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Buckling Analysis of Torispherical Head Pressure Vessel Using Finite Element Analysis

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ABSTRACT

Pressure vessels are being widely employed worldwide as means to carry, store or receive fluids. The pressure differential is dangerous and many fatal accidents have occurred in the history of their development and operation. Torispherical Heads have a dish with a fixed crown radius (CR), the size of which depends on the type of torispherical head. The transition between the cylinder and the dish is called the knuckle. The knuckle has a to roidal shape. Torispherical heads require less forming than semi-ellipsoidal heads.

The aim of the research is to carry out Buckling analysis in a torispherical head pressure vessel due to applied internal pressure.The analyses characteristics are investigated by Finite Element Method software. For Buckling, a pressure vessel will be designed and then model educing Solid Edge software.

Buckling analysis is carried out to determine the buckling strength.The research is aimed to analyze torispherical head pressure vessel for different internal pressures.

Keywords: *Pressure vessel, Torispherical Heads, Buckling analysis, Stress Intensity Factor.*

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I. INTRODUCTION

The predicted lifespan of parts and components is a key question regarding the safety of certain components, such as pressure vessels, airplanes, cars, or with regard to the reliability of micro-electronic components or implants in the human body.

Pressure vessels to re substances under pressure higher than atmospheric conditions and are found all over the place. They are used in homes and hospitals for hot water storage, in many different factories and plants, and in mining and oil refineries. Pressure vessels store large amounts of energy. The higher the operating pressure and the bigger the vessel, the moretheenergyreleasedintheeventofaruptureandconsequentlythehighertheextentof damage or disaster or the danger it poses, hence there should be no complacency about the risks. Unfortunately, pressure vessels accidents happen much more than they should.

The objective of the Research is to Identify the Critical Buckling Pressure for Torispherical Head Pressure Vessel subjected to various Internal Pressure.

II. METHODOLOGY

To achieve the objectives listed above the following steps are considered:

- Designing of a torispherical head pressure vessel
- Modeling the pressure vessel as per designdata
- Buckling analysis using ANSYSsoftware
- Finding the Buckling Pressure.

III. DESIGN DETAILS

3.1 Material Selection

By literature survey we have selected the material as SA-240 304, which is widelyused for pressure vessels. Type 304 stainlesssteel is a variation of 18% chromium - 8% nickel austenitic alloy, the most familiar and most frequently used alloy in the stain less teel family. These alloys may be considered for a wide variety of applications: resistance to corrosion, prevention of product contamination, resistance to oxidation, ease of fabrication, excellent formability, beauty of appearance, ease of cleaning high strength with low weight, good strength and toughness at cryogenic temperatures, ready availability of a wide range of product forms. Table 1 shows the chemical composition of material SA-240304.

Mechanical & Physical properties

- Density, $\rho = 8.03 g/cm^3$
- Modulusofrigidity, $E = 200 GPa$
- Yield strength, $\sigma_y = 215 MPa$
- Tensilestrength, $\sigma_t = 505\ MPa$
- Hardness, $= 201 BHN$

Tab. 1: SA-240 304 Chemical composition

Element	Percent by weight
Carbon	0.08
Manganese	2.00
Phosphorous	0.045
Sulphur	0.03
Silicon	0.75
Chromium	18.00
Nickel	8.00
Nitrogen	0.10
Iron	70.995

3.1.1 Thickness Calculations

Assumptions

Internal Pressure, $P_i = 5 N/mm^2$

Internal Diameter, $D_i = 1000 mm$

Poisson'sratio, $\mu = 0.29$

$$\sigma_h = \frac{p_i\, r_i}{t} = \frac{5 * 500}{t} = \frac{2500}{t}\ N/mm^2 \quad (3.1)$$

$$\sigma_a = \frac{p_i\, r_i}{2\,t} = \frac{5 * 500}{2\,t} = \frac{1250}{t}\ N/mm^2 \quad (3.2)$$

Where, σ_h= Hoop orTangentialstress

σ_a=Axialstress

According to Von-Misescriterion,

$$\sigma_y = \sqrt{\sigma_h^2 + \sigma_a^2 - (\sigma_h * \sigma_a)} \quad (3.3)$$

$$\Rightarrow\ 215^2 = ({}^{2500}/_t)^2 + ({}^{1250}/_t)^2 - [({}^{2500}/_t) * ({}^{1250}/_t)]$$

$$Thus,\ t = 10.07\ mm \approx 11\ mm$$

Thickness calculation for Torispherical head

According to UG 31 of ASME sec VIII Div 1, minimum thickness required is given by

$$t = \frac{(p_i\, D_i) + C}{(2\,\sigma_y\, E) - (0.2\, p_i)} \quad (3.4)$$

Where,

C = Corrosion allowance =3mm

E=Efficiencyofthejoint=1.0

$$\Rightarrow\ t = \frac{(5 * 1000) + 3}{(2 * 215 * 1) - (0.2 * 5)}$$

$$Thus,\ t = 11.66\ mm \approx 12\ mm$$

Therefore, taking the higher value for thickness as **12 *mm***

Dimensions of cylinder

- Inner radius, r_i = 500 mm
- Outer radius, $r_o = r_i + t = 512\ mm$
- Length of the cylinder, L_c = 2000 mm

