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Design and Analysis of Cryogenic Pressure Vessel Using Tori-Spherical Dish

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Abstract- In this paper we have designed a pressure vessel as per ASME section VIII and division I, of capacity 1 kl to store cryogenic liquid like nitrogen, oxygen and argon etc. The literature has indicated a growing interest in the field of stress concentration in the pressure vessels. These stresses are studied by using FEM and compared with theoretical value. In this paper we considered uniform thickness to the entire vessel which is having trori spherical dish end. Modeling of the particular vessel is carried out using solid works, meshing is carried out using hyper mesh 6.1 for different cases. Working pressure and operating pressure and maximum operating pressure, The analysis is carried out using ANSYS software. Finally, all the results are checked for the accuracy and operating conditions. This type of structure vessels are built up by enclosing a series of sheets over a main or core tube.

Keywords:- Cryogenic pressure vessel, ASME code, finite element method, Vonmises stress.

I. INTRODUCTION

Pressure vessel is used for storing the high pressurized fluid at very low temperature. And due to this the pressure difference is observed between inner shell and jacket shell. The inner vessel pressure is normally higher than the outside pressure. The fluid is undergoing the change of its state. The design of pressure vessel is depend upon its uses.

The pressure vessels are used in nuclear and thermal power plant and chemical factory, steam, gas, cryogenic fields and air supply system in industries. The different types of material can be used. Uses of material and its grade are depends on the location and area of work for pressure vessel it may be brittle such as cast iron or ductile such as mild steel, stainless steel [1].

The cylinder generally manufactured by bending or rolling a sheet of metal with longitude weld. Pressure vessel can be made up of two or more concentric shells. In this paper we consider two concentric shell. Thick-walled cylindrical vessels are used for high pressure vessel.

The size of the pressure vessel and the pressure which is consider for our work will dictate the type of construction used. Hetero construction is considered for the use of several layers of material, usually for the purpose of quality control and optimum properties and its utility.

In this paper we take Multilayer (two vessels) Pressure vessel for design calculation. Multilayer construction is used for higher pressures. It provides heigh safety, minimum use of material, and provide cost reduction also, and due to this no stress relief is required. For corrosive applications the inner liner is made of special like stain steel SA 240 TP 304L/ 304 material grade and is not considered for strength criteria[3]. The outer load bearing shells can be made of high tensile low carbon alloys like mild steel IS 2062 GR BR.

Tori spherical Heads: A tori spherical shape, which is extensively used as the end closure for a large variety of cylindrical pressure vessels. This type of dishes are easy to manufactured and cost effective also. Tori spherical heads are made of a dish, with a constant radius. Joining the dish directly to the cylindrical section of the vessel would lead to a rapid change in geometry, resulting in excessive local stresses. To avoid this, a transition section (the “knuckle”) is used between the dish and the cylinder.

Normally, tori spherical heads with pressure ratings much above 10bar are uneconomic [6]. The tori spherical head is actually very similar to the ellipsoid in shape and benefits.

II. LITERATURE REVIEW

In this part of research papers are discussed related to the present work. Some published papers are mentioned here.

There is a long history of innovative and near innovative efforts to improve the performance and versatility of spherical and cylindrical pressure vessel.

Some of them are as follows;
B.S. Azzam, M.A.A. Muhammad, M.O.A. Mokhtar et al 1996) was based on a new design technique that enables rapid and efficient design calculations.

This plan technique empowers the fashioner of the composite pressure vessel to get promptly a definitive disappointment pressure of these vessels depending upon the quantity of layers, layer thickness, fiber introductions, and proper uses of materials. This comparison has shown a good agreement between the theoretical and experimental analysis.

B.S.Thakkar, S.A.Thakkar; “design of pressure vessel using asme code, section viii, division 1”; international journal of advanced engineering research and studies, vol. i, issue ii, january-march, 2012 [7] asme boiler and pressure vessel code 2017 sec 8 Division 1 (2017) [9].

Bandarupalli Praneeth (2012) performed finite element analysis of pressure vessel and piping design. Various parameters of Solid Pressure Vessel & Multilayer Pressure vessels are designed and checked according to the principles of A.S.M.E.

The stresses developed in Solid wall pressure vessel and Multilayer pressure vessel are analysed by using ANSYS. The theoretical values and ANSYS values are compared for both solid wall and multilayer pressure vessels.

