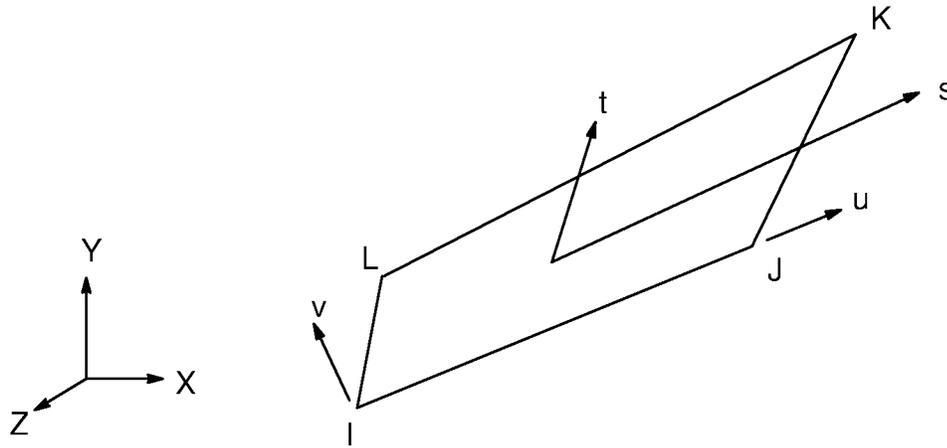


# 14.41 SHELL41 — Membrane Shell



Matrix or Vector	Geometry	Shape Functions	Integration Points
Stiffness Matrix	Quad	Equations (12.5.8–1) and (12.5.8–2) and, if modified extra shape functions are included (KEYOPT(2) = 0) and element has 4 unique nodes Equations (12.5.9–1) and (12.5.9–2)	2 x 2
	Triangle	Equations (12.5.1–1) and (12.5.1–2)	1
Foundation Stiffness Matrix	Quad	Equation (12.5.8–3)	Same as stiffness matrix
	Triangle	Equation (12.5.1–3)	Same as stiffness matrix

Matrix or Vector	Geometry	Shape Functions	Integration Points
Mass Matrix	Quad	Equations (12.5.8–1), (12.5.8–2) and (12.5.8–3)	Same as stiffness matrix
	Triangle	Equations (12.5.1–1), (12.5.1–2), and (12.5.1–3)	Same as stiffness matrix
Stress Stiffness Matrix	Same as mass matrix		Same as stiffness matrix
Thermal and Normal Pressure Load Vector	Same as stiffness matrix		Same as stiffness matrix
Edge Pressure Load Vector	Same as mass matrix, specialized to the edge		2

Load Type	Distribution
Element Temperature	Bilinear in plane of element, constant thru thickness
Nodal Temperature	Bilinear in plane of element, constant thru thickness
Pressure	Bilinear in plane of element and linear along each edge

References: Wilson(38), Taylor(49)

### 14.41.1 Assumptions and Restrictions

There is no out-of-plane bending stiffness.

When the 4-node option of this element is used, it is possible to input these four nodes so they do not lie in an exact flat plane. This is called a warped element, and such a nodal pattern should be avoided because equilibrium is lost. The element assumes that the resisting stiffness is at one location (in the plane defined by the cross product of the diagonals) and the structure assumes that the resisting stiffnesses are at other locations (the nodes). This causes an imbalance of the moments. The warping factor is computed as:

$$\phi = \frac{D}{\sqrt{A}} \quad (14.41-1)$$

where:

- D = component of the vector from the first node to the fourth node parallel to the element normal
- A = element area

A warning message will print out if the warping factor exceeds 0.00004 and a fatal message occurs if it exceeds 0.04. Rigid offsets of the type used with SHELL63 are not used.

## 14.41.2 Wrinkle Option

When the wrinkle option is requested (KEYOPT(1) = 2), the stiffness is removed when the previous iteration is in compression, which is similar to the logic of the gap elements. This is referred to as the wrinkle option or cloth option. The following logic is used. First, the membrane stresses at each integration point are resolved into their principal directions so that shear is not directly considered. Then, three possibilities exist:

1. Both principal stresses are in tension. In this case, the program proceeds with the full stiffness at this integration point in the usual manner.
2. Both principal stresses are in compression. In this case, the contribution of this integration point to the stiffness is ignored.
3. One of the principal stresses is in tension and one is in compression. In this case, the integration point is treated as an orthotropic material with no stiffness in the compression direction and full stiffness in the tension direction. Then a tensor transformation is done to convert these material properties to the element coordinate system. The rest of the development of the element is done in the same manner as if the option were not used.