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Design and Analysis of the Pressure Vessel

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ABSTRACT-
The pressure vessel contains high pressurized fluid so that the selection of material and the design of the pressure vessel are most important. The pressure vessel contains high internal pressure. It must passes the sequence of hydrostatic test this test gives the capability of the construction to survive internal pressure. The analytical design of the pressure vessel is by using as per ASME code sec VIII division I. The dimension and stresses which works on pressure vessel can be found out by ASME code. These stresses are studying by using FEM and equate with theoretical value.

Key Word: Pressure vessel, ASME code, Design, FEM, Stress.

1. INTRODUCTION

Pressure vessel is reservoirs which have high pressurized fluid inside it. The pressure is variance between inside and outside of the container. The inside pressure is normally greater than the outside pressure .The fluid inside the vessel may undergoes change in state as in case of steam boiler ,or may combine with other substances as in the reservoir. The size and geometry from of pressure vessel are differs as per application. The large cylinder-shaped vessel used for high –pressure gas loading to the minor size used as hydraulic components for air craft With increasing demands from industrial processes for higher operating pressures and higher temperature, new machineries have been industrialized to grip the present day specialized necessities. Multilayer Pressure Vessels have extended the art of pressure vessel structure and presented the process designer with a dependable portion of equipment useful in a wide range of operating circumstances for the problems generated by the storage of hydrogen and hydrogenation processes the term pressure vessel signified to those reservoirs or containers, which are subjected to internal or external pressures. The pressure vessels are used to store fluids under pressure.

The fluid being stored may undergo a change of state inside the pressure vessels as in case of steam boilers or it may combine with other reagents as in chemical plants. Pressure vessels find wide applications in thermal and nuclear power plants, process and chemical industries, in space and ocean depths, and in water, steam, gas and air supply system in industries. Solid wall pressure vessels consist of a single cylindrical shell with close end. Due to high internal pressure and large thickness the shell is considered as thick cylinder. For thick cylinder wall thickness must exceed one-tenth(1/10) of the inside diameter .A solid wall vessel is also termed as mono block in pressure vessel .The application of pressure vessel in very wide in thermal and nuclear power plant process and chemical industries in space and depth and in water, steam, gas, and air supply system in industries . The material of a pressure vessel may be brittle such as cast iron or ductile such as mild steel. So these construction high pressure-vessels. A solid wall vessel produced by forging or drilling a solid rod of metal .the cylinder formed by bending a sheet of metal with longitude weld and shrink fit construction in which vessel is built up of two or more concentric shells each shell progressively shrunk on from inside outward from economic and fabrication considerations the number of shell be limited to two.

High Pressure vessels are used as reactors, separators and heat exchangers. They are vessel with an integral bottom and a removable top head, and are generally provided with an inlet, heating and cooling system and also an agitator system. High Pressure vessels are used for a pressure range of 15 N/mm2 to a maximum of 300 N/mm2. These are essentially thick walled cylindrical vessels, ranging in size from small tubes to several meters diameter. Both the size of the vessel and the pressure involved will dictate the type of construction used.

2. TYPES OF HIGH PRESSURE VESSEL

Solid wall vessel:

A solid wall vessel consists of a single cylindrical shell, with closed ends. Due to high internal pressure and large thickness the shell is considered as a „thick‟ cylinder. In general, the physical criteria are governed by the ratio of

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diameter to wall thickness and the shell is designed as thick cylinder, if its wall thickness exceeds one-tenth of the inside diameter. A solid wall vessel is also termed as Mono Block pressure vessel.

Multilayered vessel: Multilayer 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. Multilayer construction is used for higher pressures. It provides inbuilt safety, utilizes material economically, no stress relief is required. For corrosive applications the inner liner is made of special material and is not considered for strength criteria. The outer load bearing shells can be made of high tensile low carbon alloys.

3. DESIGN OBJECTIVES

(a) To show that multilayer pressure vessels are suitable for high operating pressures than solid wall pressure vessels.
(b) To show a significant saving in weight of material may be made by use of a multilayer vessel in place of a solid wall vessel.
(c) To show there may be a uniform stress distribution over the entire shell, which is the indication for most effective use of the material in the shell.
(d)To check the suitability of using different materials for Liner shell and remaining layers for reducing the cost of the construction of the vessel.
(e) To verify the theoretical stress distribution caused by internal pressure at outside surface of the shell and to ascertain that the stresses do not reach yield point value during testing.
(f) Finally check the design parameters with FEM analysis by using ANSYS package to ascertain that FEM analysis is suitable for multilayer pressure vessel's analysis.

4. ELEMENTS CONSIDERED IN DESIGNING OF PRESSURE VESSEL

(a) Measurements, Thickness, size and their limits.
(b) Working circumstances, Pressure and temperature.
(c) Accessible materials and their physical properties and cost.
(d) Destructive nature of reactants and yields.
(e) Theories of failure.
(f) Types of structure i.e. forged, welded or casted.
(g) Method of Manufacture.
(h) Fatigue, Brittle failure and Creep.
(i) Economic concern.

