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Stress and Failure Analysis of Vertical Pressure Vessel

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***Abstract*: Design of pressure vessel depends on its pressure and temperature. When pressure and temperature get changed every pressure vessel is new. In pressure vessel design safety is the main consideration. The structural integrity of mechanical components of pressure vessel requires a fatigue analysis including thermal and stress analysis. Pressure vessel parameter are designed and checked according to ASME (American society of mechanical engineering) sec. viii Div.1.Fatigue analysis improve the life of pressure vessel. Pv Elite helps engineer to comply their design and calculation strictly as per code. According to ASME SEC VIII. DIV-1 Analysis of pressure vessel is carried out at different pressure and temperature conditions.**

Pressure vessel with different end domes (torispherical and hemispherical), subjected to internal pressure have been designed for a volume of 1000 litres which will be useful for space application. Non-linear axisymmetric FEA considering both geometric and material non-linearity have been performed in ANSYS software to estimate the stress in dome and cylindrical shell of pressure vessel. Based on the analysis, optimum thickness which meets the strength requirement of the material is arrived at.

High pressure rise is developed in the pressure vessel and pressure vessel must withstand severe forces. In the design of pressure vessel safety is the primary consideration, due the potential impact of possible accident.

***Keywords*: Pressure Vessel, Fatigue analysis, Potential impact.**

1. Introduction

The term pressure vessel referred to those reservoirs or containers, which are subjected to internal or external pressure. The pressure vessels are used to store fluids under pressure. The fluid being +stored may undergo a change of state inside vessels as in case of steam boilers or it may combine with other reagents as in chemical plants. High pressure is developed in pressure vessel, so pressure vessel must withstand several forces developed due to internal pressure, so selection of pressure vessel is most critical. ASME Sec. VIII div.1 is most widely used code for design & construction of pressure vessel.Div.1 does not consider harmonic analysis. Div.1consider biaxial state of stress combined in accordance with maximum stress theory.

When pressure of operating fluid increases increase in thickness of vessel. This increase in thickness beyond a certain value possess fabrication difficulties and stronger material for vessel construction. The material of pressure vessel maybe brittle such as cast iron or ductile such as mild steel. Failure in Pressure vessel occurs due to improper selection of material, defects in material, incorrect design data, design method, shop testing, improper or insufficient fabrication process including welding. To obtain safety of pressure vessel and to design Pressure vessel the selection of code is important. Corrosion allowance is the main consideration in vessel design. Corrosion occurring over the life of the vessel. During service, pressure vessel may be subjected to cyclic or repeated stresses. Fatigue in pressure vessel occurs due to:

a) Fluctuation of pressure
b) Temperature transients,
c) Restriction of expansion or contraction during normal temperature variations,
d) Forced vibrations,
e) Variation in external load

Pressure vessels are vessels containing, which are subjected to external or internal pressure substantially different from the ambient pressure. They are used in oil, space, chemical, nuclear power and many other industries. High pressure gas bottles, propellant tank, small auxiliary tank, storage tank, solid propellant motor case, and pressurized cabins are the type of pressure vessels with internal pressure mainly used in aerospace industry. Cylindrical and spherical shapes are usually employed in a pressure vessel. Though spherical pressure vessel requires thinner walls than the equivalent cylinder for a given pressure and diameter, they are very complicated and expensive to fabricate. Hence cylindrical pressure vessels are preferred over spherical pressure vessels.


Fig. 1. Horizontal Retention Vessel

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Tanks, vessel and pipelines that carry, store or receive flu-ids are called pressure vessel. A pressure vessel is defined as a container with a pressure differential between inside and outside. The inside pressure is usually higher than the outside. The fluid inside the vessel may undergo a change in state as in the case of steam boiler or may combine with other reagent as in the case of chemical reactor. Pressure vessel often has a combination of high pressure together with high temperature and in some cases flammable fluids or highly radioactive material. Because of such hazards it is imperative that the design be such that no leakage can occur. In addition, vessel must be design carefully to cope with the operating temperature and pressure.

