Design, Analysis and Optimization of Non-Standard Weld Neck Body Flange in Small Pressure Vessel

Er. Karanjeet Singh
M.Tech Scholar
Department of Mechanical Engineering
North-West Institute of Engg. And Tech., Dhudike, Moga, Punjab, India

Er. Ramandeep Singh Dhaliwal
Assistant Professor
Department of Mechanical Engineering
North-West Institute of Engg. And Tech., Dhudike, Moga, Punjab, India

Er. Didar Singh
Assistant Professor
Department of Mechanical Engineering
North-West Institute of Engg. And Tech., Dhudike, Moga, Punjab, India

Er. Satvirpal Singh Grewal
M.Tech Scholar
Department of Mechanical Engineering
North-West Institute of Engg. And Tech., Dhudike, Moga, Punjab, India

Abstract

Pressure vessels are leak proof containers, as the name implies, their main purpose is to contain a given medium under pressure and temperature. Pressure vessels are commonly used in industry to carry both liquid and gases under required pressure and temperature limit. This pressure and temperature comes from an external source or by the application of heat from a direct or indirect source or any combination of them. After the review of many research papers, we find out that basically the most of the pressure vessels diameter was taken was from 300 mm to 2000 mm. Initially, we designed three non-standard body flanged pressure vessels different diameters. Pressure and material of vessels were selected as per practical conditions. We took SA 516 as flange material. After the designing of all cases we figure out the various stresses, loads and deformation using ANSYS and Pv-Elite. After that we redesigned Pressure vessels using standard flanges and figure out the same parameters using Pv-Elite and ANSYS. To optimize the non-standard flange we compared results of both flanges. We found that at almost same operating bolt load in non-standard flange with diameter 500mm has considerable deformation and stress intensity. Whereas in standard flange, in the same case, there is less deformation and stress intensity. The value of deformation and maximum stress intensity in 500mm diameter non-standard flange was 0.044043mm and 107.8 Mpa respectively and in standard flange value of deformation and maximum stress intensity was merely 0.014641mm and 16.548 Mpa respectively. In other two cases, in both standard and non-standard flanges, there is very small difference in deformation and stress intensity. The operating bolt load is slightly higher in standard flange due to greater bolt circle diameter, which results as the slightly higher deformation and stress intensity in both 1000mm and 1500mm diameter flange. In non-standard flange we required more thickness as compared to standard flange. But if we compare the weight of standard and non-standard flange, we found standard flange is almost double in weight.
Keywords- Pressure Vessel, ANSYS, PVElite Software, PRO-E,Mechanical Stresses, ABAQUS

I. INTRODUCTION

The pressure vessels and cylinders are commonly used to store fluid at high pressure. Sometimes pressure vessels are known as vacuum vessels, when inside pressure is lower than the atmospheric pressure. The common examples of pressure vessels are storage tanks, boilers and chemical & nuclear reactors. In steam boilers and reactors fluid may go in change in state. Sometimes, pressure vessels can be used to store radioactive materials and flammable material. In boilers there is the combination of high temperature and high pressure, which is highly dangerous and can be fatal in case of leakage. The design of pressure vessels is very complex and critical for high pressure vessels. ASME section VIII design code is used to design pressure vessels. In industrial use, there are many types of pressure vessels, but majorly classification can be done according to the thickness, and end construction. According to their dimensions, pressure vessels can be classified as thin shell or thick shell. If the thickness of the shell wall (t) is less than 1/10 of the diameter of the shell (d), then it is called a thin shell. On the other hand, if the thickness of the shell wall is greater than 1/10 of the diameter of the shell, then it is said to be a thick shell. Thin shells are used in boilers, tanks and pipes, whereas thick shells are used in high pressure cylinders, tanks, gun barrels etc.

The pressure vessels may be classified according to the end construction as open end or closed end. A simple cylinder with a piston, such as press cylinder is an example of an open end vessel, whereas a tank is an example of a closed end vessel.

A. Closed End Construction

1) Welded Dish End
Welded dish end type end construction used for very high pressure storage. It is also very common type construction and widely used for non-reactive fluid storage. This is one time construction and cleaning is not available with welded dish end type pressure vessel.

