



DESIGN AND ANALYSIS OF VENTED AND NON-VENTED PRESSURE VESSEL

NAMPALLI MAHESH BABU¹, K.V.SARATH BABU²

Mechanical Engineering, VEMU Institute of Technology

P.Kothakota, Chittoor, Andhra Pradesh

¹maheshnampalli@gmail.com



NAMPALLI MAHESH BABU



K.V.SARATH BABU

ABSTRACT

Pressure vessels are leak proof containers. These are having wide range of applications for the storage, also for carrying out reactions and many other applications. Openings are generally made in both the body and head of the shells. Due to the openings in the shell plate will have discontinuous in the body such that the penetration of the pressure restraining the boundary at the nozzle openings. Nozzle opening areas are mainly experiences the stress concentration factors, however reliability of FEM analysis always to be assessed because it is the efficient software for doing analysis.

In this present work comparison is done in between the stress concentration factors for different nozzle opening geometries, the graphs are also drawn between the SCF's v/s different diameters of the shell. To study the effect of stress distribution around the nozzle area, a case study is carried out by changing the geometry as radial and ellipse holed nozzle openings for constant shell thickness and internal pressure.

Introduction

The Pressure vessels are used to store fluids under pressure. Pressure vessels find wide applications in thermal and nuclear power plants, process and chemical industries. Synthetic building includes the use of sciences to the procedure enterprises, which are principally worried, with the change of one material in to another by substance or physical means.

Structural segments by and large contain break like imperfections, which are either inborn in the material or presented amid a creation procedure.

The methods of design are primarily based on elastic analysis. There are also other criteria such as stresses in plastic region, fatigue, creep, etc. which need consideration in certain cases. Elastic analysis is developed on the assumption that the material is isotropic and homogeneous and that it is

loaded in the elastic region. This analysis is not applicable in the plastic range.

Different types of pressure vessels are being commonly used for both aero space and ground applications: rocket motor cases, storage tanks for carrying required fuel and oxidizer in aero space vehicle, both high and low pressure storage tanks for ground-based applications such as gas cylinders etc. Most of the pressure vessels in industrial practice basically consist of a few shapes: spherical or cylindrical with hemi-spherical, ellipsoidal, conical, tori-conical, tori-spherical, or flat end closures. The shell components are welded together by means of flanges, forming a shell with a common rotational axis (Collins 1981).

The causes of failure in pressure vessels may generally be classified into three groups:

- (i) Faulty design, including wrong material selection

- (ii) Faulty manufacturing and
- (iii) Deterioration with time in service condition.

The safety assessment of pressure vessels without a fracture mechanics analysis is insufficient and may cause an unexpected reduction in the load carrying capacity of an actual pressure vessel due to the presence of unavoidable crack-like defects not being taken into consideration.

Problem Statement

The desired vented and Non-vented pressure vessels are designed as per ASME standards section. From literature review we are taken Pressure which is going to be applied on the surface of pressure vessel to now the stress concentration over the surface of pressure vessel. The pressure vessel design and material properties are going to varied in order optimized the stress distribution over the surface of pressure vessel.

Hence in this study the probabilistic failure assessment methodology has been proposed for the prediction of safe operating pressure for the flawed HSS pressure vessel, surface cracked tensile specimens and PV containing axial and surface cracks subjected to internal pressure.

Literature Review

Avinash RR.Kharat [2016] [1], Weight vessels are utilized for capacity, transportation and utilization of vitality and liquids and furthermore to carry out responses and numerous different purposes. Openings in tanks and weight vessels are important to bear on ordinary activities. Openings are by and large made in both vessel shells and heads.

Busuiocanu Paraschiva [2016] [2], This paper is indented to accentuate the potential outcomes to demonstrate the impact of present guidelines to enhance or change plan techniques for weight vessel, disregarding all issues identified with late examination programs for metallic weight control vessels and tanks which have uncovered breaking and harm in an extensive number of the vessels assessed.

Shildip D Urade [2015] [3] Multilayer weight vessel is intended to work under high weight condition. In this paper, the pressure examination of multi-layer weight vessel made of a homogeneous and isotropic material and subjected to interior weight is considered. The loop worries for 1, 2 and

3-layer weight vessel are ascertained hypothetically. The displaying of weight vessel is completed in CATIA V5 and this model is transported in ANSYS Workbench where stretch investigation is done. The psychologist fit is connected amid the CAD demonstrating of multilayer weight vessel.

