Concepts of Stress Analysis with CosmosWorks

Part 2, draft 3, 09/29/06

Element Types and Geometries

CosmosWorks currently includes solid continuum elements and curved surface shell elements (thin and thick). The shells are triangular with three vertex nodes or three vertex and three mid-edge nodes. The solids are tetrahedra with four vertex nodes or four vertex and six mid-edge nodes. They use linear and quadratic interpolation for the solution based on whether they have two or three nodes on an edge. The linear elements are also called simplex elements because their number of vertices is one more than the dimension of the space.

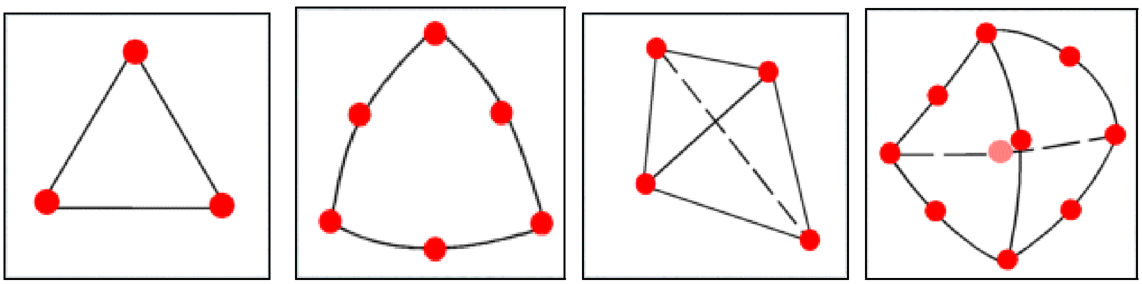
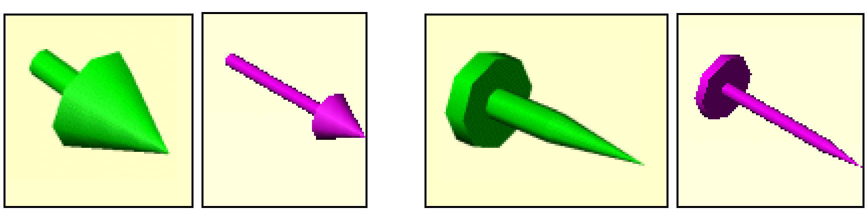


Figure 1

The solid elements have three translational degrees of freedom (dof) as nodal unknowns, for a total of 12 or 30. The shell elements have three translational degrees of freedom as well as three rotational degrees of freedom, for a total of 18 or 36. The CosmosWorks symbol for translational and rotational dof are shown in green in Figure 2, along with the corresponding force and couple vectors in pink. Since finite element solutions are based on work-energy relations, the word corresponding means that their dot product represents mechanical work done at the point. The difference in dof types means that moments or couples can only be applied directly to shell models. Solid elements require that couples be indirectly applied by specifying a pair of equivalent pressure distributions, or an equivalent pair of equal and opposite forces at two nodes on the body.



Displacement Force Rotation Couple

Figure 2

When a model can involve either translations or rotations as dof they are often referred to as generalized displacements. The CosmosWorks nodal symbols for unknown generalized displacement dof's for the solid nodes (top) and shell nodes are seen in Figure 3. You almost always must supply enough restraints to prevent any model from undergo a rigid body translation or rigid body rotation.

For simplicity many finite element examples incorrectly apply complete restraints at a face, edge or node. That is, they enforce an **Immovable** condition for solids or a **Fixed** condition for shells. Actually determining the type of restraint, as well as where the part is restrained is often the most difficult part of an analysis.

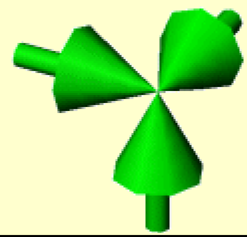
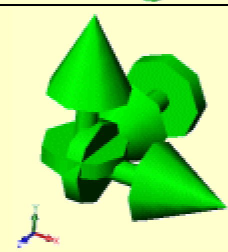
3D symbol	
3D symbol (the arrows are for translations and the discs are for rotations)	

Figure 3

Symmetry dof on a flat plane

A plane of symmetry is flat and has mirror image geometry, material properties, loading, and restraints. You need to understand the **symmetry restraints** that are applied on such planes for solids and for shells. Figure 4 shows that for both solids and shells the displacement perpendicular to the symmetry plane is zero, while for shells have the additional condition that the in-plane component of its rotation vector is zero. Of course, the symmetry plane conditions can be stated in a different way. For a solid element translational displacements parallel to the symmetry plane are allowed. For a shell element rotation is allowed about an axis perpendicular to the symmetry plane and its translational displacements parallel to the symmetry plane are also allowed.