Dimensions of Torispherical head

- Crown radius, $L = d_o$ = 1024 mm
- Knuckle radius, r = 0.1 d_o = 102.4 mm
- Straight Flange, SF = 3.5 t = 42 mm
- Dished height, DH
  $= (0.1935\ d_0) - (0.455\ t) = 192.684\ mm$
- Total head height, $T_{Hi} = SF + DH = 234.684 mm$

3.2 Finite element Model Development

3.2.1 Shell 93 (8 node) element description

- SHELL 93 is particularly well suited to model curvedshells.
- The element has six degrees of freedom at each node: translations in the nodal x, y, and z directions and rotations about the nodal x, y, andz-axes.
- The deformation shapes are quadratic in both in-planedirections.
- Theelementhasplasticity,stressstiffening,largedeflection,andlargestraincapabilities.
- The geometry, node locations, and the coordinate system for this element are shown in Figure1.

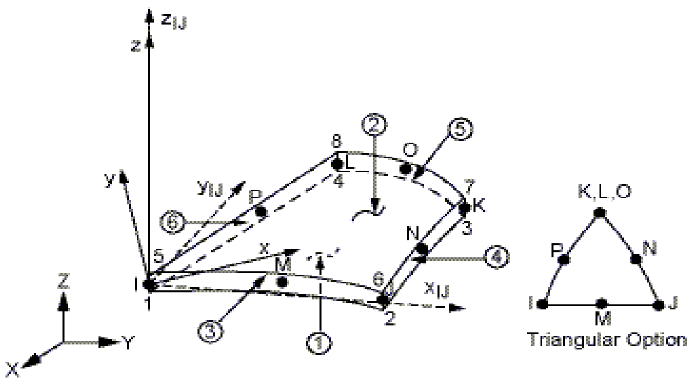

Fig. 1: Shell 93(8 Node) Geometry

- The element is defined by eight nodes, four thicknesses, and the orthotropicmaterial properties.
- A triangular-shaped element may be formed by defining the same node number for nodes K, L andO.

3.2.2 Model for buckling analysis

Eigenbucklinganalysisof3Dtorisphericalheadsubjectedtointernalpressureof1Mpa to 3 MPa is performed to determine the critical buckling load and to predict the buckling mode shape under internal pressure. The eigen value approach takes the results obtained from the static analysis. Hence we first solve for the static analysis and then run the eigen value buckling. In this case the static analysis follows the same procedure as explained in previous section. The Geometry of the 3D torispherical head is shown in figure 2. Inthis study, 8 node SHELL 93 is used as element. The Dimensions of the torispherical head is shown in table 2.

Tab. 2: Dimensions of torispherical head for buckling and modal analysis

Radius of crown	L = 1024 mm
Radius of knuckle	r = 102.4 mm
Thickness of the vessel	t = 12 mm

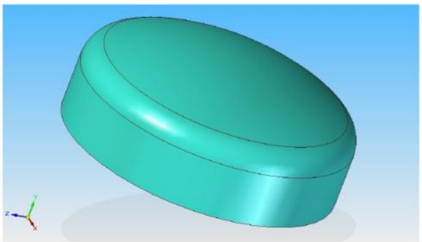

Fig. 2: Torispherical head for Buckling analysis

IV. RESULTS AND DISCUSSIONS

4.1 Buckling Analysis

The Eigen value buckling analysis of 3D torispherical head subjected to internal pressures of 1 Mpa, 2 Mpa and 3 MPa is performed. The parametric study is performed to determine the critical buckling load of the vessel. The effect of parameter such as internal pressure variation on the torispherical head is shown in the below.

Buckling shape of the vessel having thickness 12 mm subjected to an internal pressure of 1 MPa, 2Mpa and 3MPa is shown in Figures, Fig.3 to Fig.8. By the method of Eigen value buckling analysis, the critical buckling pressure at which the vessel undergoes buckling is found to be,

- 234.795 MPa for 1 MPa internal pressure
- 117.400 MPa for 2 MPa internal pressure
- 078.266 MPa for 3 Mpa internal pressure

The vessel buckling is seen in knuckle region because of geometric discontinuity.

The values of buckling stress for each mode is shown in the below table 3.

Tab. 3: Values of critical buckling pressure for different modes

Internal pressure in MPa	Mode	Critical buckling pressure in MPa	Internal pressure in MPa	Mode	Critical buckling pressure in MPa	Internal pressure in MPa	Mode	Critical buckling pressure in MPa
1	1	234.43	2	1	117.22	3	1	078.145
	2	234.63		2	117.22		2	078.147
	3	234.90		3	117.45		3	078.301
	4	234.95		4	117.48		4	078.318
	5	235.01		5	117.51		5	078.338
	6	235.04		6	117.52		6	078.348