The literature review on Pressure vessel, types of uncertainty, uncertainty propagation, uncertainty modeling and a review on design methodologies under uncertainty are reported. An overview of the methodologies and various applications of Pressure Vessels are also presented. The literature review reveals that there is an increase in interest among researchers to explore the use of Pressure vessels in real life applications.

Now in this Present Work we were Designed a Pressure vessel as per ASTM Standards:

- a. Computational formulas after Theoretical calculations are completed.
- b. We are modeled it by using Computer Aided Three Dimensional Interactive Application (CATIA) modeling software.
- c. We are modeled it by using Computer Aided Three Dimensional Interactive Application (CATIA) modeling software.
- d. Material properties are varied for the pressure vessel in order to find which material is best suited.

Numerical Simulation

The designer has to select/establish a suitable failure criterion for the intended materials. Evaluation of residual stress in welds and failure assessment on flawed and unflawed structural components will be of immense interest to the designers.

A. Research Methodology:

- 3D-Modeling has to perform as per ASTM standards By using CATIA Software.
- 3D finite element analysis are to be performed for the Estimation of vonmises stress pressure vessels by using the finite element analysis package.
- The influence of Vinmises stress on fracture strength of and failure pressure of pressure vessel are to be analysed by super imposing the residual stress and stress due to mechanical loading.

B. Design Calculations:

Design specifications for comparative study of different approaches are same as used by previous researcher for analytical analysis. As shown in above Fig.1 the dimensions are listed below are taken from [1].

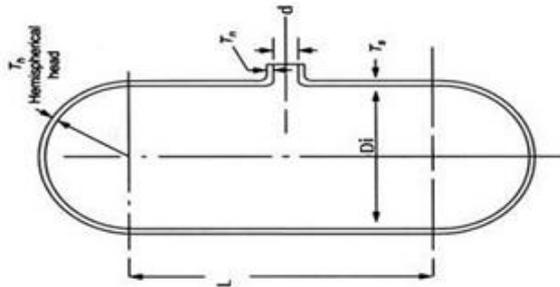


Fig. 1 A Horizontal Hemispherical shell.

1. Length of cylinder from Center to Center radius -L: 500 mm
2. Thickness of shell $T_s= 12.12$ mm
3. Radius of the cylinder $R=100$ mm
4. Thickness of shell at entrance $T_n= 6.9$ mm
5. Inner diameter of cylinder = 500 mm
6. Thickness of shell at hemispherical Nozzle entrance $T_h= 6.9$ mm
7. Diameter of hole at its opening is $d_1= 50$ mm

C. Hoop Stress

In the pressure vessels, three terms related to pressure are commonly used

Circumferential stress (or) hoop stress,

$$\sigma_1 = \frac{p_1^2 (r_1^2)}{r_{22} \left[\frac{(r_1^2 + r_2^2)}{(r_2^2 - r_1^2)} \right]} \dots\dots\dots (1)$$

$$= \frac{640000}{12570.8944} \left[\frac{(22570.8944)}{(2570.8944)} \right]$$

$$= 50.9112541746 * (8.77939381719)$$

$$\sigma_1 = 446.96 \text{ Mpa.}$$

Geometric Modelling of Pressure Vessel

Modelling is performed by using Computer Aided Three dimensional Interactive Application- CATIA-V5R21. It is Surface Modelling Software. It gives a dynamic domain in which you make and change your models through direct graphical control. You drive the outline process for your task by selecting an article (geometry) and afterward pick an instrument to conjure an activity on that question. This item activity work process gives more

prominent control over the outline of your models while permitting you to express your innovativeness. The client interface gives further backing to this outline process.

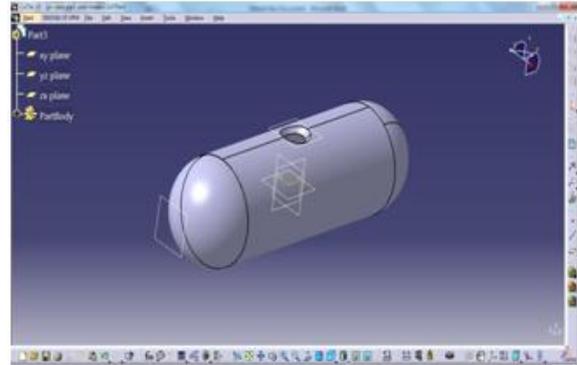


Fig. 2 Complete Modeled part of Pressure vessel in CATIA Software

The above geometric model is designed in CATIA software as per numerical simulation of non-vented pressure vessel.



