Stress Analysis of Pressure Vessel With Different Type of End Connections-A Review

Digvijay Kolekar , Jewargi S.S.

***Abstract*— Pressure Vessel is a closed container designed to hold gases or liquids at a high pressure, higher than atmospheric pressure. Due to operating conditions, high stresses are developed in Pressure vessel which results in cracking and bursting of vessel. Pressure vessel is subjected to high internal pressures as mathematically it is very difficult to solve such a complex problem. Various research papers presents analysis of pressure vessel with dished heads to resist internal pressure, analysis of vessel with different configuration of saddle support with stiffener ring and reduction of stresses. Lot of work had been carried out to develop various numerical and experimental methods to study stresses in pressure vessel. Analytical and experimental techniques have some limitations such as cost associated with multiple prototypes and experimental iterations. Therefore, Finite Element Analysis is most viable tool for design and analysis of pressure vessel with American Society of Mechanical Engineers standards. In this paper we are working on approximate stresses that exist in cylindrical pressure vessels supported on two saddles support are calculated under the different type of end connections by using Finite Element tool. Static structural analysis is done in order to calculate stresses in vessel. The thickness of vessel heads are varied with the composite material till the maximum von-moises stress is within the limits.**

***KEYWORDS*: Pressure Vessel, End connections, Stress analysis.**

I. INTRODUCTION

A pressure vessel is defined as container with internal pressure, higher than atmospheric pressure. The fluid inside the pressure vessel may undergo state of change like in case of boilers. Pressure vessel has combination of high pressure together with high temperature and may be with flammable radioactive material. because of these hazards it is important to design the pressure vessel such that no leakage can take place as well as the pressure vessel is to be designed carefully to cope with high pressure and temperature. Plant safety and integrity are one of the fundamental concerns in pressure vessel design and these depend on adequacy of design codes. In general the cylindrical shell is made of a uniform thickness which is determined by the maximum circumferential stress due to the internal pressure. Since the longitudinal stress is only one-half of this circumferential stress. The structure is to be designed fabricated and checked as per American Society of Mechanical Engineers standards .Pressure vessels are used in number of industries like power generation industry for fossil and nuclear power generation, In petrochemical industry for storage of petroleum oil in tank as well as for storage of gasoline in service stations and in the chemical industry. The size and geometric form of pressure vessel is varying from large cylindrical vessel for high pressure application to small size used as hydraulic unit of aircraft. In pressure vessel whenever expansion or contraction occurs normally as result of heating or cooling, thermal stresses are developed. There are many types of stresses developed in the vessel. Stresses are categorized into primary stresses and secondary stresses. Primary stresses are generally due to internal or external pressure or produced by moments and these are not self limiting. Thermal stresses are secondary stresses because they are self limiting. That is yielding or deformation of the part relaxes the stress (except thermal stress ratcheting).Thermal stresses will not cause failure by rupture in ductile materials except by fatigue over repeated loading applications.

David Heckman. [1] presented on set out to verify finite element analysis, when applied to pressure vessel design. While finite element analysis offers another way to analyze structures, it requires an understanding of the program and subject being modeled. If the operator does not use the correct model, time is wasted and more importantly the data is useless. Finite element analysis is an extremely powerful tool for pressure vessel analysis when used correctly. Tested models were run with errors ranging from seven to nearly zero percent error and could be run in a relatively short time. The FEA method is used for analysis of pressure vessels. Yogesh Borse [2] this paper deals with the Finite element modelling of Pressure vessels. Considering the fact that required thickness of hemispherical head for internal pressure loading is only half of that necessary for the cylindrical shell, authors have tried to develop a finite element model taking due consideration on welding involved at the end connections of cylinder to shell end in modeling using shell elements to model cylinder. The Paper was extended via analyzing the hemispherical end with different thickness to drive the polynomial for stress variation in the metal. With the growing demand of industry to save cost, many researchers have put their efforts to optimize the shape of end connections resulting in optimization of weight. The FEA method is used for analysis of pressure vessels. Vikram V. Mane [3] researcher find stress Analysis with the help of Finite Element Method and Experimental Method is necessary to find out the exact behavior of pressure vessel .To find out the stresses at the interaction between pressure vessel cylinder walls and end caps; When modeled correctly, F.E.A. proved to be useful, but the operator also needs to be able to interpret the results properly. For the validation of F.E.A. result; the measurement of stresses by the experimental method is necessary. The analyst should be able to approximate the solution using classical methodology (hand calculations) in order to verify the solution. This work set out to explore applicable methods using finite element analysis in pressure vessel analysis.

