ELK ASIA PACIFIC JOURNAL OF MECHANICAL ENGINEERING AND RESEARCH- SPECIAL ISSUE
ISSN 2349-9368(Online);EAPJMER/ISSN.2454-2962/2016;

ELK
Asia Pacific Journals

National Conference on Futuristics in Mechanical Engineering
Madan Mohan Malaviya University of Technology

A REVIEW PAPER ON DESIGN OF RECTANGULAR PRESSURE VESSEL

Shama Kausar	***Ram Bilas Prasad***
Mechanical Engineering Department, Madan Mohan Malaviya University of Technology, Gorakhpur	Mechanical Engineering Department, Madan Mohan Malaviya University of Technology, Gorakhpur

ABSTRACT

The pressure verssels are used for storing gases, liquids and solid waste. The pressure vessels are subjected to internal pressure and sometimes external pressure. There are various shapes of pressure vessel such as cylindrical, spherical, rectangular etc. These vessels must be designed carefully in order to ensure the functionality of pressure vessel with utmost safety. Design of pressure vessel is done by either ASME Code or Analysis using software. The present paper presents a review on the design and analysis of prismatic pressure vessel including selection of material and effect of stiffener or stayed plates.

Keywords: *Rectangular Pressure Vessel, Stiffener, Stay Plate, ASME.*

Introduction

A pressure vessel is a container designed to store the gases and liquids at a pressure substantially different from ambient pressure. Pressure vessels find wide applications in thermal and nuclear power plants, process and chemical industries, in space and ocean depths, and fluid supply systems in industries. The failure of pressure vessel may result in loss of life, health hazards and damage of property. Due to practical requirements, pressure vessels are often equipped with openings of various shapes, sizes and positions. Vessels have openings to accommodate manholes, handholds, and nozzles. The ASME codes give the dimension and working pressure. The pressure vessel of non-circular cross-section has been discussed in ASME Code, Section VIII, Division 1. It gives the design rules for pressure vessel of rectangular and obround cross-section with or without reinforcing and stayed plates inside or outer surface of the pressure vessel. Material of the pressure vessel is discussed in ASME Code, Section II. The material selection for pressure vessel requires condition where it is installed.

ASME Codes, Section VIII, Division 1 is design by rules and ASME Codes, Section VIII, Division 2 is design by analysis. Division 1 procedures consider a biaxial state of stress accordance with the maximum stress theory whereas Division 2 stress analysis considers all stresses in a triaxial state combined in accordance with the maximum shear stress theory. The operating pressure either internal or external for division 1 is from 1.03 bar to 206.84 bar whereas in case of division 2, it is from 3000 psi to 10000 psi but its requirements are more rigorous than division 1.

Figure 1 and 2 shows that prismatic pressure vessel with coordinate systems and the lateral pressure applied on the single plate, the moments along x- and y-axis are discussed one by one by using superposition method.

The motive of this paper is to design a rectangular pressure vessel with suitable dimensions. To reduce the membrane stresses and bending stresses stiffeners are used. The optimum number of stiffeners are used to get the effective design.

MATERIALS FOR PRESSURE VESSEL

The ASME Boiler and Pressure Vessel codes gives the standard material selection with their properties under the suitable temperature and allowable stresses. The material selection are given in Section II of Boiler and Pressure Vessel codes. The different materials choosen, to know the actual behavior of the materials stress-strain curves for each materials to be used. A design method have been used that is elastic-plastic analysis method to assess the structural integrity more accurately and also considers nonlinearities in geometry. The materials are used such as SA516-70 for shell, SA106-B for nozzle and SA36 for parallel plates, stiffeners, endbox floor and walls etc., for primary and secondary groups [1]. The pressure vessels are secured by bolts used for fastening the flange of pressure vessel with cover plate. ASTM – A193, Grade B8 material is used for bolt. A 0.16cm neoprene gasket was used to prevent the leakage in pressure vessel [5]. Analysis is done on three different types of material are SA516GR60, SA516GR70 and SA516GR65 and then compared the result of stresses and deformations. The result obtained from different materials shows that SA516GR65 has the stress value less compared to all other materials [2].