2) Body Flanged Dish End
Flanged dish end type end construction is used for moderate pressure storage. It is widely used for storage of reactive and organic compounds. In this type of vessel construction one dish end can disassemble for cleaning of internal surface. One flange is welded with shell and another flange is welded with dish end. Gasket is used for make the flange joint leak proof.

II. LITERATURE SURVEY

M Javed Hyder and M Asif performed ANSYS analysis for three thick-walled cylinders having 20 cm, 25 cm, 30 cm diameter and 30 cm height. The wall thickness of cylinders is 20 mm. Initially they analyzed tangential, longitudinal, radial, and von misses stress in cylinders without hole. Then they carried out the hole optimization with various holes having diameters 4, 8, 10, 12, 14, 16, 20 mm. They figure out that 8mm hole is the optimum hole if a thick cylinder having 20 cm diameter and 10 mm diameter hole is the optimum if a cylinder having 25 cm diameter. They found lowest value of von Misses stress in 30 cm diameter vessel. Then they placed a 12 mm hole at 1/6, 1/8, 2/8, 3/8, and 4/8 of cylinder from top in all three cylinders. They figure out that Von Misses stress is the maximum at the center 0.500 and minimum at the top of the cylinder.

Josip Kacmarcik, Nedelijko Vukojevic And Fuad Hadzikadunic In their study they compared two different to determine stress concentration factor. They used strain gauge with experimental setup and finite element analysis with ABAQUS. Two different geometries were taken and maximum von misses stresses and maximum principal stress used to define stress concentration factor. Two different nozzles were taken having different diameter and same wall thickness. After the results comparison of both methods they found maximum deviation of 15% which is acceptable for engineering applications of stress concentration factor in pressure vessels.

Binesh P Vyas, R. M. Tayade worked on the Design of pressure vessel and figure out that using PV Elite gives fine analysis result and also decreases time .A vertical pressure vessel was designed using software named PV Elite. Some important parameters are required to design the leg support of pressure vessel like volume, inside diameter, design pressure (either inside pressure or external pressure), temperature, material, processing fluid. Etc. PV Elite provides thickness of shell and head, height of head, thickness of nozzle, manhole. PV Elite figure out local stress as per welding research council (WRC) 107, further research required to explore environmental parameter such as earthquake, thermal load, and fluctuation load and so on.

Vikram V. Mane, Vinayak H .Khatawate conducted their study on stress analysis Ellipsoidal head stress analysis in pressure vessel with finite element analysis and experimental method, electrical strain gauges were used for strain measurement and result were compared with ANSYS software. They figure out that the results measured with the classical methods are more than the actual stresses measured with strain gauges and lower than the finite element analysis.

R M Tayade et al. have worked on the inclined pressure vessel (IPV) study using FEA in ANSYS to figure out stresses in the vessel to determine structural stability. For the production of nitrous oxide by ammonium nitrate, inclined position of pressure vessel is required to complete pyrolysis reaction with the steam passing through at around 200°C and 1.37895 MPa over the ammonium nitrate contained in the cylindrical vessel. Here the challenge was to design the inclined pressure vessel, because ASME codes can only applicable for horizontal and vertical vessels but there were no provisions for vertical design. This paper provides the inclined pressure vessels structural analysis having inclined legs which are under consideration.

III. METHODOLOGY

A. Design of Pressure Vessel with Non-Standard Body Flange using PV-Elite
Three non-standard body flanged pressure vessels were developed with different diameters in PV-Elite. Pressure and material of vessels were selected as per practical conditions. We took SA 516 as flange material.

B. Figure out the Results using ANSYS and Pv-Elite
After the designing of all cases we figure out the various stresses, loads and deformation using ANSYS and Pv-Elite.

C. Redesign Vessel with Standard Flange
After that we redesigned Pressure vessels using standard flanges and figure out the same parameters using Pv-Elite and ANSYS.

D. Compare the Both Results
To optimize the non-standard flange we compared results of both flanges.

IV. RESULTS

A. *Design of Pressure Vessel*

From the industrial view, we design three vessels of diameter 500mm, 1000mm, and 1500mm with standard and non-standard flange. We took pressure 10kg/sq. cm for all pressure vessels.

