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Design And Analysis of the Pressure Vessel by using FEM

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Abstract

A pressure vessel is designed to work under high pressure condition so that the selection of material and the design of the pressure vessel are most important. In this paper, the thermal analysis of pressure vessel made of a composite material and subjected to give the total heat flux. The analytical design of the pressure vessel is by using as per ASME code. The heat flux for a pressure vessel is calculated with composite material. The modelling of pressure vessel is carried out in CATIA V5 and this model is imported in ANSYS Workbench where thermal analysis is carried out. The shrink fit is applied during the CAD modeling of pressure vessel. Also weight and heat flux are carried out for the pressure vessel. The pressure vessel is designed according to procedures and specifications given in machine design and design data book. Dimensions are calculated and these are used for modelling the pressure vessel in CATIA V5R20 The main objective of the work is to compare total temperature and heat flux of a structural steel and aluminum alloy materials in pressure vessel at the top surface .

Keywords: *Temperature, Heat flux ,Pressure vessel materials etc*.

1. Introduction

The pressure vessels (i.e. cylinder or tanks) are used to store fluids under pressure. The fluid being stored may undergo a change of state inside the pressure vessel as in case of steam boilers or it may combine with other reagents as in a chemical plant. The pressure vessels are designed with great care because rupture of pressure vessels means an explosion which may cause loss of life and property. The material of pressure vessels may be brittle such that cast iron or ductile such as mild steel.

Cylindrical or spherical pressure vessels (e.g., hydraulic cylinders, gun barrels, pipes, boilers and tanks) are commonly used in industry to carry both liquids and gases under pressure. When the pressure vessel is exposed to this pressure, the material comprising the vessel is subjected to pressure loading, and hence stresses, from all directions. The normal stresses resulting from this pressure are functions of the radius of the element under consideration, the shape of the pressure vessel (i.e., open ended cylinder, closed end cylinder, or sphere) as well as the applied pressure.

1.1Structural Steel

Structural steel is a category of steel used as a construction material for making structural steel shapes. A structural steel shape is a profile, formed with a specific cross section and following certain standards for chemical composition and mechanical properties.

1.2 Aluminum alloy

Aluminum alloys are alloys in which aluminum (Al) is the predominant metal. The typical alloying elements are copper, magnesium, manganese, silicon, tin and zinc. ... About 85% of aluminum is used for wrought products, for example rolled plate, foils and extrusions.

2. Literature Survey

BHPV manual on Multilayer Pressure Vessel[1] et al has investigated There is a percentage saving in material of 26.02% by using multilayered vessels in the place of solid walled vessel. This decreases not only the overall weight of the component but also the cost of the material required to manufacture the pressure vessel. This is one of the main aspects of designer to keep the weight and cost as low as possible. The Stress variation from inner side to outer side of the multilayered pressure vessel is around 12.5%, where as to that of solid wall vessel is 17.35%. This means that the stress distribution is uniform when compared to that of solid wall vessel. Minimization of stress concentration is another most important aspect of the designer. It also shows that the material is utilized most effectively in the fabrication of shell. Theoretical calculated values by using different formulas are very close to that of the values obtained from ANSYS analysis. This indicates that ANSYS analysis is suitable for multilayer pressure vessels. Owing to the advantages of the multi layered pressure vessels over the conventional mono block pressure vessels, it is concluded that multi layered pressure vessels are superior for high pressures and high temperature operating conditions.

Henry H.Bednar [5] et al has investigated Theoretical calculated values by using Different formulas are very close to that of the values obtained from ANSYS analysis is suitable for multilayer pressure vessels. Owing to the advantages of the multi layered pressure vessels over the conventional mono block pressure vessels, it is concluded that multi layered pressure vessels are superior for high pressures and high temperature operating conditions.

Noel,M.R [15] et al has investigated Due to shrink fitting, compressive stresses developed in the layers counter tensile stresses induced due to internal pressure which results in decreased Hoop's stress. It is found that thickness required for shell of Mono Wall. Pressure vessel is higher than that of multi wall pressure vessel. Hence preference to multi wall vessel is justified both economically (material cost) and physically (material weight). Multi Wall Pressure Vessels are more useful in the high. Pressure applications than Mono Wall Pressure vessels. Thickness calculation of shell by ASME codes conforms. to Lami's theorem with very small error. Calculation on ANSYS gives the very small amount of. errors with the manually calculated quantities, which confirms the validity of design methodology.