PRESSURE VESSEL WITH STAY PLATE

The pressure vessel with one or more than one stay plates are welded inside the vessel to make the model with high strength. A researcher modified the pressure vessel by adding stay plate which is used to stiffen the model. The material of stay plate is ASTM-A240, 316 Stainless Steel. The pressure vessel with stayed plate shown in Figure-3 [5]. The developed code equation for the pressure vessel with an aspect ratio of length of the vessel by width of the vessel should be greater than 4. This paper has aspect ratio is less than 4 due to which code equations are not applicable and some dimentional changes must be required to perform the analysis.

STRESS CONCENTRATION

Stress concentration are maximum at the corners of the rectangular pressure vessel which is the region from where the rectangular pressure vessel may break. Due to which the stresses at the corner may reduce by providing round, chamfer and

ISSN 2349-9368(Online);EAPJMER/ISSN.2454-2962/2016;

fillets. This paper performed, first to compare the stresses in rectangular box by changing the length by width ratios for different thickness and varying fillet radius using FEM method and obtained that by increasing length by width ratios with increasing thickness and varying fillet radius the maximum Von-mises stresses also increases. Second, analysis stress calculations are carried out using ASME codes, Section VIII and observed that the sresses are presents at the corner and location near the corners bending stresses are vanished and only membrane stresses exists [4].

STIFFENED PRESSURE VESSEL

Cylindrical pressure vessel with or without stiffener and various types of stiffener designs are triangular, rectangular slotted, honey-comb, square, sector, circular, helical, semi-circular, linear x-crossed and quadratic x-crossed. From analysis, observed that helical stiffener design have less weight compared to basic stiffener approx 28%. The helical stiffener design has 23% less von-mises stress compared to basic cylinder but for stiffeness, the deformation was little high compared to basic cylinder. The obtained results of deformations are within the limit. After analysis observed that helical stiffener design are best for design point of view compared to others [8].

DESIGN BY ASME CODE

The ASME Code equations are provided for the evaluation of the rectangular pressure vessel in Section VIII, Division I. Due to the given formulae validation of the stresses are possible and provides analytical method to calculate the membrane stresses, bending stresses and membrane plus bending stresses at the corners M_A, middle of long side M_D and middle of short side M_E as shown in figure 4. The highest membrane stress is evaluated by Equation-1 and membrane plus bending stress equation is given in Equation-2.

FINITE ELEMENT ANALYSIS

The finite element analysis is the easy and time-consuming method to perform the stress analysis on pressure vessel. There are different types of software packages used to prepare the model and then perform the analysis. The COSMOS/M[1] software package have been used to prepare the model of rectangular pressure vessel with stayed plate. The model had 4-noded quadrilateral shell elements and also have the membrane and bending stress capabilities [5]. The Ansys software are also used for the linearization of stresses in pressure vessel. The ABACUS software package used to linearise the stresses and the model are prepared on PRO-E software [1].

CONCLUSIONS

The rectangular pressure vessels have wide application and mainly used to store the gases, liquids and waste from radioactive storage tank.

1. The rectangular pressure vessels are used where there are less space to install

the conventional type pressure vessels because of its huge structure. The volume carrying capacity of rectangular pressure vessels are more than conventional pressure vessel for the same dimension.

2. The different materials used for pressure vessel design are SA516GR60, SA516GR70 and SA516GR65. The obtained results shows that SA516GR65 has less stress distribution compared to other materials.

3. The design of pressure vessel can be done by finite element modelling and by using ASME codes derived for pressure vessel. The finite element analysis method is easy in comparision to ASME codes because it gives lenthy calculations.

4. The stress concentration obtained at sharp edges can be reduced by providing fillet and chamfer at the edges.

5. The stiffener and stay plate used in the pressure vessel design have positive effect on the vessel. The bending stresses can be reduced by adding stiffener and stay plates.

References

[1] Younseok Choi et al., "Numerical and Experimental Study of a plate-stiffened prismatic pressure vessel", Ocean Engineering 164 (2018), pp- 367-376.

[2] B. Siva kumar et al., "Stress Analysis and design Optimization of a Pressure vessel Using Ansys Package",Materials today: Proceedings 5 (2018) 4551-4562.

[3] Jaemin lee et al., "Design of a Prismatic Pressure Vessel: An Engineering Solution for Non-Stiffened –Type vessels", Ocean Engineering 142 (2017) 639-649.

[4] D.G. Lokhande et al., "Stress Analysis of Rectangular Boxes Using Fem", Int. Journal of Engineering Research and Applications ISSN : 2248-9622, Vol. 4, Issue 4(Version 3), April 2014, pp.51-59.