***Digvijay Kolekar**, P.G.Student, Mechanical Department, Siddhant College of Engineering, Sudumbare, Pune, India.*
***Jewargi S.S**, Assistant Professor, Mechanical Department, Siddhant College of Engineering, Sudumbare, Pune, India.*

Farhad Nabhani[4] worked on the finite element analysis result in design case one was compared with the allowable stress intensities of ASME BVPC Division 3 and it was found that the stresses in the cylindrical shell exceeded the value of the allowable stress with almost 70 %. Also, the result shows higher stress development along the nozzle length away from the shell and at the bottom semi spherical head. However, the stresses developed in ellipsoidal enclosures head has a very less margin than the allowable stress of about 4%, which can be improved by using better thickness to diameter ratio.The analytical and FEA methods are used. G. W. Watts [5] presents the results of computations for determining the stresses in a pressure vessel with a conical head. The accurate bending theory of shells is used to evaluate the local bending stresses in the neighborhood of the junction of the conical head and the cylindrical body. Additional results show the magnitude and location of the maximum stress in the cylinder. Curves are given showing the maximum stresses for values of cone apex angle, ratio of conical head thickness to cylinder thickness, and ratio of cylinder diameter to cylinder thickness which will include most of the vessels encountered in practice. S. K. Raparla [6] The main objective of this paper is to design and analysis of multilayer high pressure vessels features of multilayered high pressure vessels, their advantages over mono block vessel are discussed. Various parameters of Solid Pressure Vessel are designed and checked according to the principles specified in American Society of Mechanical Engineers. The stresses developed in Solid wall pressure vessel and Multilayer pressure vessel is analyzed by using ANSYS, a versatile Finite Element Package. The theoretical values and ANSYS values are compared for both solid wall and multilayer pressure vessels. A.H. Weisberg [7] This paper describes an innovative approach to hydrogen delivery. This approach minimizes hydrogen delivery cost through utilization of glass fiber pressure vessels to produce a synergistic combination of container characteristics and properties of hydrogen gas is more compact for a small increase in theoretical storage energy and these cold temperatures strengthen glass fibers by as much as, expanding trailer capacity without the use of much more costly carbon fiber composite vessels. John Makinson [8] the Project had an interest in further understanding the effect of cuts to the surface of composite tanks, and how the burst pressure would be affected during the lifetime of the pressure vessel. A test program was initiated to provide data on initial burst pressure, and burst pressure after pressure cycling, of composite cylinders with cuts of different depth. It should be noted that this experiment was to provide information on the flaw tolerance of composite pressure vessels and the effect of cycling to design pressure. These results only apply to this vessel design, and should not be extrapolated to significantly different pressure vessel designs. Gongfeng Jiang [9] This team worked on the experimental results of uniaxial ratcheting tests for stainless steel under stress-controlled condition at room temperature showed that the elastic domain defined in this paper expands with accumulation of plastic strain. Both ratcheting strain and viscoplastic strain rates reduce with the increase of elastic domain, and the total strain will be saturated finally. If the saturated strain and corresponded peak stress of different experimental results under the stress ratio are plotted, a curve demonstrating the material shakedown states of SS304 can be constituted. Using this curve, the accumulated strain in a pressure vessel subjected to cyclic internal pressure can be determined by only an elastic-plastic analysis, and without the cycle-by-cycle analysis. J. Zamani [10] The Authors studied on an elastic solution of cylinder-truncated cone shell intersection under internal pressure is presented. The edge solution theory that has been used in this study takes bending moments and shearing forces into account in the thin-walled shell of revolution element. The general solution of the cone equations is based on power series method. The effect of cone apex angle on the stress distribution in conical and cylindrical parts of structure is investigated. Nitant M. Tandel [11] This work gives the information such as design and component development time was analyzed and modelled to ensure the effect of implementation of this approach to product development cycle and design efficiencies This paper discusses some design principles that are deals with vessels are subjected to various applied forces acting in combination with internal or external pressure. These result in axial tensions and compressions in the shell, which must be combined with the effects of the pressure loading to give the total longitudinal stress acting in the shell. The design method to be used depends on whether the longitudinal stress in the shell is tension or compression, and on whether the vessel is subjected to internal or external pressure K. Yogesh [12] In the present work an attempt is made to design a mounded bullet with a huge capacity. The mounded bullet which is nothing but a pressure vessel, being buried underground, the chances of explosion and consequent trowels of debris is almost nullified. In additional to the internal pressure of the vessel, mound load, earthquake load, uneven displacement/settlement of the sand bed, weight of the vessel, test conditions have been considered for the analysis. The analysis reveals that the design stresses are within the limit and the design is safe. Manish M. Utagikar [13] This paper presents the work carried out for determination of stresses in an open ended pressure vessel of obround shape. In some situations, due to the limited space available, exit pipes are made of elliptical or obround shape. In this study, the stresses in the obround pressure vessel are determined using finite element method. The material of the vessel is aluminium alloy. Deformation in the obround pressure vessel is also very much higher as compared to the deformation in circular pressure vessels. As radius of curved portion of obround pressure vessel goes on increasing, the hoop stresses go on reducing. As the thickness of vessel goes on increasing, stresses go on reducing. Hoop stress is directly proportional to the pressure applied inside the vessel. B.S.Thakkar [14] Studied on high pressure rise is developed in the pressure vessel and pressure vessel has to withstand severe forces. The pressure vessel Selection Procedure after determining the inputs is a simplified process and can be automated to shorten the design cycle. The following additional conclusions were made from the project study. Selection of pressure vessel components should be according to standards rather than customizing the design. As abiding by the standards lead to: A universal approach, Less time consumption, Easy replacement, So less overall cost. L. P. Zick [15] The purpose of this study is to indicate the approximate stresses that exist in cylindrical vessels supported on two saddles at various locations. Knowing these stresses, it is possible to determine which vessels may be designed for internal pressure alone, and to design structurally adequate and economical stiffening for the vessels which require it. This can be approximated for heads where by representing the pressure on the head and theongitudinal stress as a clockwise couple on the head. Procedure for Paper Submission