Fig. 3 Pressure vessel model in CATIA Software by contains radius of 25mm

The above geometric model is vented type pressure vessel consists of nozzle on its outer most shell with a radius of 25mm modified design in the present project in order to reduce the stress distribution effect.

D. Finite Element Analysis

The numerical method which is used to find unknowns at each and every point of structure is known as FEM.

It contains three steps Preprocessing, Processing, Post processing.

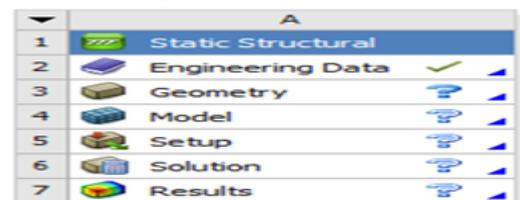


Fig. 4 Sequence of steps involved in static structural analysis

	A	B	C	D
1	Contents of Engineering Data	Source		Description
2	Material			
3	E-Glass Fiber			
4	Structural Steel			Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5-110.1

Fig. 5 Material Properties assigned to Engineering data in Ansys Workbench.

Pressure vessel is modeled as per ASTM Standards is imported in to Ansys Workbench from CATIA Software in Pressure vessel. stpfile format after imported into Ansys-Workbench it is represented in below figure.

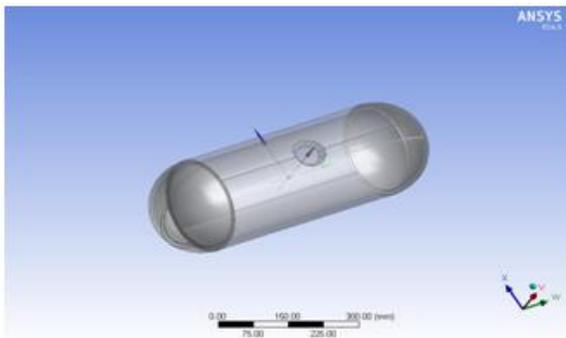


Fig. 6 Pressure vessel model imported into Ansys Workbench.

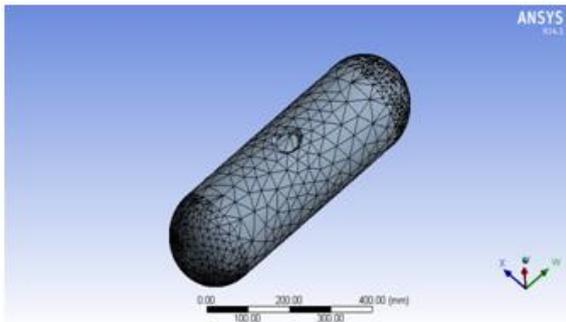


Fig. 7 Fine meshed Pressure vessel in Ansys Workbench.

For most pressure vessels element selection is made from three categories of elements: Axis symmetric solid elements, shell or plate elements and 3D-brick elements [7] in order to identify the element that gives the best results in minimum time, model with 4-noded shell element and 8-noded shell elements are analyzed separately. Hence 4-noded element,

shell-181 was selected for present analysis. Fine meshed model pressure vessel contains Nodes: 27181 and Elements: 13898.

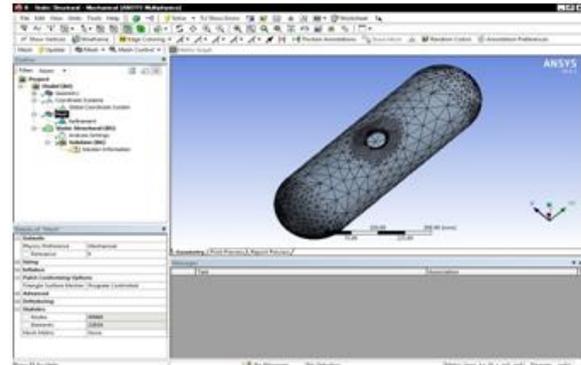


Fig. 8 Refined mesh at opening area Pressure vessel in Ansys Workbench.

In plane stress condition stresses are concentrated over the surroundings of hole in order to improve the mesh over the surface of the hole we are going for refinement by doing refinement meshing is improved only near pressure vessel opening due to improvement in meshing number of nodes are improved due to this accuracy of results are improved. Refine meshed model pressure vessel contains Nodes: 40968 and Elements: 22854.