[5] M.A Rezvani et al., "Stress Analysis and Evaluation of a Rectangular Pressure Vessel",Westingghouse Hanford Company October (1992), pp- 1-5

[6] A.E. Blach et al., "Rectangular Pressure Vessel of Finite Length ", In Journal of Pressure Vessel Technology. February (1990), pp- 50-56.

[7] J.H. Faupel., "Pressure Vessel and Piping Codes",Journal of Pressure Vessel Technology. August (1979) vol. 101, pp- 255-267.

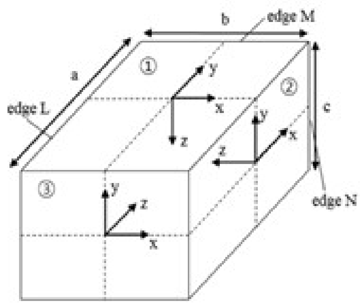
[8] E. Kumar.A, R. K. Santosh, "Static and Dynamic Analysis of Pressure Vessels with Various Stiffeners", Materials Today: Proceedings 5 (2018) 5039–5048.

[9] M. P. Kumar, K. Vanisree, S. Raj, "Design and Implmentation of Circular Cross Sectional Pressure Vessel Using Pro-E and Ansys", International Journal of Modern Engineering Research (IJMER), Vol. 3, Issue. 4, Jul.-Aug. 2013, pp-2350-2355, ISSN: 2249-6645.

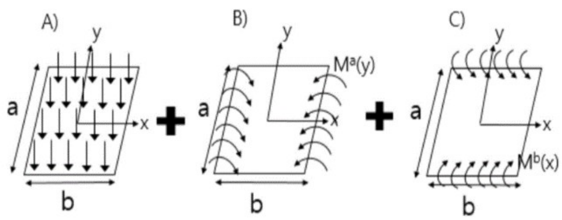
[10] Michael A. Porter, Dennis H. Martens, "On Using Finite Element Analysis for Pressure Vessel Design", American Society of Mechanical Engineers, Pressure Vessels and Piping

ISSN 2349-9368(Online);EAPJMER/ISSN.2454-2962/2016;

Division (Publication) PVP, 22 August 2015.G. Momin, M. Ramgir, "Stress Analysis for a Rectangular shaped Quench tank", International Journal of Engineering Development and Research, 2014



A. ***Figure 1:*** *Prismatic Pressure vessel and coordinate systems [3]*



B. ***Figure 2:*** *superposition method [3]*

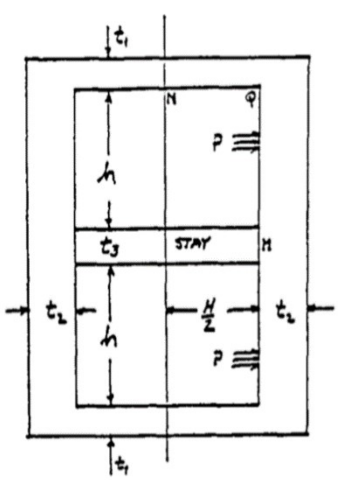


Figure 3: *Rectangular Pressure Vessel with single stayed design [5].*

ISSN 2349-9368(Online);EAPJMER/ISSN.2454-2962/2016;

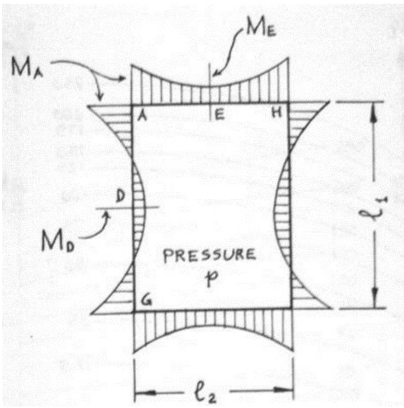


Figure 4: *Moment location in rigid frame*

$$S_m = \frac{Ph}{2t} \quad (1)$$

$$S_{T,M} = \frac{PH}{2t} + \frac{Ph}{2t}\left[\frac{3}{2} - \frac{(1+\alpha^3)}{(1+\alpha)}\right] \quad (2)$$

Where, $\alpha = H / h$

S_m= membrane stress

P = pressure

h = long side of rectangular plate

H = short side of rectangular plate

t = thickness of the plate

α = rectangular vessel parameter

$S_{T,M}$ = total stress, at mid-point of long side plate