A. Objective of the project

1. To design smart Interactive Short cut Method tool incorporating the ASME code manual.
2. To evaluate the application that can support engineers for Pressure Vessel Designing

The theoretical values and ANSYS values are compared for both solid wall and Head of pressure vessels.

2. Concept of pressure vessel

Design of pressure vessel depends on its pressure and temperature. When pressure and temperature get changed every pressure vessel is new. In pressure vessel design safety is the main consideration. The structural integrity of mechanical components of pressure vessel requires a fatigue analysis including thermal and stress analysis. Pressure vessel parameter are designed and checked according to ASME (American society of mechanical engineering) sec. viii Div.1.Fatigue analysis improve the life of pressure vessel. Pv Elite helps engineer to comply their design and calculation strictly as per code. According to ASME SEC VIII. DIV-1 Analysis of pressure vessel is carried out at different pressure and temperature conditions.

Pressure vessel with different end domes (torispherical and hemispherical), subjected to internal pressure have been designed for a volume of 1000 litres which will be useful for space application. Non-linear axisymmetric FEA considering both geometric and material non-linearity have been performed in ANSYS software to estimate the stress in dome and cylindrical shell of pressure vessel. Based on the analysis, optimum thickness which meets the strength requirement of the material is arrived at.

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A. Component of pressure vessel

There are three main Type are given below

1. Shell
2. Head
3. Nozzle

1) Shell

The shell is the primary component that contains the pressure. Pressure vessel shells are welded together to form a structure that has a common rotational axis.

2) Head

All pressure vessel shells must be closed at the ends by heads (or another shell section). Heads are typically curved rather than flat. Curved configurations are stronger and allow the heads to be thinner, lighter, and less expensive than flat heads. Heads can also be used in side a vessel. These "intermediate heads" separate sections of the pressure vessel to permit different design conditions in each section. Heads are usually categorized by their shapes. Ellipsoidal, hemispherical, torispherical, conical, toriconical and flat are the common types of heads are shown below.

3) Nozzle

A nozzle is a cylindrical component that penetrates the shell or heads of a pressure vessel. The nozzle ends are usually flanged to allow for the necessary connections and to permit easy disassembly for maintenance or access. Nozzles are used for the following applications

1. Attach piping for flow into or out of the vessel.
2. Attach instrument connections, (e.g., level gauges, thermo wells, or pressure gauges).
3. Provide access to the vessel interior at midways.
4. Provide for direct attachment of other equipment items, (e.g., a heat exchanger or mixer).
5. Nozzles are also sometimes extended into the vessel interior for some applications, such as for inlet flow distribution or to permit the entry of thermowells.

3. Design Phase-I

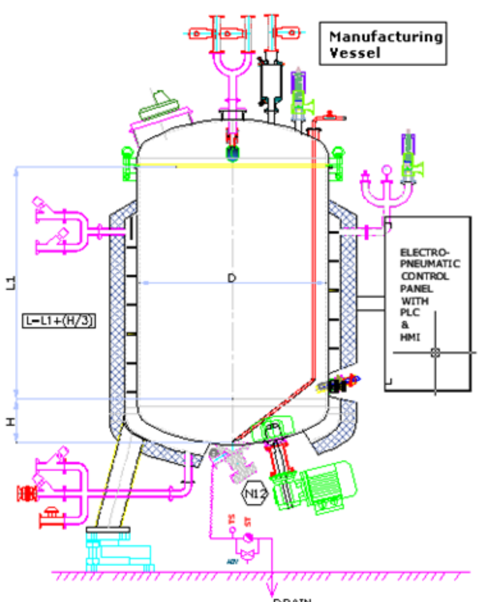

Fig. 2. Vessel Design (2DModel)

A. Design Calculation

Purpose: The Purpose of Mixing vessel is to produce desired mixing in the process.

1) Shell design

The minimum thickness or maximum allowable working pressure of cylindrical shells shall be the greater thickness or lesser pressure Circumferential Stress (Longitudinal Joints).