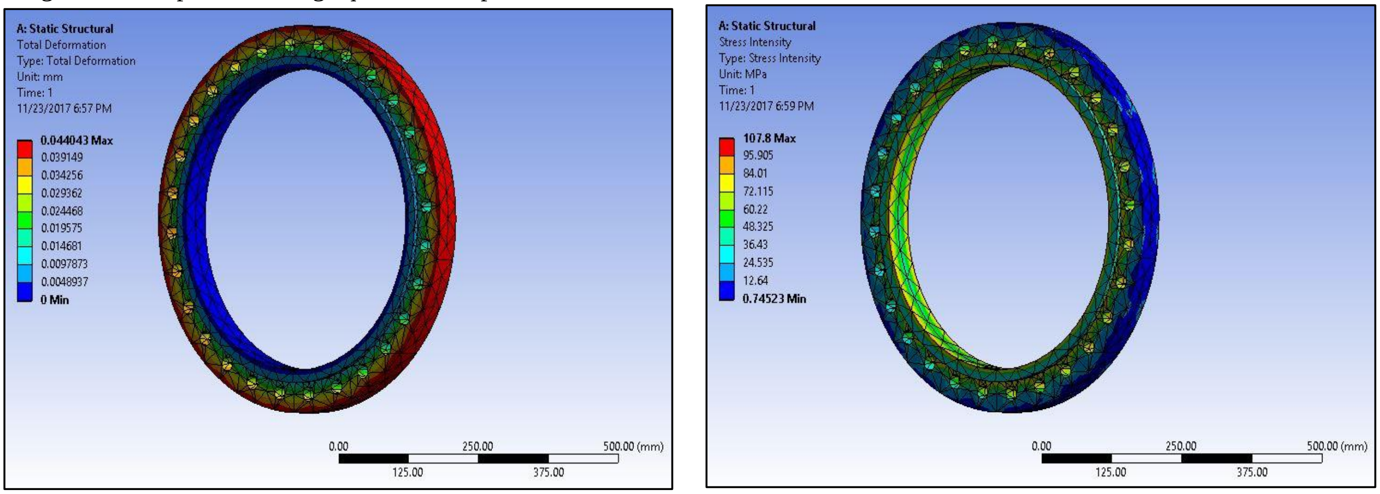

Fig. 1: ANSYS results for non-standard body flange of 500mm diameter pressure vessel