II. Discussion

Finite element analysis is a powerful tool in the field of engineering. Initially, finite element analysis was used in aerospace structural engineering. This project set out to verify finite element analysis, or FEA, when applied to pressure vessel design. While finite element analysis offers another way to analyze structures, it requires an understanding of the program and subject being modeled. The stress Analysis with the help of Finite Element Method and Experimental Method is necessary to find out the exact behavior of pressure vessel .To find out the stresses at the interaction between pressure vessel cylinder walls and end caps; When modeled correctly, FEA proved to be useful, but the operator also needs to be able to interpret the results properly. For the validation of F.E.A. result; the measurement of stresses by the experimental method is necessary. The analyst should be able to approximate the solution using classical methodology (hand calculations) in order to verify the solution. This project set out to explore applicable methods using finite element analysis in pressure vessel analysis.

III. CONCLUSION

It has been observed that the changes in end connections of pressure vessel the stress concentration zone are changes for different end connections for the same pressure. Some researchers have considered composite structures in their study to analyse the effect of composite materials in various components of pressure vessels. The use of composite material gives the more advantages like reduces manufacturing cost of pressure vessel, find optimal thickness of pressure vessel head, reduce the weight of the pressure vessel, increase corrosive resistance of the pressure vessel.

Acknowledgment

I would like to express my deep sense of gratitude to my supervisor Prof. Jewargi S. S. for his inspiring & invaluable suggestions. I am deeply indebted to him for giving me a chance to study this subject & providing constant guidance throughout this work.