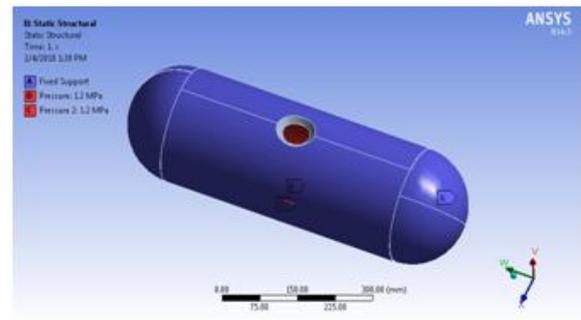


Fig.9 Boundary Conditions applied to the pressure vessel

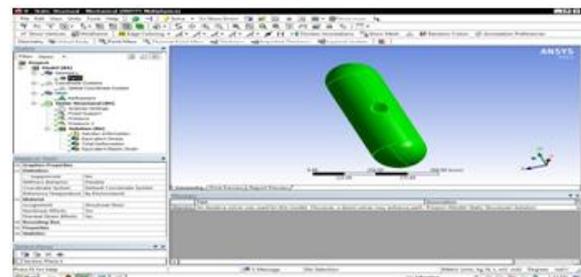


Fig.10 Assignment of Materials to the pressure vessel

Structural steel Material Properties:

Young's Modulus (EX) : 210,000Mpa
Poisson's Ratio (PRXY) : 0.3
Density : 7850kg/m³

Pressure Applied : 8Mpa

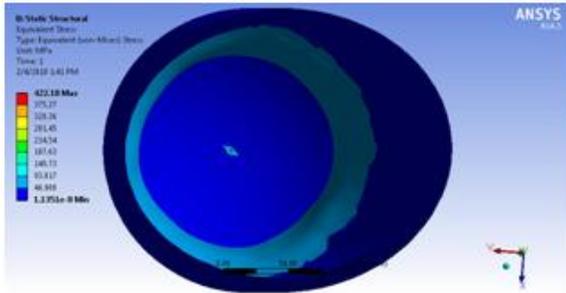


Fig.11 Cross sectional view of Von-Misses Stress Distribution

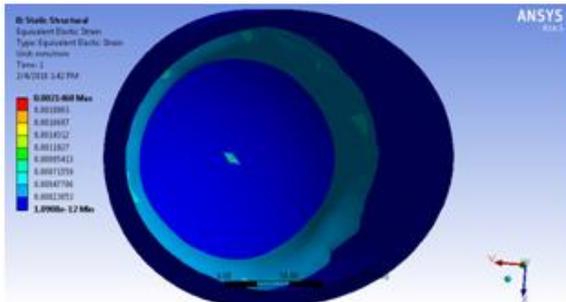


Fig.12 Cross sectional view of Von-Misses Strain Distribution

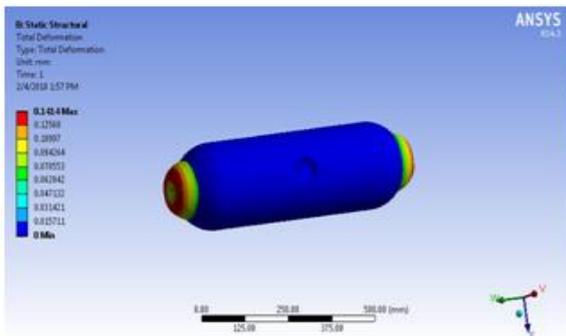


Fig.13 Total deformation over the outer Surface of the Pressure vessel

E-Glass Fiber Material Properties:

Young's Modulus (EX) : 80000Mpa

Poisson's Ratio (PRXY) : 0.28

Density : 2.55g/cm³

Pressure Applied : 8Mpa

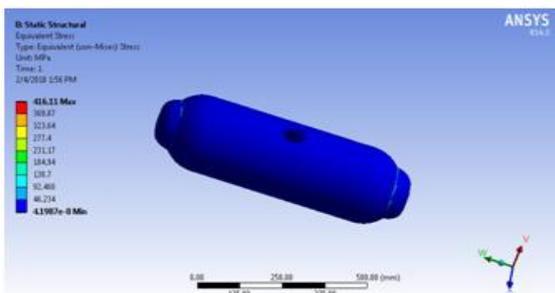


Fig.14 Von-Misses Stress Distribution over Outer side of Pressure Vessel

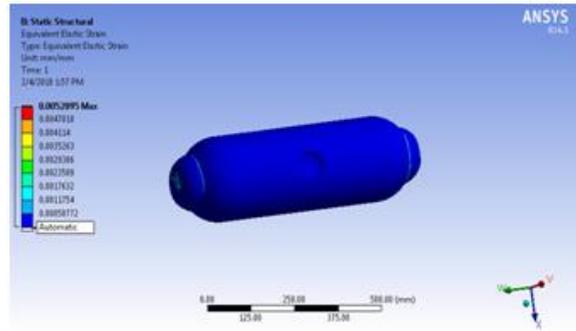


Fig.15 Von-Misses Strain Distribution over Outer side of Pressure Vessel

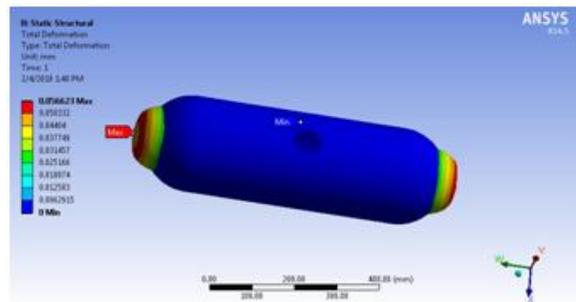


Fig.16 Total deformation over the outer Surface of the Pressure vessel

E. Structural Analysis on Vented Pressure Vessel

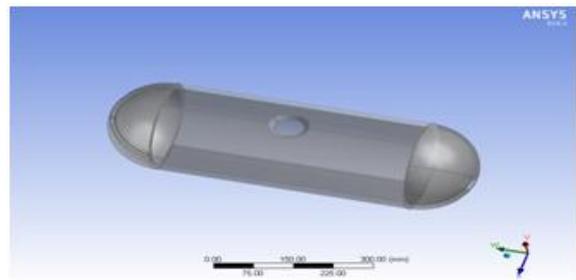


Fig.17 Vented Pressure vessel model imported into ANSYS Workbench.

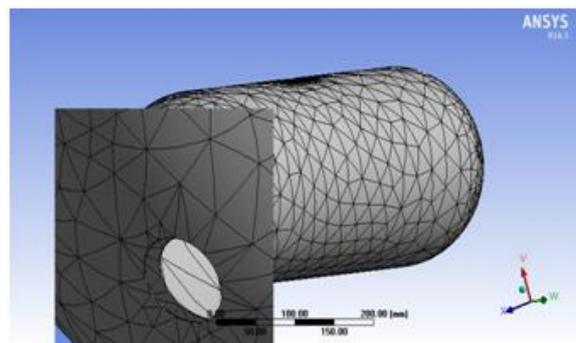


Fig.18 Refined geometry of the pressure vessel at vent hole.

Refine meshed model pressure vessel contains Nodes: 27226 and Elements: 13903 with

improvement in mesh at both top and side hole of the pressure vessel.

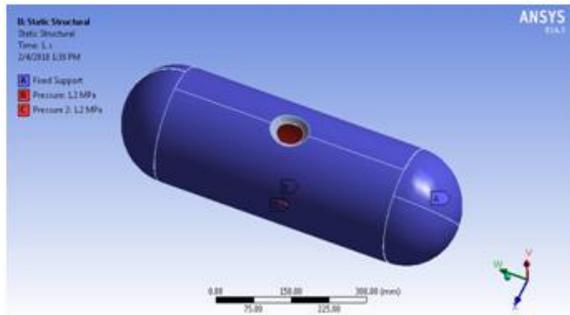


Fig.19 Boundary Conditions applied to the pressure vessel

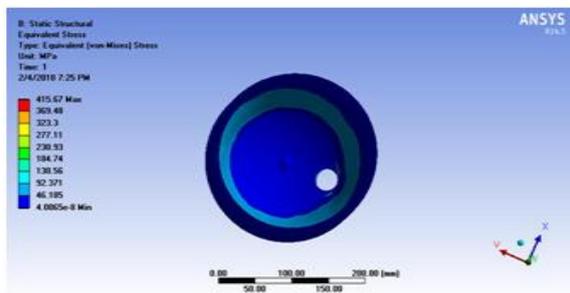


Fig.20 Von-Mises Stress Distribution over the inner Surface of the Structural steel assigned Pressure vessel

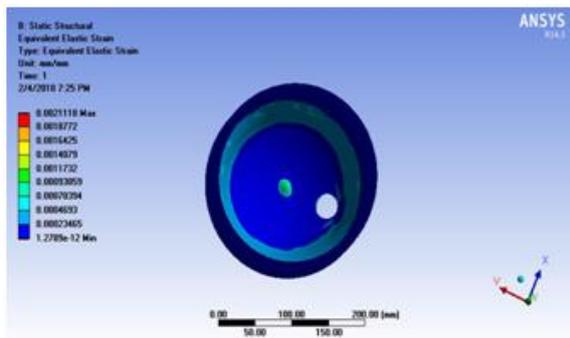


Fig.21 Von-Mises Strain Distribution over the inner Surface of the Structural steel assigned Pressure vessel