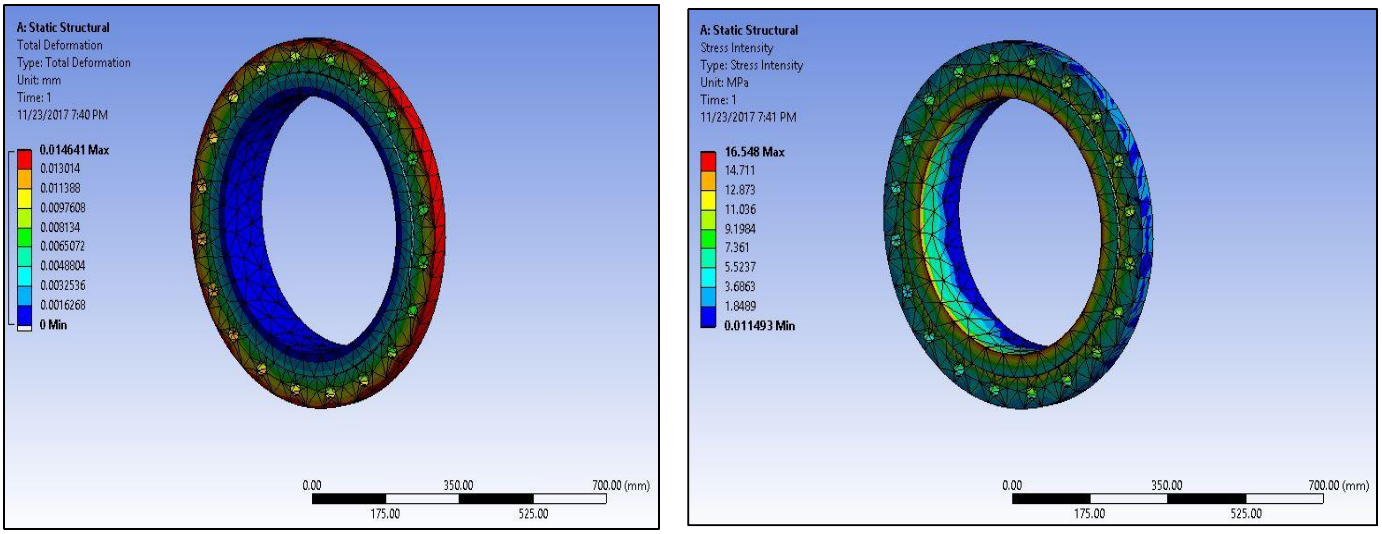

Fig. 2: ANSYS results for standard body flange of 500mm diameter pressure vessel

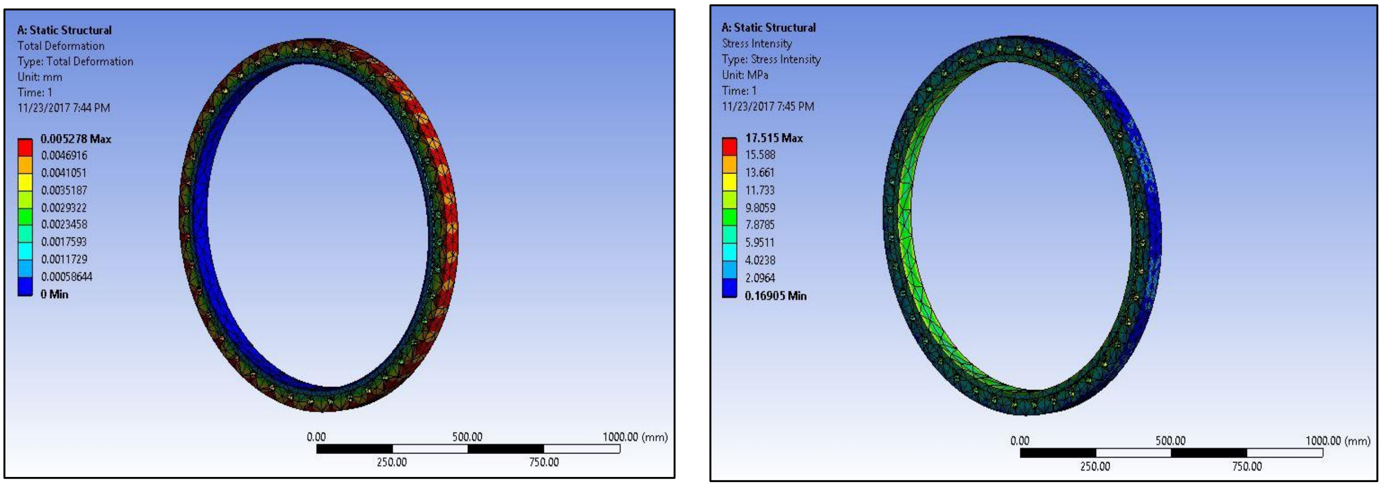

Fig. 3: ANSYS results for non-standard body flange of 1000mm diameter pressure vessel