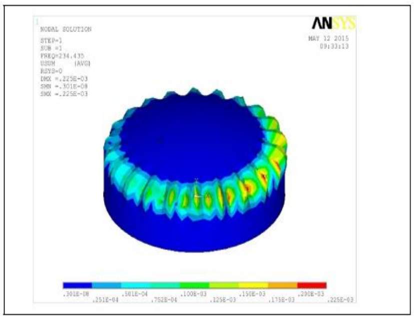

Fig. 3: Modes shape for 1 MPa internal pressure

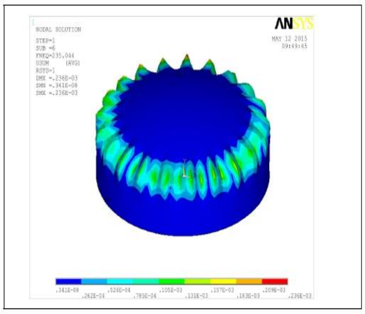

Fig. 4: Modes shape for 1 MPa internal pressure

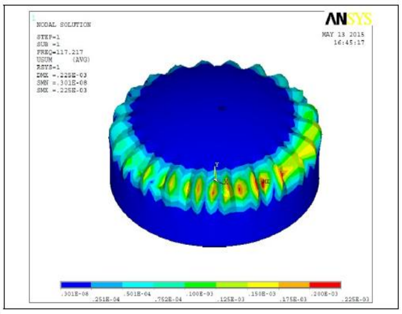

Fig. 5: Modes shape for 2 MPa internal pressure

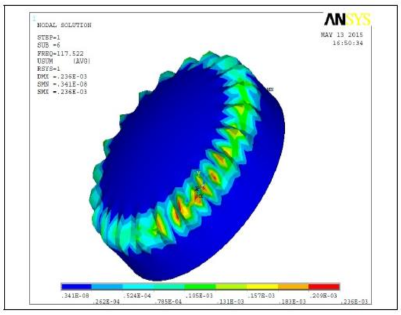

Fig. 6: Modes shape for 2 MPa internal pressure

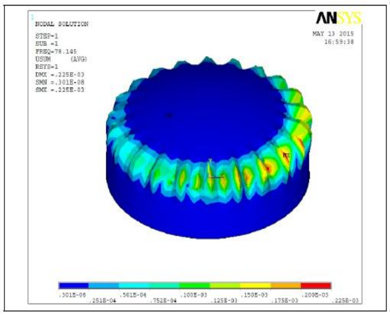

Fig. 7: Modes shape for 3 MPa internal pressure

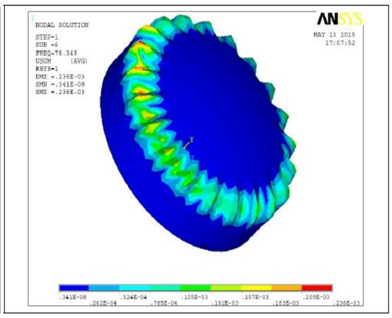

Fig. 8: Modes shape for 3 MPa internal pressure

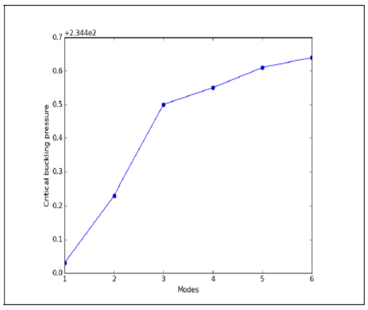

Fig. 9: Variation of critical buckling pressure for 1 MPa internal pressure

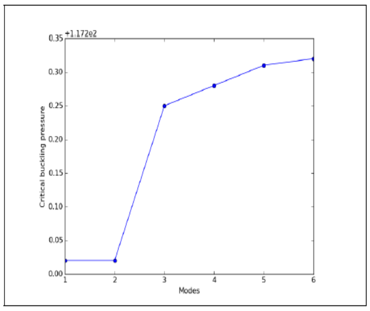

Fig. 10: Variation of critical buckling pressure for 2 MPa internal pressure

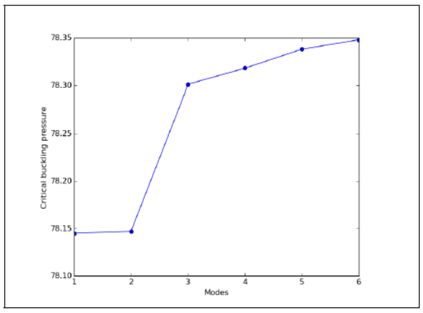

Fig. 11: Variation of critical buckling pressure for 3MPa internal pressure

Fig 9, 10 & 11 shows the of Buckling Pressure for various modes.From the figure it is evident that the Buckling Pressure is decreasing with increase in internal Pressure.

V. CONCLUSION AND SUGGESTIONS FOR FUTURE WORK

5.1 Conclusion

From the finite element analysis performed on a torispherical head pressure vessel subjected to different internal pressures, the following conclusions were made:

- Eigen value buckling analysis was carried out to determine the critical buckling pres- sure at which the vessel undergoes buckling effects. It was found that time taken to buckle is more for least pressure and goes on increasing as the pressure increases. Based on the study performed to determine the critical buckling pressure of the vessel, buckling pressure is influenced by the thickness of the vessel. Higher the thicknesses of the vessel better the buckling resistance.

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