Harold H.Wait[11] has investigated Fatigue analysis will be carried out for entire equipment for specified regeneration cycles and we will found fatigue life more than required cycles. Accordingly we conclude that all evaluation points for fatigue are within allowable limits specified by code. The maximum fatigue damage fraction observed which less than unity as required by code.

Fratcher [8]et al has investigated At present solid wall pressure vessels are used extensively. But by using multilayered vessels, there is a huge difference in weight. The weight is almost decreased by 18495Kg when multilayered vessels are used in place of solid vessels. This decreases not only the overall weight of the component but also the cost of the material required to manufacture the pressure vessel. This is one of the main aspects of designer to keep the weight and cost as low as possible. The stresses developed in the multilayered vessels are more when compared with solid vessels. Minimization of stress concentration is another most important aspect of the designer. It also shows that the material is utilized most effectively in the fabrication of shell. Owing to the advantages of the multi layered pressure vessels over the conventional single walls pressure vessels, it is concluded that multi layered pressure vessels are superior for high pressures and high temperature operating conditions.

The pressure vessel is designed according to procedures and specifications given in machine design and design data book. Dimensions are calculated and these are used for modeling the pressure vessel in CATIA V5R20 as shown in Fig

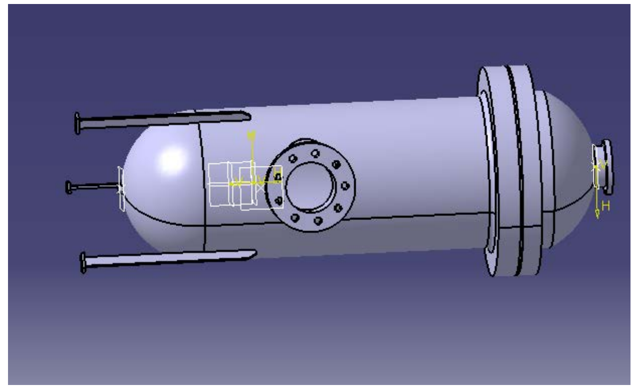

Fig.2.1 Pressure vessel.

Boundary Condition for Thermal Analysis of pressure vessel:

The thermal boundary conditions consist of applying a convection and temperature of the pressure vessel of two different materials of structural steel and aluminum alloy.

3. Methods for Design & Analysis to Develop the Work

3.1 CATIA V5 R18: As the world's one of the supplier of software, specifically intended to support a totally Integrated product development process. Dassault Systems (DDS) in recognized as a strategic partner which can help a manufacturer to the turn a process into competitive advance, greater market share and higher profits and industrial and mechanical design to functional simulation manufacturing and information management.

Catia Mechanical design solution will improve our design productivity. Catia is a suit of programs that are used in design, analysis and manufacturing of a virtually unlimited range of the product." Feature based" means that we create parts and assemblies by defining feature like extrusion sweeps, cuts, holes, round and so on instead of specifying low level geometry like lines, areas circles. This means that the designer can think of the computer model at a very high level and leave all low geometry detail for Catia to figure out.

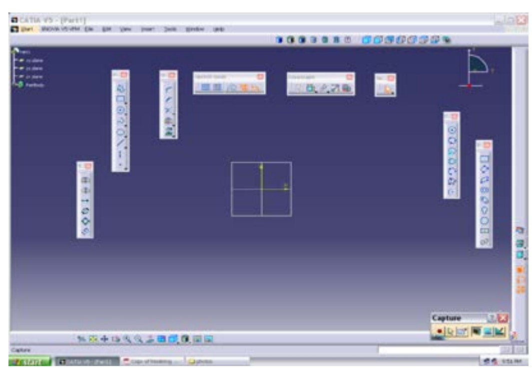

Fig.3.1 **Sketch 1 for Catia Manubar**

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The figure shows the sketcher Manu bar in catia.For this sketch Catia V5R18 software is using. It provides a greater flexibility for change, for example, if we like to change the dimensions in design assembly, manufacturing etc. will automatically change. It provides clear 3-D Model which are easy to visualize or model created and & it Also decrease the time required for the assembly to a large extent.