It was found that multi layered pressure vessels are superior for high pressures and high temperature operating conditions.[13]

Dr. M. M. Patil (2014) carried out experimental investigations using hydrostatic pressure tests with water. In the case of numerical investigations, the FEA models are constructed using material SA240 Gr 316. The results obtained from both FEA models and experimental tests were compared which shows close agreement. Comparing the flat flange and hub flange model on the ANSYS with the same loading and operating condition, he found 15 to 20 % reduction in stress.[14]

III. DESIGN OBJECTIVES

- To show how hydro structure pressure vessels are suitable for high pressure than single solid pressure vessels.
- To show how we can save in weight of material by using hetero structure vessels in place of a thick size pressure vessel.
- To show the uniform stress can be induced on shell, therefore it is most effective method of uses of the material in the shell. And it can be use for high pressure also.
- To check the effectively of using different types of material shell and jacket shell for reducing the cost of the manufacturing of the vessel.
- What kind of stress formation induced by internal pressure on the outer surface of jacket shell and to make sure that the value of stresses do not reach yield point value during testing.
- And finally check the design with FEM analysis by using ANSYS whiter it is suitable for hetero structure pressure vessel’s analysis.
- To check the feasibility of tori spherical dish.

1. Elements Considered in Designing of Pressure Vessel:

- Working parameters, pressure and temperature of the vessel
- Dimensions, thickness of the plate, size and their limits
- Available materials and their properties and cost.
- Destructive nature of reactants and yields.
- Areas where the defect can be occur.
- Types of pressure vessel design.
- Manufacturing methods.
- Cost consideration.
- Effectiveness of tori spherical dish end

2. Input Design Data:

- Thickness Calculation for Shell Cylinder:
- Design Code - Asme Sec. Viii Division-I
- Volume Of The Pressure Vessel (V): 947 Liters
- Design Pressure (P): 19.88 Bar(G)
- Design Temperature T (Max/Min): (65˚c/-198˚c)
- Inside Diameter of Vessel (Di): 925mm
- Positive Tolerance on Inside Diameter (C1): 0 Mm
- Allowable Stress For Shell Material (S): 2709.640 Bar(G)
- Joint Efficiency For Long. Seam (E): *1.00 Min. Joint Efficiency For Circ. Seam (Ec): *1.00
- Corrosion Allowance (C): 0mm

3. Evaluation for Hydro, Cold Stretch and Pneumatic Test Pressure:

3.1 Hydro Pressure at Top Pc

= 1.3 * P in psig

= 1.3*288.343 psig

= 374.8 psig

= 2.58443 Mpa (g)

= 26.35 kg/cm2 (g)

= 25.84 bar(g)

Table 1. Input Design values.

Particulars	Symbol	Value	Unit
Design Pressure (Maximum Allowable Pressure)	P	288.34	Psig
Total InsideHeight of Iv	H	61.53	Inch
Inside Dia. of Inner Vessel	Di	36.4	Inch
		0.9250	M

3.2 Stress at Hydro Pressure:

P*(R+0.6T)/ET

1931.27 psig

13.31542 Mpa (g)

135.78 kg/cm2 (g)

Hydro Test Position = Horizontal

3.3 Hydro Test Pressure at Bottom

= Pc + (1000 * 9.81 * Di In M / 10^6)

= [2.585+ (0.925000000009*1000*9.81/10^6)]

= 2.594 Mpa (G)

Say = 2.59 Mpa (G)

= 26.4 Kg/Cm2 (G)

= 376.2 Psig

3.4 Minimum Cold Stretch Pressure=

1.5 X Design Pressure

29.82 Bar(G)

3.5 Maximum Cold Stretch Pressure =

31.81 Bar(G)

3.6 Used Cold Stretch Pressure =

29.82 Bar(G)

Note: The cold stretch pressure range should be between 29.82bar (g) to 31.81bar(g) and should not exceed 31.81bar(g)

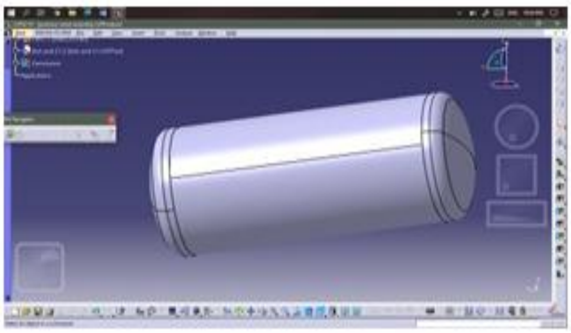

Fig 1. 3 Dimension model of pressurevessel with tori spherical dish end.

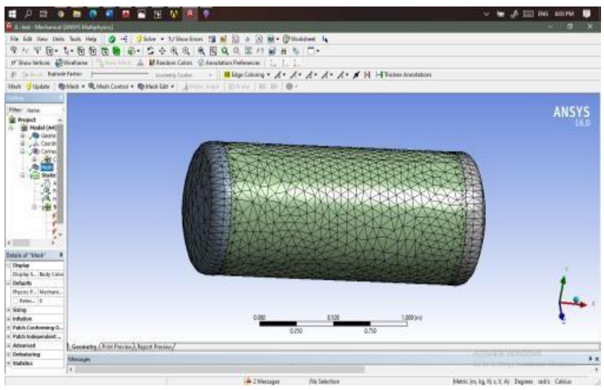

Fig 2. Meshing of Model.

