DESIGN AND STATIC THERMAL ANALYSIS OF PRESSURE VESSELS WITH VARIOUS MATERIALS USING FEM

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ABSTRACT:
Stress assessments are required for a great deal of plant components, including the pressure vessel. A pressure vessel is a container designed to store liquids or gases at pressures much higher than the surrounding air. The finite element analysis of pressure vessels with various types of heads that maintain the same cylindrical volume and thickness is the focus of this project. The intended pressure vessel is made for 8 bar of pressure and 24 lit of volume in accordance with ASME standard section VIII, division I. In order to identify the source of the stress concentration zone in each kind of pressure vessel head at the same volume and reasonable pressure, certain end connections are evaluated under FEA. The project's goal is to use Ansys software to analyse various designs and static and thermal data. It finds that elliptical and flat head pressure vessels have lower distributed stresses than other types of heads, making them the preferred choice for most applications. It displays the fundamental construction and uses finite element modelling to analyse pressure vessels made of various materials, such as Nimonic 80A and SA516 Gr70, and with several types of heads under high stress conditions. In this project, we use the Finite Element tool to compute the estimated stresses that occur in cylindrical pressure vessels supported by two saddles under various end connection types. In order to determine the appropriate design and material, static structural analysis and thermal analysis are performed to compute the stresses in the vessel.

Keywords: Pressure Vessels, Thermal Analysis, Different Fem

1.INTRODUCTION

A container with an interior pressure greater than atmospheric pressure is called a pressure vessel. Similar to boilers, the fluid within the pressure vessel may change states. Pressure vessels may contain flammable radioactive material in addition to having high temperatures and pressures. Due to these risks, it is crucial to properly build the pressure vessel so that it can withstand high temperatures and pressures without leaking. One of the main considerations in pressure vessel design is plant safety and integrity, which depends on how suitable the design codes are. The greatest circumferential stress caused by the internal pressure usually determines the uniform thickness of the cylindrical shell. Given that the circumferential stress is twice as much as the longitudinal stress. The American Society of Mechanical Engineers' guidelines must be followed in the design, construction, and inspection of the building.

Figure 1: Pressure vessel

Pressure vessels range in size and geometric shape from enormous cylindrical vessels used for high pressure applications to tiny vessels used as aeroplane hydraulic units. Thermal stresses arise in pressure vessels anytime normal expansion or contraction results from heating or cooling. The vessel has generated a variety of strains.

Applications Of Pressure Vessels:

There are numerous applications that require the use of containers for storage or transmission of gasses and fluids under high pressure. Pressure vessels have been used for a long time in various applications in both industry and the private sector. Pressure vessels are probably one of the most widespread equipment within the different industrial sectors. In fact, there is no industrial plant without pressure vessels, steam boilers, tanks, autoclaves, collectors, heat exchangers, pipes, etc. More specifically, pressure vessels represent fundamental components in sectors of paramount industrial importance, such as the nuclear, oil, petrochemical, and chemical sectors and also in the sectors as industrial compressed air receivers and domestic hot water storage tanks.

2. LITERATURE REVIEW

V. V. Wadkar, S.S. Malgave, et al [1]. This study is about some of the current developments in the determination of stress concentration factor in pressure vessels. The literature has indicated a growing interest in the field of stress concentration analysis in the pressure vessels.

Aziz onder, onur sayman, [2] In this study, optimal angle-ply orientations of symmetric and antisymmetric [h/h] s shells designed for maximum burst pressure were examined. Burst pressure of filament wound composite pressure vessels under alternating pure internal pressure was investigated.

A.th. Diamantoudis, [3] A comparative study for design by analysis and design by formula of a cylinder to nozzle intersection has been made using different finite element techniques. The cylinder to nozzle intersection investigated is part of a typical vertical pressure vessel with a skirt support. For the study the commonly used ductile P355 steel alloy and the high strength steel alloy P500 QT were considered.