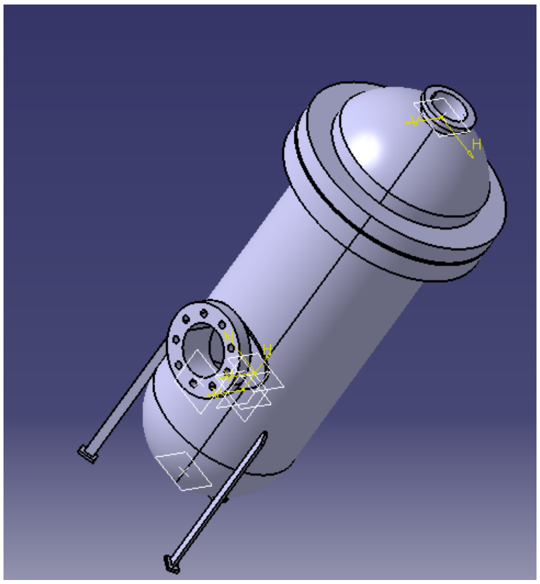

Fig.3. 2 Sketch 2 Pressure Vessel Design

This figure also shows the complete drawing of the pressure vessel in Y-direction.

3.2 ANSYS:

Dr. John Swanson founded ANSYS. Inc in 1970 with a vision to commercialize the concept of computer simulated engineering, establishing himself as one of the pioneers of Finite Element Analysis (FEA). ANSYS inc. supports the ongoing development of innovative technology and delivers flexible, enterprise wide engineering systems that enable companies to solve the full range of analysis problem, maximizing their existing investments in software and hardware. ANSYS Inc. continues its role as a technical innovator. It also supports a process-centric approach to design and manufacturing, allowing the users to avoid expensive and time-consuming "built and break" cycles. ANSYS analysis and simulation tools give customers ease-of-use, data compatibility, multi platform support and coupled field multi-physics capabilities.

4. Analysis

The goal of this project is to determine both temperature and heat flux distributions of pressure vessel. Effects of the different materials of structural steel and aluminium alloy on temperature and heat flux distributions are investigated, including comparisons with results from an pressure vessel of Thermal analysis Using CATIA and ANSYS.

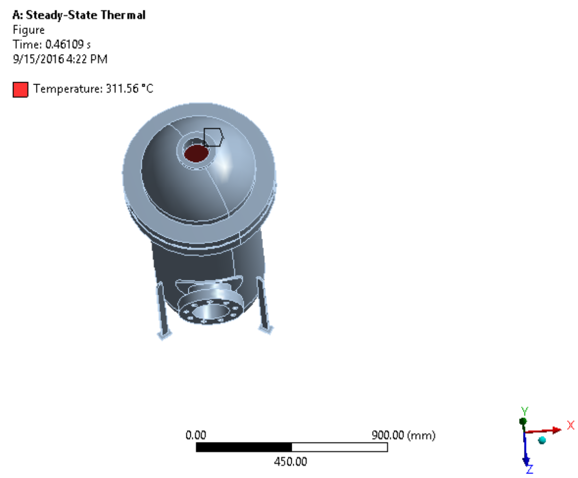

Fig 4.1 Steady-State Thermal when temperature is given

The figure shows the steady state thermal condition of the pressure vessel when the initial temperature is 311.56°c is given.

