Structural Analysis of Mono and Multi Layer Pressure Vessels

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***Abstract* - Stress and strain estimation is very important in predicting and preventing failure in engineering structures. The main objective of this project is to design a multilayer high pressure vessel and study its advantages over mono block pressure vessel. In order to perform the structural analysis of the multilayer pressure vessel using finite element analysis (FEA), a solid pressure vessel is modeled using Solid Works 2012, followed by the exporting it to a meshing software HYPERMESH 10. Finally the meshed model is exported to analysis platform ANSYS for carrying out the required analysis for both mono and multilayer pressure vessels. The mono block pressure vessel is altered into multilayered pressure vessel using layers feature in ansys.**

Static analysis is performed to determine deflection and stresses experienced by the both mono block and multilayered pressure vessels. With the given uniform pressure in the vessel, static stresses and the deflection of the pressure vessels are determined. Both material and geometrical linearity are considered in the analysis. Linear stress analysis is performed assuming the deformations to be very small. The distortion energy theory (Von-Mises) is considered as an yield criteria.

From the results obtained in analysis, a comparison is made between multilayered pressure vessel and the conventional mono layer pressure vessel.

Keywords: Design, Analysis, Mono block & Multilayer Pressure vessel, ANSYS, HYPERMESH

1. INTRODUCTION

Structures such as LPG tanks capable of holding internal pressure have been very important in the history of science and technology. In order to make a better flow of gas and fluid, an aqueduct or tank must be constructed so they can run all the way from the reservoir to the destination. However, temperature & pressure differential is dangerous and many fatal accidents have occurred in the history of their development and operation. The temperature& pressure differences create stresses in the shell.

A pressure vessel is a closed container designed to hold gases or liquids under internal or external pressure. Pressure vessels are designed to operate safely at a specific pressure and temperature technically referred to as the "Design Pressure" and "Design Temperature". ASME sec VIII and BS standard are the design codes used to design pressure vessel. Pressure vessels may theoretically be of almost any shape, but shapes made of sections of spheres, cylinders, and cones are usually employed. A common design is a cylinder with hemispherical end caps called heads.

Type of pressure vessels:

a. Horizontal vessel on saddle support
b. Vertical vessel on leg support
c. Tall vertical tower
d. Vertical reactor
e. Spherical pressurized storage vessel
f. Vertical vessel on lug support.

Design Objectives

a. To illustrate that multilayer pressure vessels are more suitable for high operating pressures than solid wall pressure vessels.
b. To give you an idea about a significant saving in weight of material may be made by use of a multilayer vessel in place of a single layer vessel.
c. To determine there will be a uniform stress distribution over the entire shell, which is the indication for most effective use of the material in the shell.

2. LITERATURE SURVEY

This section reviews literature available in this area. Pavo et.al. have chosen a pressure vessel of elliptical head to analyze its strength and they described a method for calculating strength, and also described the distribution of total circumferential forces and radial forces of the cylindrical vessel with ellipsoidal heads [1].

Dwivedi and Kumar made the analysis on burst pressure prediction of pressure vessel using FEA [2]. They considered the two cases of pressure vessel for analysis - first is pressure vessel with end caps and second one is pressure vessel without end caps. Considering the vonmises yield criteria, they analyzed that the relative error between the experimental value and the FEA result in case of the pressure vessel with end caps is much less than the pressure vessel without end caps.

Ski made a study on stress analysis on pressure vessel [3]. He found out the stresses in cylinder and sphere, failure modes of pressure vessel under bulk yielding and buckling, stress concentration and cracking and also hoop, longitudinal and volumetric strain.

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3. TYPES OF PRESURE VESSELS

3.1. Mono layered Pressure Vessel

Mono layerd pressure vessels are those having the shell and heads made up of single layer. Both cylindrical and spherical pressure vessels are common structures that are used for applications ranging from large gas storage tanks to small compressed air tanks in industries. In this paper, only thin-walled pressure vessels will be analyzed. Thin-walled pressure vessels are also known as shell structures and are efficient storage structures.