When the thickness does not exceed one-half of the inside radius, or P does not exceed 0.385SE, the following formulas shall apply for thickness calculation:

$$t = \frac{PR}{SE - 0.6P} \quad \text{or} \quad P = \frac{SEt}{R + 0.6t}$$

Longitudinal Stress (Circumferential Joints)

When the thickness does not exceed one-half of the inside radius, or P does not exceed 1.25SE, the following formulas shall apply for thickness calculation:

$$t = \frac{PR}{2SE + 0.4P} \quad \text{or} \quad P = \frac{2SEt}{R - 0.4t}$$

2) Closure design

The required thickness at the thinnest point after forming of ellipsoidal, torispherical, hemispherical, conical, and tori conical heads under pressure on the concave side shall be computed by the appropriate formulas. In addition, provision shall be made for any of the other loadings. The thickness of an unstayed ellipsoidal or torispherical head shall in no case be less than the required thickness of a seamless hemispherical head divided by the efficiency of the head-to-shell joint.

3) Ellipsoidal Heads design

The required thickness of a dished head of semi ellipsoidal form, in which half the minor axis equals one-fourth of the inside diameter of the head skirt, shall be determined by,

$$t = \frac{PD}{2SE - 0.2P} \quad \text{or} \quad P = \frac{2SEt}{D + 0.2t}$$

4. Finalised 3D model

Fig. 3. 3D Model in CATIA

A. Numerical analysis

1) For Torispherical Head

Pd= 1.5Pi

T= Pd*Di/(4*Ϭall*1)-0.4Pi

6.35= 2210*203.2/(4*Ϭall*1)-0.4*2210

Ϭall=17901 N/MM2

Ϭall=€E

€=1791/14.5e6

Dl/l=1.23e-3

Dl=1.23e-3*8.25

Dl=0.01018mm

2) For Cylinder

Ϭt=Pi(Do^2+Di^2)/(Do^2-Di^2)

Ϭt =1700(215.9^2+203.2^2)/(215.9^2-203.2^2)

Ϭt =28774 N/MM2

Ϭt=€E

€=28774/145e6

Dl/l=1.9844e-3

Dl=1.9844e-3*15.5

Dl=0.03mm

5. Results and discussion

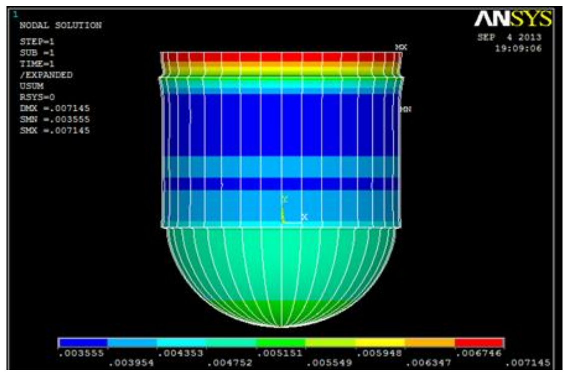

Fig. 4. Maximum Stress in Cylinder is tensile stress σ_t= 28172N/mm^2

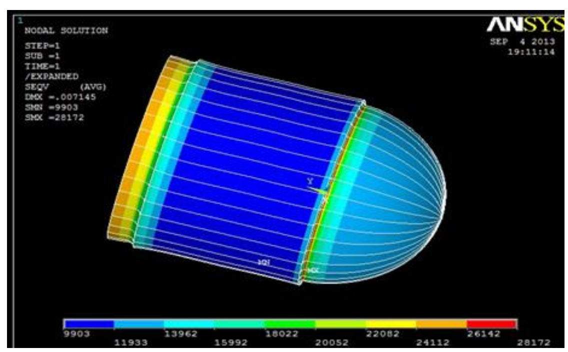

Fig. 5. Maximum Displacement in cylinder =0.007145mm

6. Conclusion

- 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.

- The fabrication of torispherical pressure vessel is much easier as compared to spherical dome pressure vessel and have common use in aerospace industry.

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