4.1 Material-Structural Steel

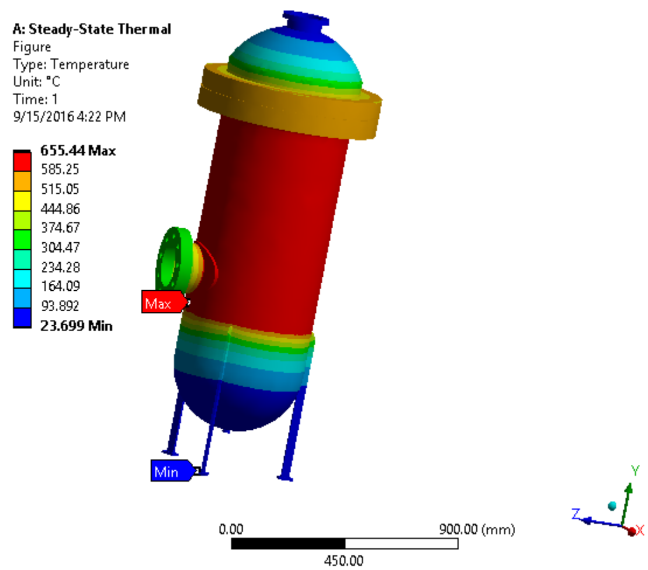

Fig 4.2 Temperature of pressure vessel in structural steel material

The above fig. Shows total temperature distribution throughout the pressure vessel.

In this condition the temperature distribution is varies from one element to other element. The minimum temperature of the component is 23.699°c and the maximum temperature of the components is 655.44°c.

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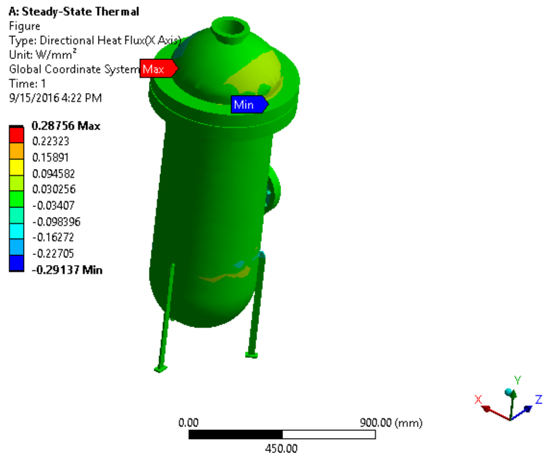

Fig 4.3 Heat flux of pressure vessel in structural steel

The above fig. Shows total Heat flux distribution throughout the pressure vessel. In this condition the heat flux distribution is varies from one element to other element. The minimum heat flux of the component is -0.29137 W/mm^2 and the maximum heat flux of the component is 0.28756 W/mm^2.

4.2 Material-Aluminum Alloy

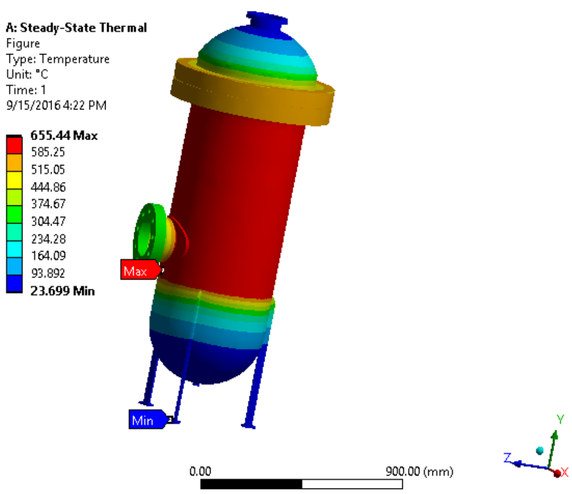

Fig 4.4 Temperature of pressure vessel in aluminum alloy

The above fig. Shows total temperature distribution throughout the pressure vessel.
In this condition the temperature distribution is varies from one element to other element. The minimum temperature of the component is 23.699°c and the maximum temperature of the components is 655.44°c.