3.2. Multilayered Pressure Vessels

Multilayer pressure vessels are those having the shell and heads made up of two or more separate layers. The concept of multilayer design was originated in second half of 19th century for artillery and later for riveted type pressure vessels.

4. DESIGN OF MONO AND MULTI-LAYERED PRESSURE VESSELS

A mono block vessel contains a single cylinder shaped casing, with sealed finishes. Due to high internal pressure and large thickness, the shell is considered as a 'thin' cylinder. Multi layer vessels are built up by wrapping a series of sheets over a core tube. The construction involves the use of several layers of material, usually for the purpose of quality control and optimum properties. Multi layer construction is used for higher pressures. It provides inbuilt safety, utilizes material economically and no stress relief is required.

4.1. Design Considerations

a. A joint efficiency of 100% for longitudinal seam on inner shell is taken
b. The thickness of the liner shell is taken as 12 mm.
c. The thickness of subsequent layers is considered as 6 mm.

4.2. Input Data

Design pressure, p= 9.67N/mm^2
Inside radius of shell, R_i=1143mm
Outside radius of shell, R_o=1305mm
Joint efficiency, η_j=1

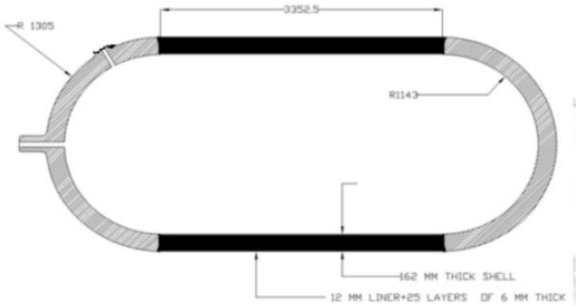

Fig. 1. Sectional view of Pressure Vessel

4.3. Design Model of Saddle Supported Pressure Vessel

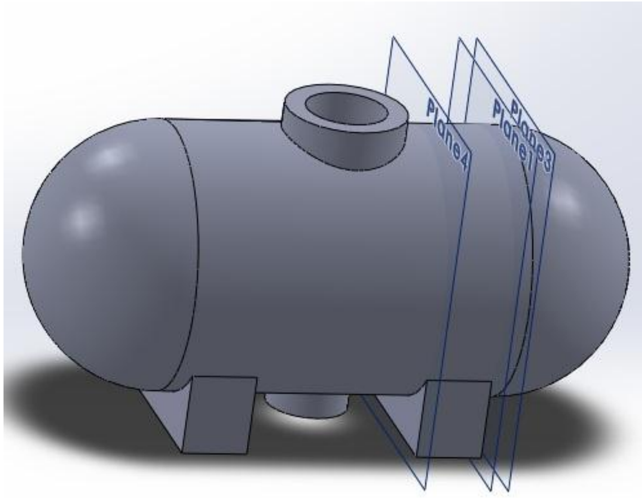

Fig. 2. Saddle Supported Pressure Vessel

5. VALIDATION & ANALYSIS RESULTS

In this work, analysis is done using Finite Element Method based software ANSYS. FEA analysis in ANSYS is done in three steps namely, Preprocessing, Solution and Postprocessing. The modeling of the cylinder has been done with solid works and then it has been meshed by using Hypermesh and then loading conditions have been imposed. After imposition of the boundary conditions and loading conditions the FEA model has been solved in ANSYS through static analysis. Then the cylinder is analyzed for displacements along x,y,z directions and Von Mises stress. Following
tables and figures represent the outcomes of the analysis.
Allowable Stress value for monolayer pressure Vessels 166 N/mm^2
Allowable Stress value for multilayer pressure vessels 125 N/mm^2