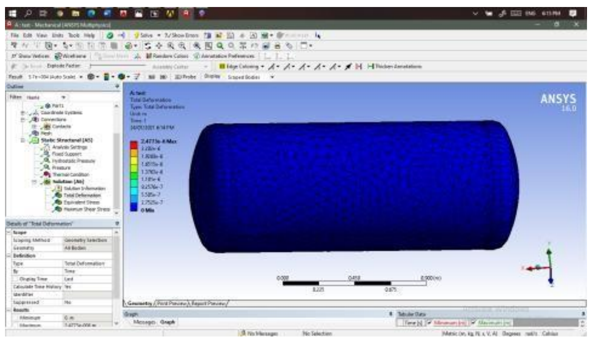

Fig 3. Total Deformation.

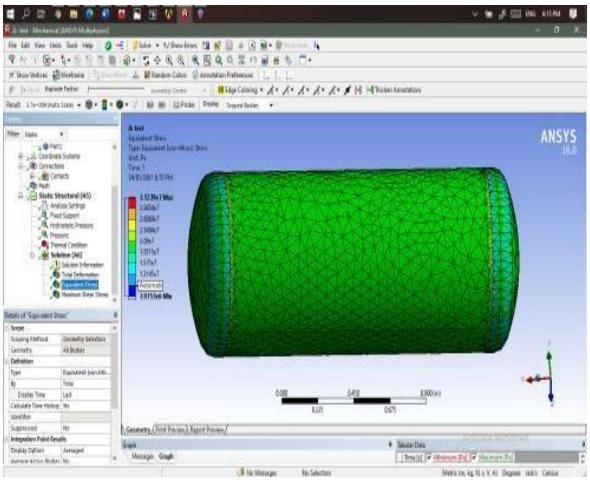

Fig 4. Equivalent stress.

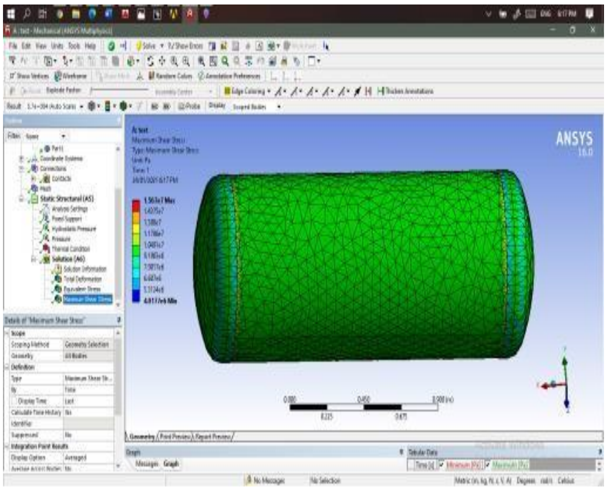

Fig 5. Maximum shear stress analyses.

IV. DISCUSSION

From the present work, it is observed that stresses & deformation in hemispherical heads is the lowest. Maximum Von Mises Stresses in elliptical & torispherical heads are observed 2.5 times (150.67 % more) & 3.58 times (258.22 % more) respectively as compared to Maximum Von Mises stresses in hemispherical head. Maximum deformations observed in elliptical & torispherical heads are 9.26 times (826.83 % more) & 9 times (801.96 % more) respectively as compared to deformation in hemispherical head.

Observed deformations in elliptical & torispherical dish ends are in close agreement. As forming cost of torispherical heads is less than elliptical heads & hemispherical heads, it is recommended for the present case (P<34 bar), though the stresses are slightly on higher side than elliptical head.

V. CONCLUSION

Finite element analysis is used for analysis for pressure vessel. A various type of analysis is carried out by using Ansys software like structural, thermal analysis of the pressure vessel. The design method to be used depends on whether the stress induced in the shell is and its types like tension or compression, and on whether the vessel is subjected to internal or external pressure. And in this paper we generate the report for two different types of material 1st is structural steel and 2nd is stainless steel.

For checking the design of the pressure vessels is safe. We consider factor of safety which is permissible and by which the design is considered safe. Ultimate value of bursting pressure and stresses are taken into consider so that the design may not fail and the input data are validated by comparing output of the theoretical and the design value. This indicates that the design is safe and there are no failure occurs in the pressure vessel.

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