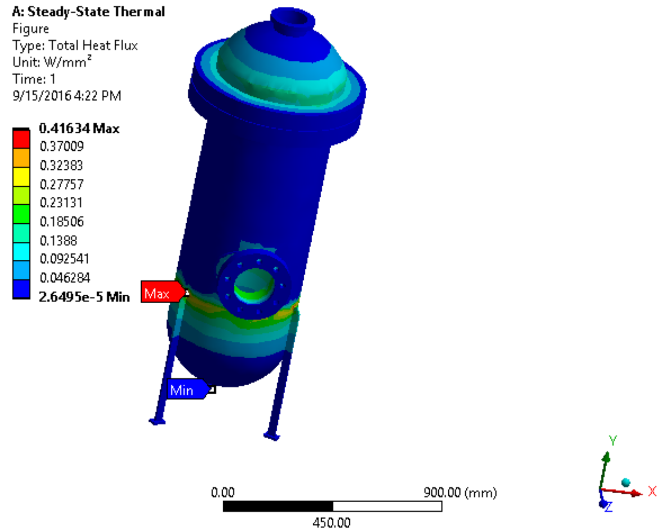

Fig 4.5 Heat flux of pressure vessel in aluminum alloy

The above fig. Shows total Heat flux distribution throughout the pressure vessel. In this condition the heat flux distribution is varies from one element to other element. The minimum heat flux of the component is -0.26495 W/mm^2 and the maximum heat flux of the component is 0.41634 W/mm^2 .

5. Results and Discussion

Structural Steel

Table: 5.1: analysis between Structural Steel Vs Constants

Properties	Values
Compressive Yield Strength MPa	280
Tensile Yield Strength MPa	280
Tensile Ultimate Strength MPa	310
Reference Temperature °C	22

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Properties	Structural Steel	aluminium alloy
Temperature (^{O}c) Min	23.699	0.52725
Temperature (^{O}c) Max	655.44	0.27489
Heat flux in max (w/mm^2)	-0.29137	-0.2649
Heat flux in max (w/mm^2)	0.28756	0.4163

Properties	Values
Compressive Ultimate Strength MPa	0
Compressive Yield Strength MPa	250
Tensile Yield Strength MPa	250
Tensile Ultimate Strength MPa	460
Reference Temperature° C	22

The table shows the properties of the component of the pressure vessel and their values. Compressive Ultimate Strength is 0 MPa, Compressive Yield Strength is 250 MPa, Tensile Yield Strength is 250 MPa, Tensile Ultimate Strength is 460 MPa and Reference Temperature is 22° C.

Aluminium Alloy

Table: 5.2: Values of the aluminium alloy properties

This table discuss about the properties of the aluminum alloy Compressive Yield Strength is 280 MPa, Tensile Yield Strength is 280 MPa, Tensile Ultimate Strength is 310 MPa,and Reference Temperature is 22°C.

Table: 5.6 Comparison between Structural Steel and aluminium alloy

This table shows the comparison between the minimum and maximum temperatures of structural steel and aluminium alloy. Whereas minimum and maximum heat flux of structural steel and aluminium alloy are also compared.

Conclusion

The paper has led to numerous conclusions. However, major conclusions are as below:

- The design of pressure vessel is initialized with the specification requirements in terms of standard technical specifications along with numerous requirements that lay hidden from the market.
- The design of a pressure vessel is more of a selection procedure, selection of its components to be more precise rather designing each and every component.
- The pressure vessel components are merely selected, but the selection is very critical, a slight change in selection will lead to a different pressure vessel al-together from what is aimed to be designed.
- It is observed that all the pressure vessel components are selected on basis of available ASME standards and the manufactures also follow the ASME standards while manufacturing the components. So that leaves the designer free from designing the components. This aspect of Design greatly reduces the Development Time for a new pressure vessel.

Scope of Future Work

In design of pressure vessels FEA tool can be effectively used. Typically it helps the designer to understand thermo mechanical behaviour of pressure vessel. Overall conclusions based on present study are as below:

- Pressure vessel is designed and analyzed for the given thermo mechanical loads.
- Maximum stress induced due to pressure alone in the shell is calculated using ASME formula and compared. With the analysis values and the maximum percentage error is 15%.
- Safe operating conditions for the vessel are verified within framework of FEA advanced techniques.
- Design approach of pressure vessel are by ASME codes and Finite element analysis out of which analysis of Pressure vessel by FEA method is easy and get optimum parameters.

- Design calculation of FEA is compare with ASME boiler and pressure vessel regulations. In Comparison of the results and design parameters calculated by ASME boiler and pressure
- Vessel code and finite element analysis are in thickness and reduces in weight of pressure vessel.
- Optimize design by FEA reduces the total Cost of pressure vessel.
- The optimization in design of pressure vessel using FEA is safe and has successfully satisfied the goal of economics.

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