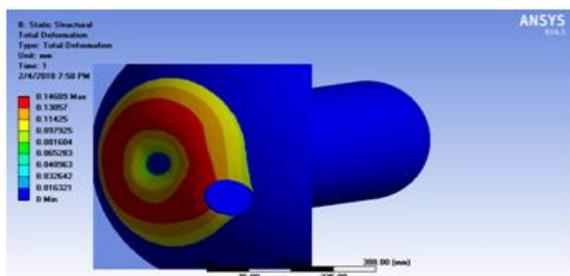


Fig.22 Total deformation over the outer Surface of the Pressure vessel

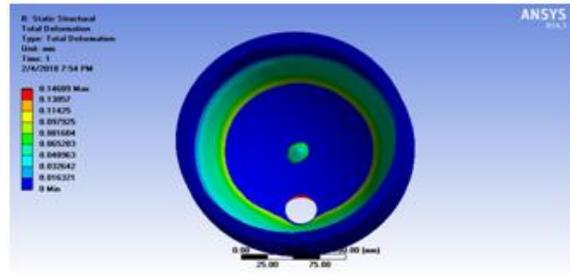


Fig.23 Total deformation over the Inner periphery of the Pressure vessel

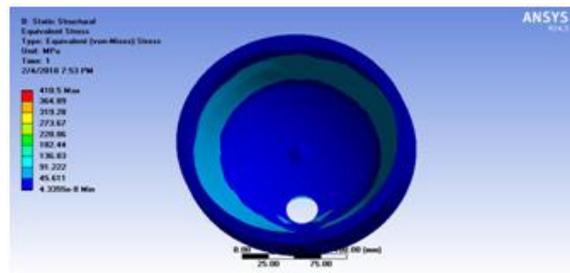


Fig.24 Von-Mises Stress Distribution over the inner Surface of the E-Glass fiber assigned Pressure vessel

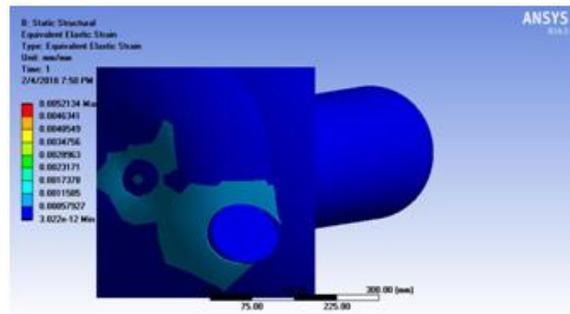


Fig.25 Von-Mises Strain Distribution over the inner Surface of the E-Glass fiber assigned Pressure vessel

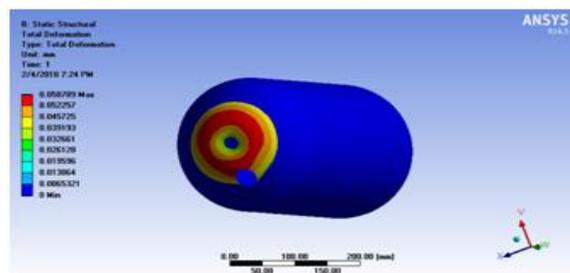


Fig.26 Total deformation over the outer Surface of the E-Glass fiber assigned Pressure vessel

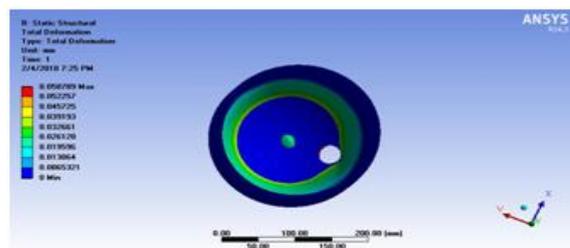


Fig.27 Total deformation over the Inner Surface of the E-Glass fiber assigned Pressure vessel

Results and Discussions

The above results demonstrated by Ansys Workbench among the all the acquired results the hoop stress calculations for Theoretical and Analytical calculations are listed below.