Aniruddha A. et al [4] The aim of this project is to perform the detailed design & analysis of pressure vessel for optimum thickness using SOLIDWORKS software The selected components of pressure vessel like Shell, Heads, Nozzles, Supports and Lifting Lugs etc. are compared with Standard available thickness and optimization being done for the allowable stresses for MOC. The thickness of the pressure vessel is checked for different load cases.

Davidson, Thomas E. et al [5] The report is a review of the theory and practice of pressure vessel design for vessels operating in the range of internal pressures from 1 to 55 kilobars approximately 15,000 to 800,000 psi and utilizing fluid pressure media. The fundamentals of thick-walled cylinder theory are reviewed, including elastic and elastic-plastic theory, multi-layer cylinders and autofrettage

3. METHODOLOGY:

- To achieve the above objective the following methodology has been adopted in the present work.
- A pressure vessel is select the two heads in this project hemi spherical, toriconical head and flat conditions
- Modeling of the pressure vessel is done using CATIA software.
- The model is imported to Ansys and analysis is performed as follows.
- Material properties are added.
- Meshing is done, finally static and thermal boundary conditions are applied & it is solved. After solution the results are viewed in general postprocessor and check stress, deformation and Heat flux.
- Then the results from the analytical method Shown in graphical method concluded the suitable material

Mathematical Modeling:

The design method in this paragraph is based on an analysis of the longitudinal stresses exerted within the cylindrical shell by the overall bending of the vessel, considered as a beam on two supports, the shear stresses generated by the transmission of the loads on the supports, and the circumferential stresses within the cylindrical shell, the head shear and additional tensile stress in the head, and the possible stiffening rings of this shell, by this transmission of the loads on the supports. The stress calculation method is based on linear elastic mechanics and covers modes of failure by excessive deformation and elastic instability Typical horizontal vessel geometry is shown Saddle supports for horizontal vessels shall be configured to provide continuous support for at least one-third of the shell circumference, or 6 >120°.

Table 1: Major Modelled Dimensions of The Demo Vessel

Shell outside diameter D	880 mm
Shell length L	1520mm
Spherical head outside diameter	880mm
Corrosion allowance	1.28mm
Thickness of all ribs , tr	16mm
Distance b/w saddles, ds	937.6mm
Height of ribs, Hr	470mm
Width of rib Wr	176mm
Length of base plate	815mm
Saddle angle, 0	120°
Shell angle, (j)	117.4°
Thickness of all plates (shell), ts	20 mm

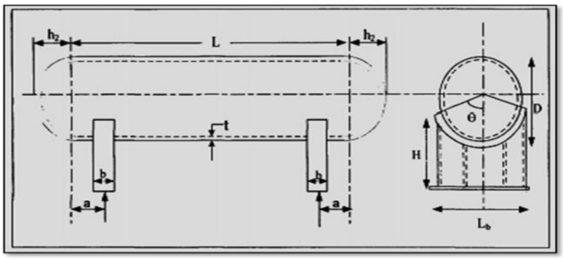


Figure: specification of pressure vessel

Table 2: material properties

Material	Density (g/cm³)	Young's Modulus (GPa)	Poisson's Ratio	Thermal Conductivity (W/(m·K))	Specific Heat Capacity (J/(kg·K))
High-Strength Low-Alloy Steel	7.85	200	0.3	45	460
Nimonic 75	8.37	220	0.33	11	410
SA-516 Gr.70 (Carbon Steel)	7.85	200	0.3	52	470
Nimonic 80A	8.19	220	0.33	11	410

