5.1 Introduction

This chapter presents finite element modeling of vessel with hemispherical and torispherical heads. These shells possess axial symmetry and hence can be modeled by using axisymmetric shell element and axisymmetric solid element in ANSYS 8.0 FE software. The section 5.2 describes the modeling of hemispherical headed vessel using axisymmetric shell element (section 5.2.1) and axisymmetric solid element (section 5.2.2). The modeling of torispherical head vessel with knuckle of uniform and variable thicknesses using axisymmetric shell and axisymmetric solid finite element are presented in the sections 5.3.1 and 5.3.2 respectively.

5.2 Pressure vessel with hemispherical head

The section describes the modeling of hemispherical headed vessel using axisymmetric shell element (section 5.2.1) and axisymmetric solid element (section 5.2.2).

5.2.1 Hemispherical headed vessel using axisymmetric shell element

Hemispherical headed vessel is modeled, using the axisymmetric two node or three node shell finite elements. The middle surface of the vessel is considered in Fig. 5.1. The junction of hemispherical head and the cylinder end is considered critical from stress point of
view. Uniform shell thickness \( h_c = h_d = 8 \text{ mm} \) is assumed for these two geometrical parts. The finite element meshes obtained using two node and three node axisymmetric shell elements are shown in Figs. 4.1(c) and 4.1(d) respectively. These elements have three dof: two translations \((x, y)\) and one rotation in xy plane. The pole displacement (node 1) is constrained in radial direction (in x direction) and restrained against rotation in the xy plane, and the mid point of cylinder portion displacement (node 22) is constrained in the axial direction (along y direction). The combustion pressure of 6.5 N/mm\(^2\) \((\approx 1000 \text{ psi})\) is applied as internal pressure, Fig. 5.1. In the case of two node elements, the number of nodes is 22 and the number of elements is 11. In the case of three node elements, the number of nodes is 43 and the number of elements is 11.

![Fig. 5.1 Axisymmetric shell element (two node) with boundary conditions and loading.](image)

### 5.2.2 Modeling of hemispherical head vessel using axisymmetric solid element

In the modeling, the three axisymmetric solid elements, i.e. four node axisymmetric solid element (section 4.3.1), four node incompatible mode axisymmetric solid element (section 4.3.2) and eight node axisymmetric solid element (section 4.3.3) are considered. The
FEM, being a numerical process, the numerical accuracy obtained depends on the meshing. Three types of meshing are considered for the present study: (i) single element across the thickness, Fig. 5.2(a), (ii) two elements across the thickness, Fig. 5.2(b) and (iii) four elements across the thickness, Fig. 5.2(c). Outer and inner surfaces of the vessel are obtained. These are the models for the case of uniform wall thickness of hemispherical head. These elements have two degree of freedom per node, i.e. two translations ((i) along x direction and (ii) along y direction). The pole nodes (top end of the hemisphere) are constrained in radial direction (along x direction) and the nodes on the middle of cylinder are constrained in the axial direction (along y direction). An internal pressure is applied as a load on the inner surface. For four node element (i) in the case of one element across thickness, the number of nodes is 62 and the number of elements is 30 (Fig. 5.2(a)), (ii) in the case of two elements across thickness, the number of nodes is 93 and the number of elements is 60 (Fig. 5.2(b)) and (iii) in the case of four elements across thickness, the number of nodes is 124 and the number of elements is 120 (Fig. 5.2(c)).
5.3 Torispherical head

The modeling of torispherical head vessel with knuckle of uniform and variable thicknesses using axisymmetric shell and axisymmetric solid finite element are presented in the following sections 5.3.1 and 5.3.2 respectively.

5.3.1 Torispherical head with knuckle of uniform thickness using axisymmetric shell element

Using the two node (Fig. 4.1(c)) or three node (Fig. 4.1(d)), axisymmetric shell element, the torispherical head with knuckle of uniform thickness is modeled. The torispherical head vessel consists of three parts crown, knuckle and cylinder as given in chapter 3 (Fig. 3.8). The knuckle is the critical zone where the higher stresses are developed. In order to capture this higher stresses, the finer meshes are used in this region. The finite element mesh is shown in Fig. 5.3. In the case of two node elements, the number of nodes is
Fig. 5.3 FE Model of torispherical head vessel using axisymmetric shell element.

35 and the number of elements are 34. In the case of three node elements, the number of nodes is 69 and the number of elements is 34. The boundary and loading are same as that of the hemispherical headed vessel, section 5.6. The same meshes are used in the case of knuckle of variable thickness also. However, the variation of nodal thickness is input as a parameter, whereas in the case of shell of uniform thickness, single values of thickness are given separately.

5.3.2. Torispherical head knuckle of uniform thickness using axisymmetric solid element

In general, the finite element meshes in Fig. 5.4 are same as that given in Fig. 5.2 (single element across the thickness, two elements across the thickness and four elements across the thickness) except the finer element in the knuckle region. The local thicknesses are computed using the coordinates of the nodes. The coordinates are different for the two cases of tangent method and spline method in the knuckle region. Figs. 5.5 and 5.6 show the finite element meshes of tangent method and spline method respectively.
Fig. 5.4 Axisymmetric solid element with boundary condition and loading (a) one element across the thickness (b) two elements across the thickness and (c) four elements across the thickness.

Fig. 5.5 Axisymmetric solid element with boundary condition and loading of knuckle of variable thickness-tangent method: (a) one element across the thickness (b) two elements across the thickness and (c) four elements across the thickness.
Fig. 5.6 Axisymmetric solid element with boundary condition and loading of knuckle of variable thickness-spline method: (a) one element across the thickness (b) two elements across the thickness and (c) four elements across the thickness.