TABLE I: Results from Structural Analysis

S. No	Results	Non-Vented		Vented	
		Structural Steel	E-Glass Fiber	Structural Steel	E-Glass Fiber
1.	Von misses Stress (Mpa)	422.18	416.11	415.67	410.5
2.	Von misses Strain	0.0021 468	0.0052 895	0.0021 118	0.0052 134
3.	Total Deformation	0.1414	0.0566 23	0.1468 9	0.0587 89

TABLE III: Results from THEORETICAL AND ANALYTICAL CALCULATIONS

S. No	Material	Theoretical Values	Analytical Values		% of Error	
			Non-Vented	Vented	Non-Vented	Vented
1.	Structural Steel	446.96 Mpa	422.18 Mpa	415.67 Mpa	5.54	7.00
2.	E-Glass Fiber		416.11 Mpa	410.5 Mpa	6.90	8.15

The Ansys 15 workbench for anxiety, strains, complete distortion, temperature, warmth flux we acquire ten qualities going from most extreme to least. In view of the qualities we plotted the charts as demonstrated as follows .Also in view of diagrams we propose best grating material for Pressure vessel.

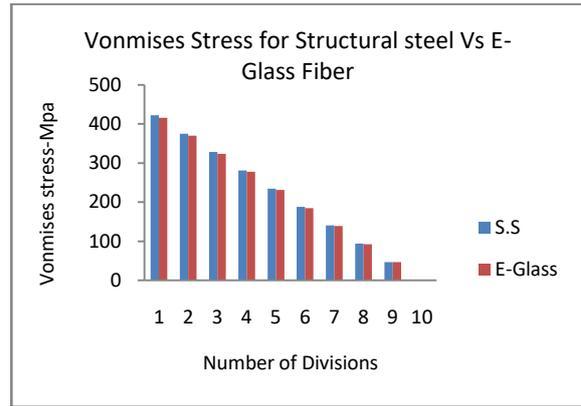


Fig.28 Vonmises stress for Non-Vented Pressure vessel by varying materials

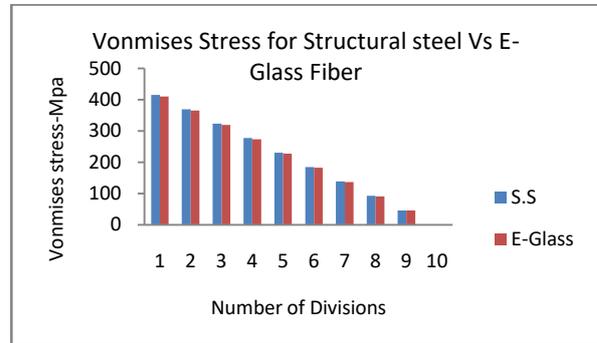


Fig.29 Vonmises stress for Vented Pressure vessel by varying materials

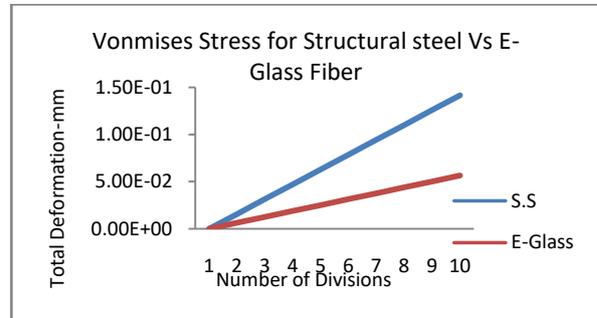


Fig.30 Total Deformation for Non-Vented Pressure vessel by varying materials

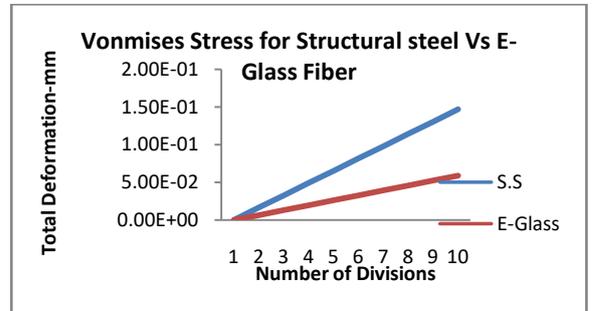


Fig.31 Total Deformation for Vented Pressure vessel by varying materials

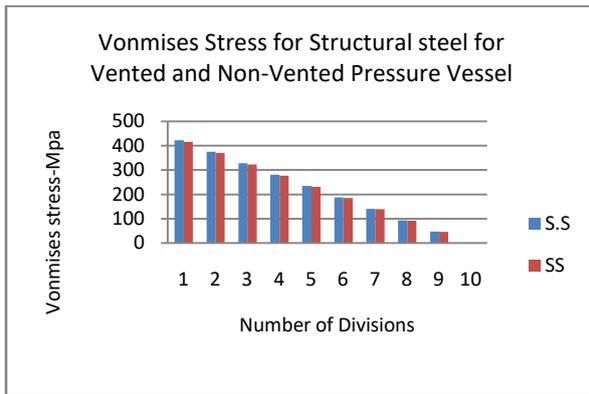


Fig.32 Vonmises Stress for Structural steel material Non-Vented Vs Vented Pressure vessels