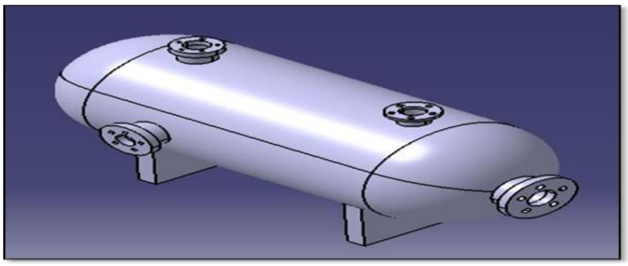


Figure: elliptical head in Catia

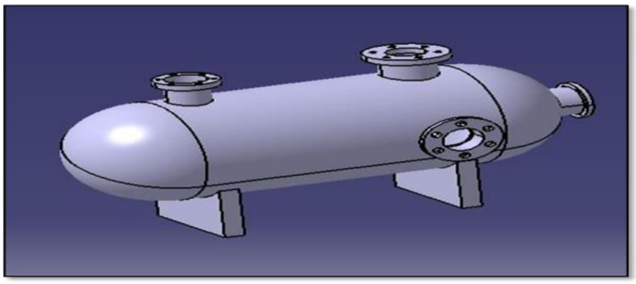


Figure: isometric view in Catia workbench

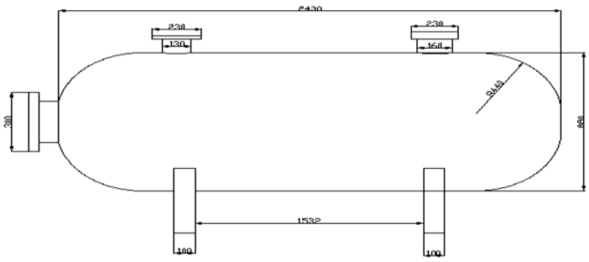


Figure: Elliptical head dimensions

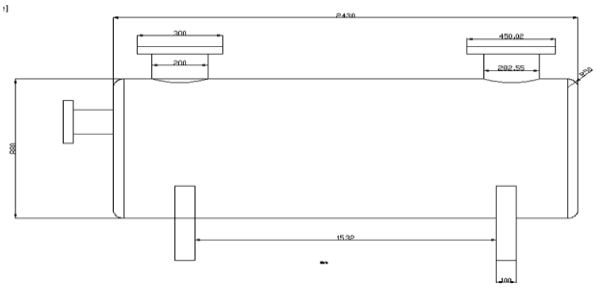


Figure: dimensions of flate head pressure vessel

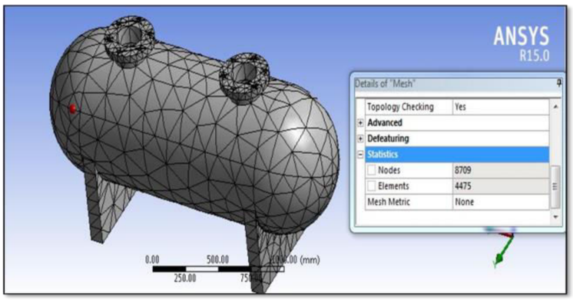


Figure: Meshed model

4. RESULTS AND DISCUSSIONS

This analysis is performed to find Structural and thermal parameters such as Stresses, Deformation, heat flux, of horizontal pressure vessel and saddle support with two designs and two materials in this project boiler and saddle designed in Catia and analysis using Ansys fixed the bottom of saddle and apply boundary conditions on pressure vessel as shown final figures.

Carbon Steel Material:

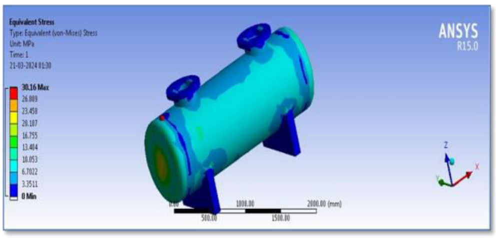


Figure: von misses stresses of flat head carbon steel material

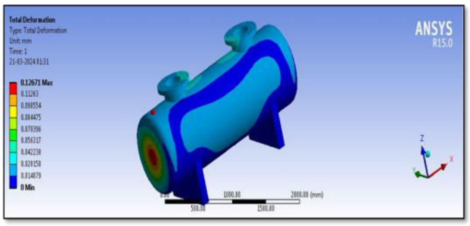


Figure: total deformation of flat head carbon steel material

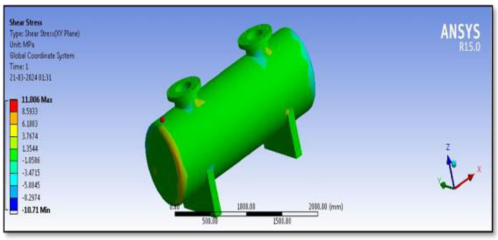


Figure: shear stress of flat head carbon steel material

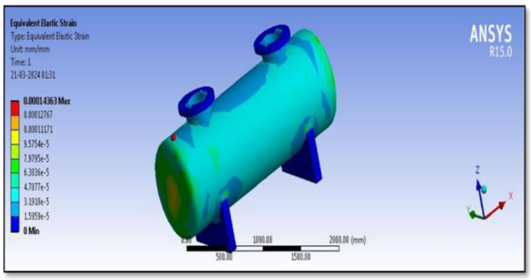


Figure: strain of flat head carbon steel material

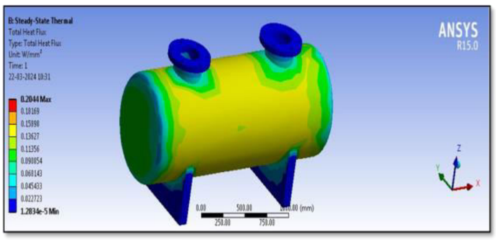


Figure: total heat flux of flat head carbon steel material

HSLA

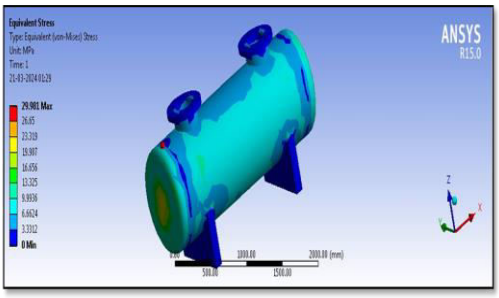


Figure: von misses stresses of flat head HSLA material

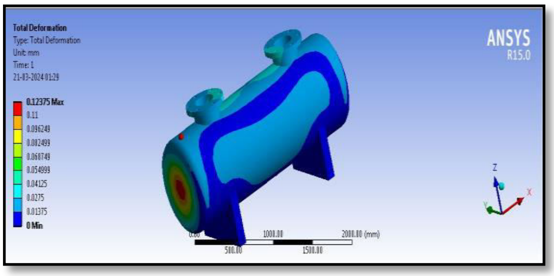


Figure: total deformation of flat head HSLA material

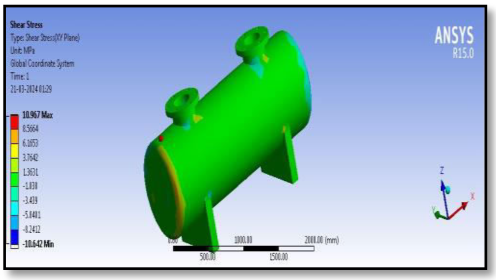


Figure: shear stress of flat head HSLA material

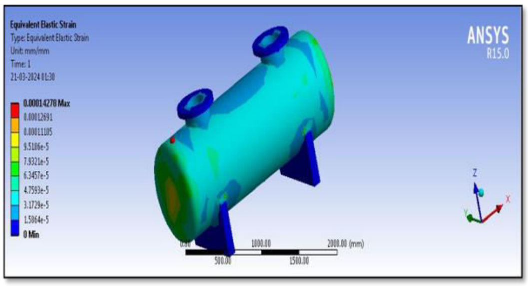


Figure: strain of flat head HSLA material

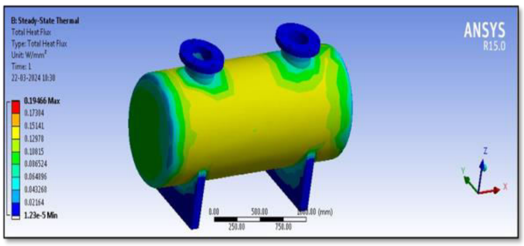


Figure: Total heat flux of flat head HSLA material

Nimonic 75 Material

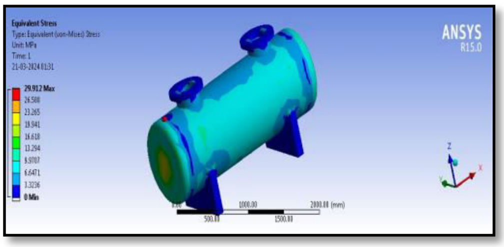


Figure: von misses stresses of flat head nimonic 75 material

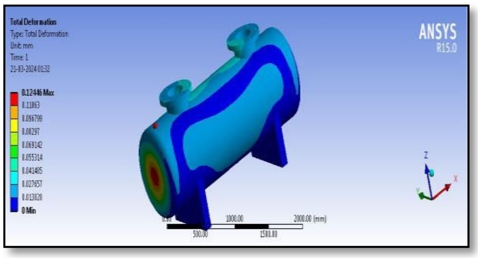


Figure: total deformation of flat head nimonic 75 material

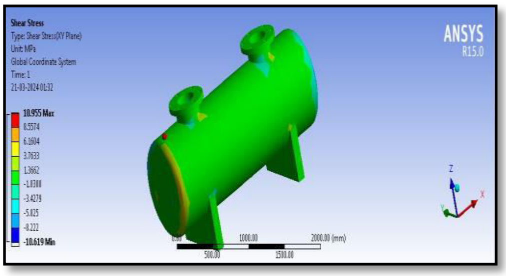


Figure: shear stress of flat head nimonic 75 material

