert SOLID70 to a nonlinear steady–state fluid flow element. Pressure is the variable rather than temperature. From equation (6.2–7), the element conductivity matrix is:

$$\left[K_c^{tb}\right] = \int_{vol} [B]^T [D] [B] \; d(vol) \qquad (14.70\text{–}1)$$

[B] is defined by equation (6.2–7) and for this option, [D] is defined as:

$$[D] = \begin{bmatrix} \frac{K_x^{\infty} \rho}{\mu + K_x^{\infty} E} & 0 & 0 \\ 0 & \frac{K_y^{\infty} \rho}{\mu + K_y^{\infty} E} & 0 \\ 0 & 0 & \frac{K_z^{\infty} \rho}{\mu + K_z^{\infty} E} \end{bmatrix}$$

where:
- K_x^{∞} = absolute permeability of the porous medium in the x direction (input as KXX on **MP** command)
- ϱ = mass density of the fluid (input as DENS on **MP** command)
- μ = viscosity of the fluid (input quantity VISC on **MP** command)
- E = $\rho \; \beta \; S^{\alpha}$
- β = visco–inertial parameter of the fluid (input quantity C on **MP** command)
- S = seepage velocity (at centroid from previous iteration, defined below)
- α = input as MU on **MP** command

For this option, no “specific heat” matrix or “heat generation” load vector is computed.

The pressure gradient components are computed by:

$$\begin{Bmatrix} g_x^p \\ g_y^p \\ g_z^p \end{Bmatrix} = [B] \{T_e\} \qquad (14.70\text{–}2)$$

where:
- g_x^p = output quantity PRESSURE GRADIENT (X)
- $\{T_e\}$ = vector of element temperatures (pressures)

The pressure gradient is computed from:

$$g^p = \sqrt{\left(g_x^p\right)^2 + \left(g_y^p\right)^2 + \left(g_z^p\right)^2} \quad (14.70\text{–}3)$$

where: g^p = output quantity PRESSURE GRADIENT (TOTAL)

The mass flux components are:

$$\begin{Bmatrix} f_x \\ f_y \\ f_z \end{Bmatrix} = -[D] \begin{Bmatrix} g_x^p \\ g_y^p \\ g_z^p \end{Bmatrix} \quad (14.70\text{–}4)$$

The vector sum of the mass flux components is:

$$f = \sqrt{f_x^2 + f_y^2 + f_z^2} \quad (14.70\text{–}5)$$

where: f = output quantity MASS FLUX

The fluid velocity components are:

$$\begin{Bmatrix} S_x \\ S_y \\ S_z \end{Bmatrix} = \frac{1}{\rho} \begin{Bmatrix} f_x \\ f_y \\ f_z \end{Bmatrix} \quad (14.70\text{–}6)$$

where: S_x = output quantity FLUID VELOCITY (X)

and the maximum fluid velocity is:

$$S = \frac{f}{\rho} \quad (14.70\text{–}7)$$

where: S = output quantity FLUID VELOCITY (TOTAL)