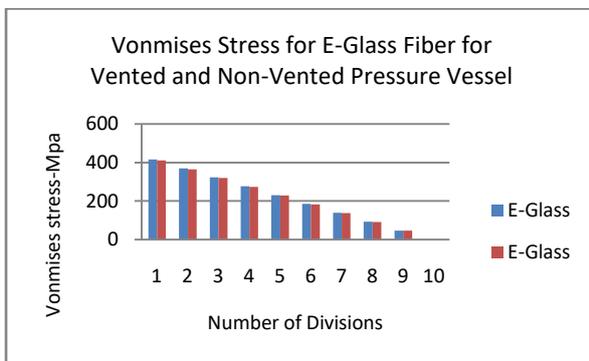


Fig.33 Vonmises Stress for E-Glass material Non-Vented Vs Vented Pressure vessels

Conclusions

Computational configuration demonstrating and Structural Analysis of Non-Vented and Vented Pressure vessels by varying Material Properties Structural steel and E-Glass fiber and modification of Pressure vessel design is designed.

By investigation, the Vonmises Stress distribution over the outer and Inner surfaces of pressure vessel Vonmises stress are reduced by varying the material properties from structural steel to E-glass fiber from 422.18 Mpa to 416.11 Mpa. Total deformation is reduced by varying structural steel material to E-glass fiber is 0.1414mm to 0.056623mm. In the same manner for Vented Pressure vessel material properties are varied from structural to E-Glass fiber Vonmises stress is reduced from 415.67 Mpa to 410.5 Mpa and its Total Deformation is reduced from 0.14689 to 0.058789mm.

The Vonmises is reduced for structural steel material by varying for Non-vented to Vented Pressure vessel is 422.18 Mpa to 415.67Mpa and for E-Glass fiber Material Vonmises stress is varied from 416.11 Mpa to 410.5 Mpa. From Theoretical Values

to Analytical values for structural steel non vented pressure vessel 5.5% stresses are reduced. E-Glass fiber analytical values for non-vented pressure vessel are 6.9% stresses are reduced. Analytical values for structural steel vented pressure vessel 7.00% stresses are reduced. E-Glass fiber analytical values for vented pressure vessel are 8.15% stresses are reduced.

References

- [1]. Jaya kishor S,Lava Kumar M"Structural Analysis of Multi-Plate Clutch"-[IJCTT]-Volume 4 Issue 7- July 2013 ISSN:2231-2803.
- [2]. V.V.Wadkar,S.S.Malgave,D.D.Patil,H.S.Bhore,P.P .Gavade"Design and Analysis of Pressure vessel using ANSYS"Journal of Mechanical Engineering and Technology(JMET)-Vome3, Issue 2, July-Dec 2015.
- [3]. Kishore,J.S., Rao,B.S.,"FEM Analysis on Submarine propeller Blade for Improved efficiency by using Solidworks and ANSYS-Workbench", International Journal of Emerging Engineering Research and Technology, Volume 3, Issue 11,PP 144-151 November 2015.
- [4]. Avinash Kharat,V.V.Kulkarni"Stress Concentration at Openings in Pressure Vessels-A Review"International Journal of Innovative Research in Science, Engineering and Technology, Volume 2,Issue 3, March 2013.
- [5]. Shildip D Urade,Bhope DV and Khamankar SD,"Stress Analysis of Multilayer Pressure Vessel"J Appl Mech Eng 4:157.doi:40.4172/2168-9873.1000157.
- [6]. Deval Nitin Bhinde and Rajanarsimha" FEA Analysis of Pressure Vessel With Different Type of End Connections" JETIR, Volume 4, Issue 02, February 2017.
- [7]. Digvijay Kolekar, Jewargi S.S. "Stress Analysis of Pressure Vessel with Different Type of End Connections" International Journal of Science,Engineering and Technology Research (IJSETR), Volume 3, Issue 12, December 2014.