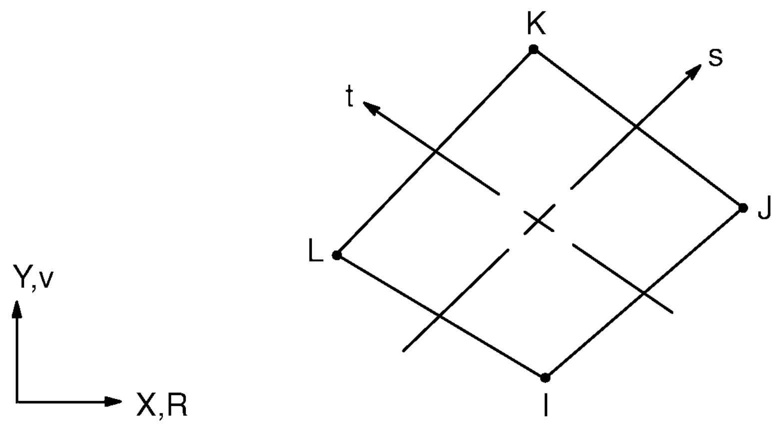
14.55 PLANE55 — 2–D Thermal Solid



Matrix or Vector	Geometry	Shape Functions	Integration Points
Conductivity Matrix	Quad	Equation (12.6.5–20)	2 x 2
	Triangle	Equation (12.6.1–20)	1 if planar 3 if axisymmetric
Specific Heat Matrix	Same as conductivity matrix. Matrix is diagonalized as described in Section 13.2.		Same as conductivity matrix
Heat Generation Load Vector	Same as conductivity matrix		Same as conductivity matrix
Convection Surface Matrix and Load Vector	Same as conductivity matrix evaluated at the face		2

14.55.1 Other Applicable Sections

Chapter 6 describes the derivation of the element matrices and load vectors as well as heat flux evaluations. Section 14.70 describes fluid flow in a porous medium, accessed in PLANE55 with KEYOPT(9) = 1. Section 13.1 describes integration point locations.

14.55.2 Mass Transport Option

If KEYOPT(8) > 0, the mass transport option is included as described in Section 6.1 with equation (6.1–1) and by K_e^{tm} of equation (6.2–7). The solution accuracy is dependent on the element size. The accuracy is measured in terms of the non–dimensional criteria called the element Peclet number (Gresho(58)):

$$P_e = \frac{VL\rho C_p}{2K} \tag{14.55–1}$$

where:
- V = magnitude of the velocity vector
- L = element length dimension along the velocity vector direction
- ϱ = density of the fluid (input as DENS on **MP** command)
- C_p = specific heat of the fluid (input as C on **MP** command)
- K = equivalent thermal conductivity along the velocity vector direction

The terms V, L, and K are explained more thoroughly below:

$$V = \left(V_x{}^2 + V_y{}^2\right)^{1/2} \tag{14.55–2}$$

where:
- V_x = fluid velocity (mass transport) in x direction (input quantity VX on **R** command)
- V_y = fluid velocity (mass transport) in y direction (input quantity VY on **R** command)

Length L is calculated by finding the intersection points of the velocity vector which passes through the element origin and intersects at the element boundaries.

For orthotropic materials, the equivalent thermal conductivity K is given by:

$$K = K_x K_y \left[\frac{\left(1 + m^2\right)}{K^2{}_y + m^2 K_x{}^2}\right]^{1/2} \tag{14.55–3}$$

where::
- K_x, K_y = thermal conductivities in the x and y directions (input quantities KXX and KYY on **MP** command)
- m = slope of the velocity vector in the element coordinate system
- = $\frac{V_y}{V_x}$ (if KEYOPT(4) = 0)

For the solution to be physically valid, the following condition has to be satisfied (Gresho(58)):

$$P_e < 1 \tag{14.55–4}$$

This check is carried out during the element formulation and an error message is printed out if equation (14.55–4) is not satisfied. When this error occurs, the problem should be re–run after reducing the element size in the direction of the velocity vector.