5. DESIGN OF SOLID WALLED PRESSURE VESSEL

A solid wall vessel contains of a single cylinder-shaped casing, with sealed finishes. Due to high internal pressure and large thickness the shell is considered as a 'thick' cylinder. In general, the physical standards are directed by the ratio of diameter to wall thickness and the shell is designed as thick cylinder, if its wall thickness exceeds one-tenth of the inside diameter.

6. DESIGN FACTORS

The design of solid pressure vessel comprises:

a. Design of vessel thickness.
b. Design of Curved ends thickness.
c. Calculation of Hydrostatic Test Pressure.
d. Calculation of Bursting Pressure.

Fig. no. 1 pressure vessel

7. INPUT DATA

Volume of the pressure vessel: **300 litres**
Design pressure p - **30 N/mm2 (300 bar)**
Design Temperature T - **20˚C**
Design Code - **ASME Sec. VIII Division-I**
Inside radius of wheel Ri - **325mm**
Inside Diameter of vessel Di - **650mm**
Factor of safety (F.S): **4**
Corrosion Allowance, C.A **- 3.0mm**
Mass of the air: **106.95 kg**

8. PROPERTIES OF MATERIAL

Name of Material	CrNiMo(17-12-2)
Yield Strength	686.5 N/mm^2

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Ultimate Tensile Stress	1384 N/mm^2

9. CALCULATIONS

The thickness of the pressure vessels can be calculated as:

a. Lame's equation-

t= $R_i \sqrt{[\frac{(\sigma_t + p)}{(\sigma_t - p)}]}$-1

= 325 $\sqrt{[\frac{(346+30}{346-30}]}$-1

= 29.5+corrosion allowance

= 29.5+ 3

= 32.5 mm

t= 35 mm

b. The thickness of the dished end can be calculated as:

Hydrostatic test pressure (P_h):

= 1.3×Design pressure

$\mathbf{P_h}$ = 1.3×30

$\mathbf{P_h}$= 39 N/mm^2

c. Thickness of the dished end (t_d):

$t_d = \frac{P \times R_i}{(2\sigma_t - 0.2\ P)}$ + Corrosion allowance

$t_d = \frac{30\times325}{(2*346-0.2*30)}$ + 3.0

t_d = 17.21 mm

The stress developed inside the dished ends:

(S_{hd}) = $\frac{(\mathbf{P_h \times R_i + 0.2 \times Ph \times t})}{2t}$

$S_{hd} = \frac{(39\times325 + 0.2\times39\times35)}{2\times35}$

S_{hd} = 184.97 N/mm^2

d. Stress developed during Hydrostatic test:

(i) In Vessel:

t= $R_i \times\sqrt{[\frac{\sigma_t\times j+p}{\sigma_t\times j-p}]}$-1

35=325×$\sqrt{[\frac{\sigma_t\times1+39}{\sigma_t\times1-39}]}$-1

σ_t =382.54N/mm^2

The stress developed 382.54N/mm^2 is less than the allowable stress value 617.85N/mm^2 which is 90% of the yield stress.

(ii) In dished end:

The stress developed inside the dish is given by the equation

$S_{hd} = \frac{(P_h\times R_i + 0.2\times P_h\times t)}{2t}$

= $\frac{(39\times325 + 0.2\times39\times35)}{2\times35}$

=184.97N/mm^2

The stress developed 184.97N/mm^2 is less than allowable stress value 617.85N/mm^2 which is 90% of the yield stress.

Calculation of Bursting Pressure:

Ultimate tensile strength of material

= 1384N/mm^2

K= Outer diameter **/** Inner diameter

= 685/650

=1.053

Bursting pressure is calculated as per Lame's method

P_b = U.T.S× [$\frac{K2-1}{K2+1}$]

= 1384×[$\frac{(1.053)2-1)}{(1.053)2+1)}$]

P_b = 71.41 N/mm^2

Stress developed inside the dished end is given by equation:

$S_{hd} = \frac{(Pb\times Ri + 0.2\times Pt)}{2t}$

$S_{hd} = \frac{(71.41\times325 + 0.2\times71.41\times35)}{2\times35}$

S_{hd} = 338.68 N/mm^2

The stress is developed (338.68 N/mm^2) is less than allowable stress value (685.5N/mm^2).which is 100% yield stress. Hence the design is safe.

10. CONCLUSION

The design of the Pressure vessels is safe. The Factor of safety that we consider is permissible and by which the design are considered safe. The bursting pressure is under the allowable stress so that the design does not fail. And the analysis are so close to the Analytical design hence the both data are validate and the design is considered as safe And there are no failure occurs in the pressure vessel.

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