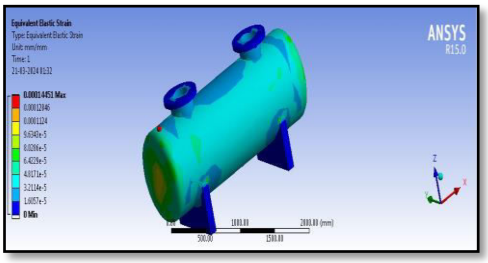


Figure: strain of flat head nimonic 75 material

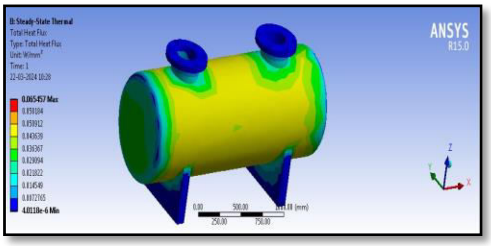


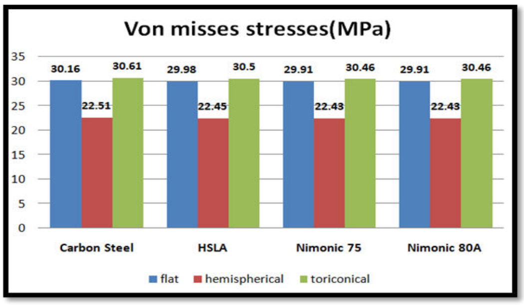
Figure: total heat flux of flat head nimonic 75 material

The below tabulated data is the maximum results obtained by all materials with the all three head shapes like flat, hemi spherical and toriconical shapes. The static structural von misses stresses, total deformation, shear stress and total deformation values are tabulated in below

Table: structural analysis results

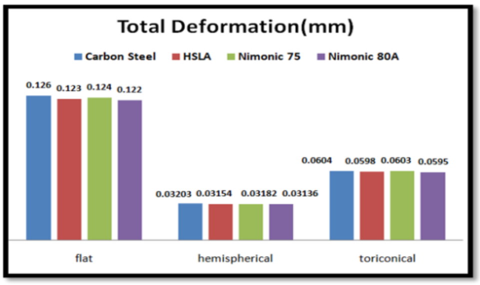
	Von Misses Stresses(Mpa)			Total deformation(mm)			Strain			Shear stress(Mpa)			Total heatflux(W/mm2)		
Materials	flat	hemispherical	toriconical	flat	hemispherical	toriconical	flat	hemispherical	toriconical	flat	hemispherical	toriconical	flat	hemispherical	toriconical
Carbon Steel	30.16	22.51	30.61	0.126	0.03203	0.0604	0.00014	0.00011	0.000147	11.006	4.54	7.81	0.204	0.174	0.267
HSLA	29.98	22.45	30.5	0.123	0.03154	0.0598	0.00014	0.00011	0.000146	10.967	4.23	7.8	0.195	0.166	0.254
Nimonic 75	29.91	22.43	30.46	0.124	0.03182	0.0603	0.00014	0.0001179	0.000148	10.955	4.12	7.79	0.065	0.059	0.08
Nimonic 80A	29.91	22.43	30.46	0.122	0.03136	0.0595	0.00014	0.0001163	0.000146	10.955	4.12	7.79	0.08	0.075	0.104