5.1. Stress Distribution in Monolayer and Multilayer Pressure Vessels

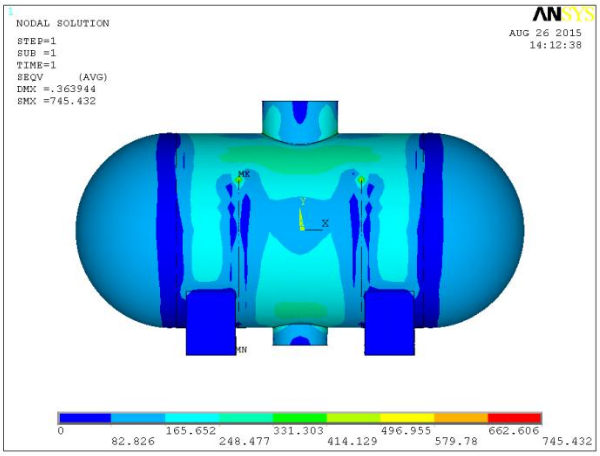

Fig. 3. Von Mises stress in monolayer pressure vessel

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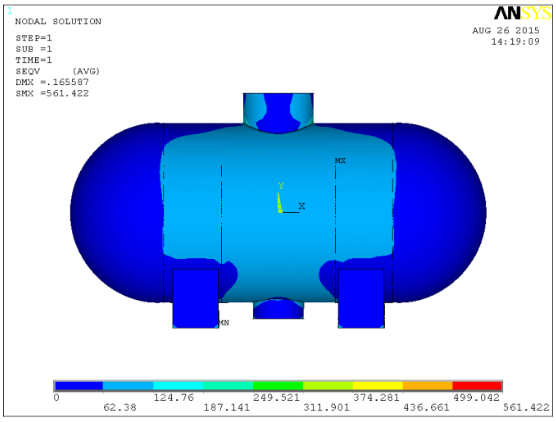