.

REFERENCES

[1] Heckman, David "Finite element analysis of pressure vessels" mbari 1998.

[2] Yogesh Borse, Avadesh Sharma "Modelling of Pressure Vessels with different End Connections using Pro Mechanica" International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 Vol. 2, Issue 3, May-Jun 2012, pp.1493-1497.

[3] Vikram V. Mane, Vinayak H.Khatawate. Ashok Patole "Finite Element Analysis of Ellipsoidal Head Pressure Vessel" International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 National Conference on Emerging Trends in Engineering & Technology (VNCET-30 Mar'12).

[4] Farhad Nabhani, Temilade Ladokun and Vahid Askari. "Reduction of Stresses in Cylindrical Pressure Vessels Using Finite Element Analysis" Finite Element Analysis – From biomedical applications to industrial developments.

[5] G. W. Watts, H. A. Lang, Chicago, Il. "Stresses in a Pressure Vessel With a Conical Head" ASME TRANSACTIONS, 1952 pp-207-218

[6] Siva Krishna Raparla , T.Seshaiah "Design And Analysis of Multilayer High Pressure Vessels" International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 Vol. 2, Issue 1, Jan-Feb 2012, pp. 355-361.

[7] A.H. Weisberg,S.M. Aceves, F.E.Loza,E.L.Orozco, B.Myers, Brian Spencer "Cold hydrogen delivery in glass fiber composite pressure vessels: Analysis, manufacture and testing" International Journal o f hydrogen energy 3 8 (2 0 1 3).

[8] John Makinson, Norman L. Newhouse "Flaw Testing of Fiber Reinforced Composite Pressure Vessels" Journal of Pressure Vessel Technology 2014 by ASME AUGUST 2014, Vol. 136 / 041409-1

[9] Gongfeng Jiang, Gang Chen, Liang Sun, Yiliang Zhang, Xiaoliang Jia, Yinghua Liu "A Noncyclic Method for Determination of Accumulated Strain in Stainless Steel 304 Pressure Vessels" Journal of Pressure Vessel Technology DECEMBER 2014, Vol. 136 / 061204-1.

[10] J. Zamani, B. Soltani, M. Aghaei. "Analytical Investigation of Elastic Thin-Walled Cylinder and Truncated Cone Shell Intersection Under Internal Pressure" Journal of Pressure Vessel Technology by ASME October 2014, Vol. 136 / 051201-1.

[11] Nitant M. Tandel, Jigneshkumar M. Parmar "A Review on Pressure Vessel Design and Analysis" indian journal of research Volume : 3 Issue 4 May 2013 ISSN - 2250-1991

[12] K. Yogesh, M.S.R. Lakshmi "Design And Finite Element Analysis of Mounded Bullet" Journal of Exclusive Management Science – October 2012-Vol 1 Issue 9 - ISSN 2277 – 5684.

[13] Manish M. Utagikar, Prof. S.B. Naik "Finite Element Analysis of Obround Pressure Vessels" International Journal of Modern Engineering Research (IJMER) www.ijmer.com Vol. 3, Issue. 5, Sep - Oct. 2013 pp-2717-2725 ISSN: 2249-6645.

[14] B.S.Thakkar, S.A.Thakkar "Design of Pressure Vessel Using ASME Code, Section VIII, Division 1" International Journal of Advanced Engineering Research and Studies E-ISSN2249–8974.

[15] L. P. Zick "Stresses in Large Horizontal Cylindrical Pressure Vessels on Two Saddle Supports" the welding journal research supplement September 1951.

[16] C. Y. Lin, M. Wu, J. A. Bloom, I. J. Cox, and M. Miller, "Rotation, scale, and translation resilient public watermarking for images," *IEEE Trans. Image Process.*, vol. 10, no. 5, pp. 767-782, May 2001.

Digvijay Kolekar*,P.G.Student, Mechanical Department, Siddhant College of Engineering, Sudumbare, Pune, India.*

Jewargi S.S*, Assistant Professor, Mechanical Department, Siddhant College of Engineering, Sudumbare, Pune, India.*