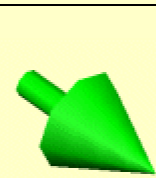
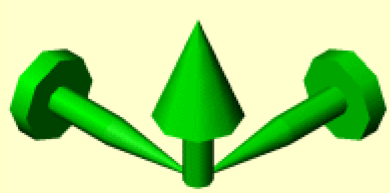
Attribute	Value
DOFs restrained for solid meshes	1 translation
DOFs restrained for shell meshes	1 translation and 2 rotations
3D symbol	 solid mesh  shell mesh
Selectable entities	Flat faces only

Figure 4

Table 1 Restraints for solid stress analysis

Restraint Type	Solid Element Definition
Fixed or **Immovable**	All three translations are zero on face, edge, or vertex.
Hinge	On a cylindrical face, only the circumferential displacement is allowed.
On cylindrical face	The cylindrical coordinate displacements normal to and/or on the cylindrical surface are given.
On flat face	Displacements normal to and/or tangent to a flat face are given.
On Spherical face	The spherical coordinate displacements normal to and/or on the spherical surface are given.
Roller/Sliding or **Symmetry**	Two displacements tangent to a flat face are allowed.
Use reference geometry	A face, edge, or vertex can translate a specified amount relative to a reference plane and axis.

Table 2 Restraints for mid-surface shell analysis

Restraint Type	Mid-surface Shell Definition
Fixed	All translations and rotations are zero on an edge, or vertex. .
Hinge	On a cylindrical face, only the circumferential displacement is allowed.
Immovable	All three translations are zero on a face, edge or vertex.
On cylindrical face	The cylindrical coordinate displacements and rotations normal to and/or on the cylindrical surface are given.
On flat face	Displacements and rotations normal to and/or tangent to the flat face are specified.
On Spherical face	The spherical coordinate displacements and rotations normal to and/or on the spherical surface are given.
Roller/Sliding Symmetry	Two displacements tangent to a flat face and the rotation normal to the flat face are allowed.
Use reference geometry	A face, edge, or vertex can translate and or rotate a specified amount relative to a reference plane and axis.

Table 3 Restraints for picked-surface shell analysis

Restraint Type	Picked-surface Shell Definition
Fixed	Translations and rotations are zero on surface edge or vertex..
Hinge	On a cylindrical face, only the circumferential displacement is allowed.
Immovable	All three translations are zero on surface, its edge, or vertex..
On cylindrical face	The cylindrical coordinate displacements and rotations normal to and/or on the cylindrical surface are given.
On flat face	Displacements and rotations normal to and/or tangent to the flat face are given.
On Spherical face	The spherical coordinate displacements and rotations normal to and/or on the spherical surface are given.
Roller/Sliding Symmetry	Two displacements tangent to a flat face and the rotation normal to the flat face are allowed.
Use reference geometry	A face, edge, or vertex can translate and or rotate a specified amount relative to a reference plane and axis.

Table 4 Load conditions for solid stress analysis

Load Type	Solid Element Definition
Apply force	The total force on a face, edge, or vertex is given relative to a single edge or axis direction.
Apply normal force	The total force normal to a face, at its centroid, is specified and converted to an equivalent pressure.
Apply torque	The total torque on a face is specified with respect to an axis and converted to an equivalent pressure.
Bearing Load	On a cylindrical surface give the total force in a Cartesian X or Y direction to convert to a sine distribution pressure.
Centrifugal	The angular acceleration and angular velocity are given about an axis, edge, or cylindrical surface.
Connectors	See CosmosWorks help files.
Gravity	The gravitation acceleration value is given and oriented by an axis, edge, or a direction in or normal to a selected plane.
Remote load	See CosmosWorks help files.
Temperature	Not recommended. Transfer from thermal analysis.

Table 5 Load conditions for mid-surface shell analysis

Load Type	Mid-surface Shell Definition
Apply force	The total force on a mesh face is specified. Or, given on a side face or edge to define the mid-surface edge or vertex value, respectively.
Apply moment	The total moment on a mesh face is specified. Or, given on a side face or edge to define the mid-surface edge or vertex value, respectively.
Apply normal force	The total force normal to a face, at its centroid, is specified and converted to an equivalent pressure.
Apply torque	The total torque on a face is specified with respect to an axis and converted to an equivalent pressure.
Bearing Load	On a cylindrical surface give the total force in a Cartesian X or Y direction to convert to a sine distribution pressure.
Centrifugal	The angular acceleration and angular velocity are given about an axis, edge, or cylindrical surface.
Connectors	See CosmosWorks help files.
Gravity	The gravitation acceleration value is given and oriented by an axis, edge, or a direction in or normal to a selected plane.
Remote load	See CosmosWorks help files.
Temperature	Not recommended. Transfer from thermal analysis.

Table 6   Load conditions for picked-surface shell analysis

Load Type	Picked-surface Shell Definition
Apply force	The total force on a mesh face is specified. Or, given on the picked surface edge or vertex value.
Apply moment	The total moment on a mesh face is specified. Or, given on the picked surface edge or vertex value.
Apply normal force	The total centrodial force normal to a picked surface face is specified and converted to an equivalent pressure.
Apply torque	The total torque on a picked surface face is specified with respect to an axis and converted to an equivalent pressure.
Bearing Load	On a picked cylindrical surface give the total force in a Cartesian X or Y direction for a sine distribution pressure.
Centrifugal	The angular acceleration and angular velocity are given about an axis, edge, or cylindrical surface.
Connectors	See CosmosWorks help files.
Gravity	The gravitation acceleration value is given and oriented by an axis, edge, or a direction in or normal to a selected plane.
Remote load	See CosmosWorks help files.
Temperature	Not recommended. Transfer from thermal analysis.