Fig. 4. Von Mises stress multilayer pressure vessel

5.2. Displacements in Monolayer Pressure Vessel

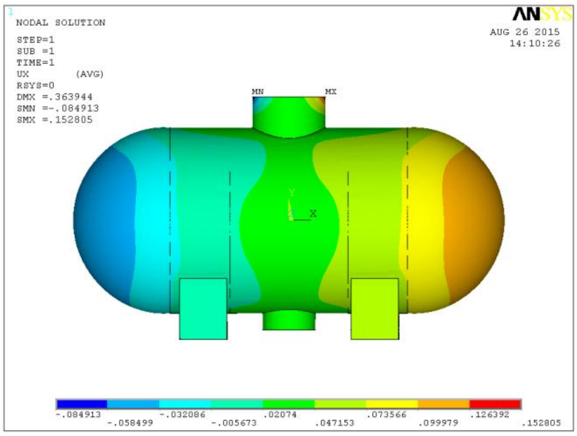

Fig. 5. Displacement in X-Direction

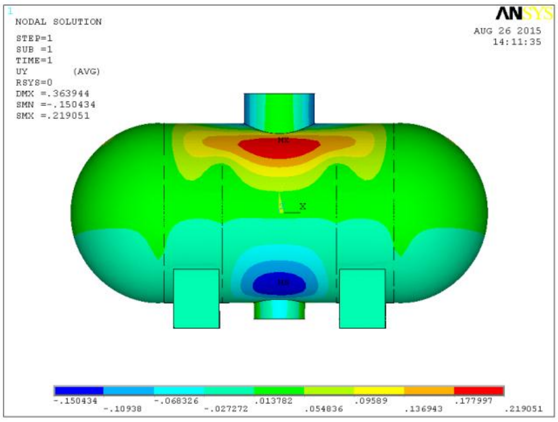

Fig. 6. Displacement in Y-Direction

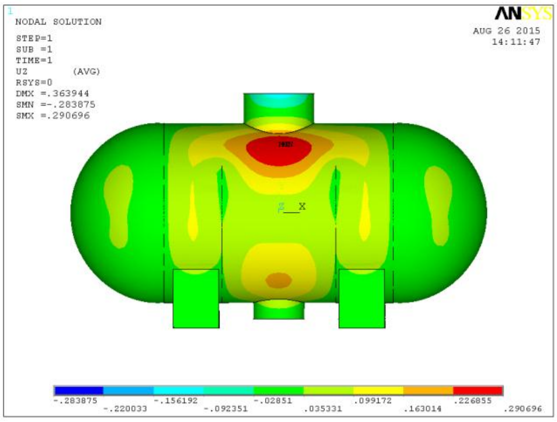

Fig. 7. Displacement in Z-Direction

5.3. Displacements in Multilayer Pressure Vessel

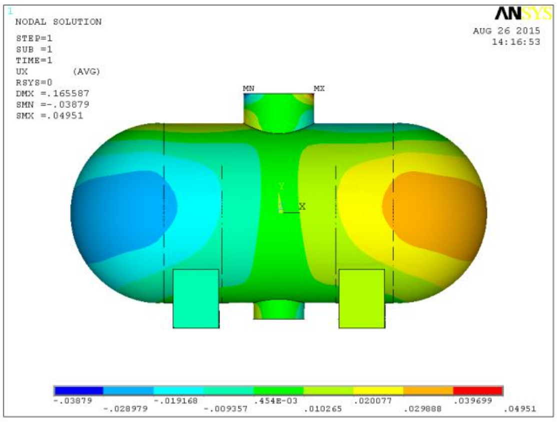

Fig. .8. Displacement in X-Direction

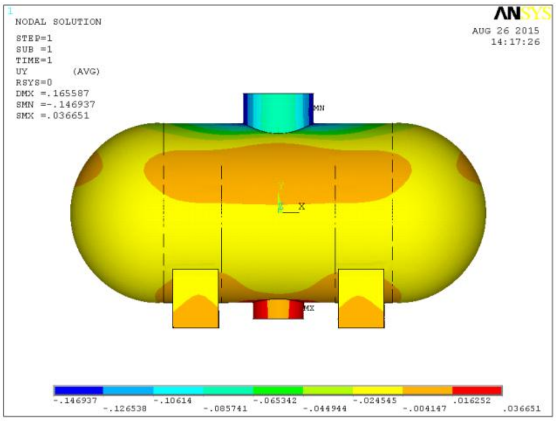

Fig. 9. Displacement in Y-Direction

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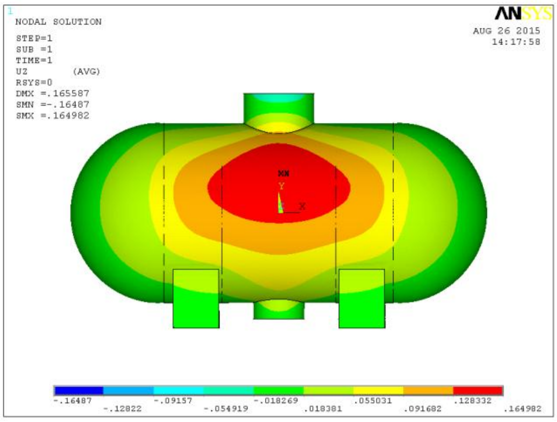

Fig. 10. Displacement in Z-Direction

6. CONCLUSION

As per the results it has been observed that the stress in monolayer pressure vessel is 746 N/mm^2 and the stress in multilayer pressure vessel is 562 N/mm^2. By this, it has been observed that stress developed is reduced in multilayer

7. FUTURE SCOPE

The present work can be extended for the following cases

1. Optimization of material by decreasing thickness for the given conditions.
2. Determining permissible pressure in a multilayer vessel by applying stresses developed in a monolayer vessel of same size as allowable stresses

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