The below graph shows that Variation of stresses The Three different designs Flat head, Hemispherical head, Toriconical head and Four different materials SA-516 GR.70 (CARBON STEEL) MATERIAL, NIMONIC 75 MATERIAL, HSLA, NIMONIC 80A, Finally Nimonic 80A, Nimonic 75 Hemispherical head have least Von-misses stress compared to remaining materials as shown below figure



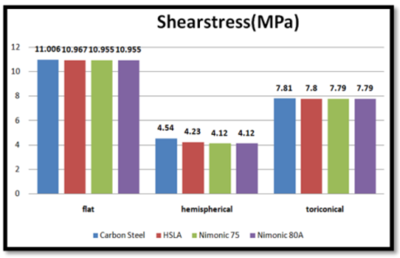
Graph:7.1 Von misses stresses

The below graph shows that Variation of Total deformation Three different designs Flat head, Hemispherical head, Toriconical head and Four different materials SA-516 GR.70 (CARBON STEEL) MATERIAL, NIMONIC 75 MATERIAL, HSLA, NIMONIC 80A, Finally Nimonic 80A, Nimonic 75 Hemispherical head have least Total deformation compared to remaining designs and materials as shown below figure.



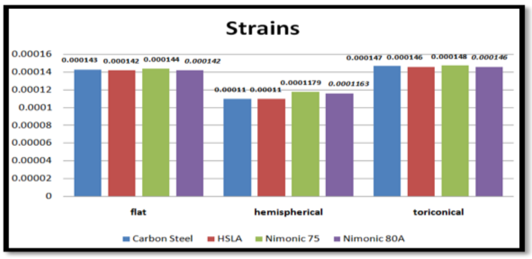
Graph: 7.2 total deformation

The below graph shows that Variation of Shear stress The Three different designs Flat head, Hemispherical head, Toriconical head and Four different materials SA-516 GR.70 (CARBON STEEL) MATERIAL, NIMONIC 75 MATERIAL, HSLA, NIMONIC 80A, Finally Nimonic 80A, Nimonic 75 Hemispherical head have least Shear stress compared to remaining materials as shown below figure



Graph: shear stresses

Finally Nimonic 80A, Nimonic 75 Hemispherical head have least Strain compared to remaining materials as shown below figure



Graph: strains

CONCLUSION

The application of heat from a direct or indirect source, or from an external source, may create pressure. Horizontal pressure vessel modelling CATIA software is used to create the flat head, hemispherical head, and torticonical head models. The models are then loaded into ANSYS software for structural and thermal study on pressure vessels to verify the quality of materials such Four distinct substances Materials: SA-516 GR.70 (CARBON STEEL), NIMONIC 75, HSLA, NIMONIC 80A, Materials known as haste alloys are often used to construct pressure vessels. Derived from the materials' respective Von-misses stresses, strain, total deformation, shear stress, and heat flux compared using four distinct materials with various head configurations. Ultimately, there are decreased stresses, deformations, and heat flux values in Nimonic80A material.Ultimately, based on findings from thermal and structural analyses, it is determined that with holes Since nickel and chromium make up the majority of NIMONIC alloys, Nimonic80A material is appropriate for use in pressure vessels. These alloys are renowned for their excellent performance and reduced creep at high temperatures. The wrought, age-hardened NIMONIC alloy 80A is reinforced with carbon, aluminium, and titanium additions. It is produced by casting in air after high-frequency melting. It is comparable to NIMONIC alloy 80A and is appropriate for use in industrial processes due to its strong resistance to oxidation and corrosion.

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