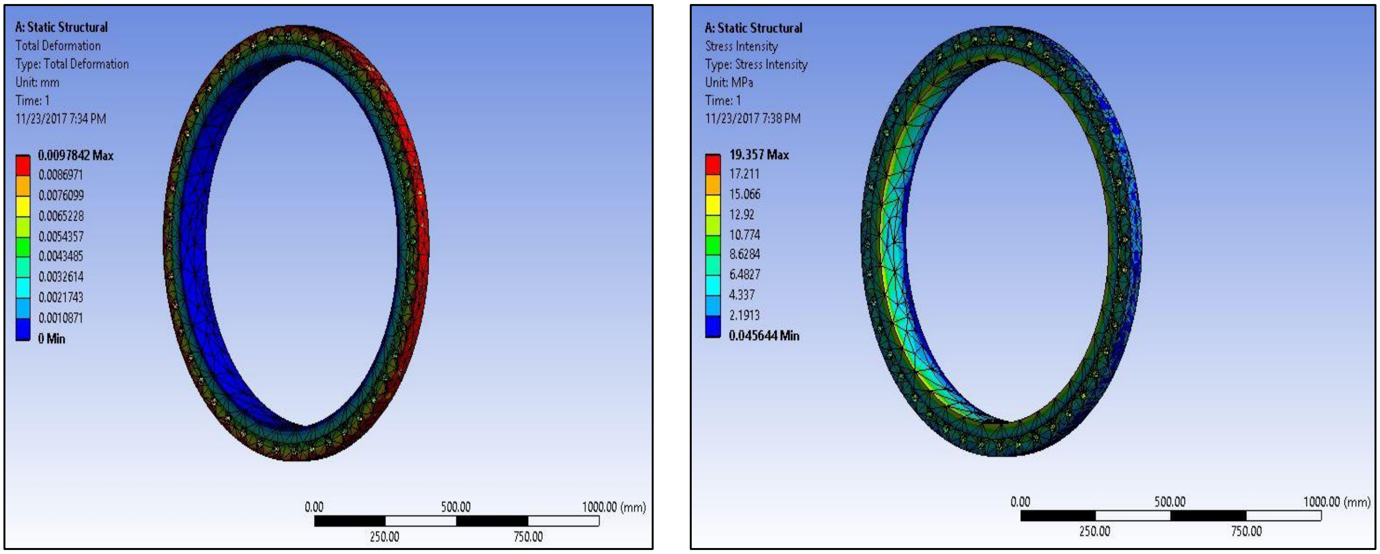

Fig. 4: ANSYS results for standard body flange of 1000mm diameter pressure vessel

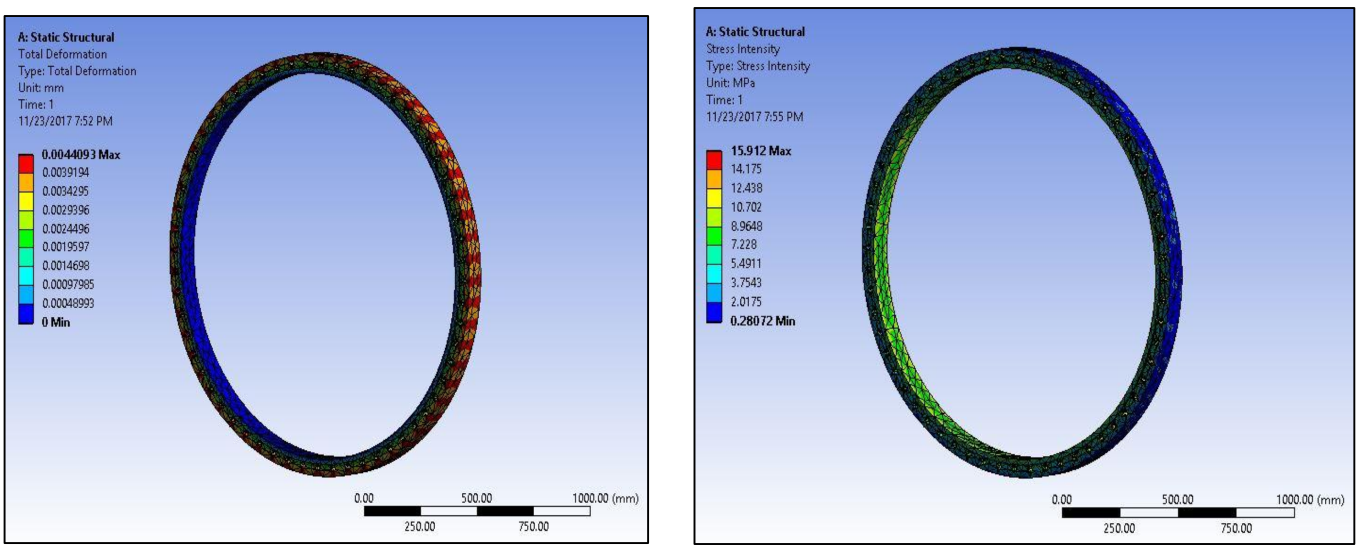

Fig. 5: ANSYS results for non-standard body flange of 1500mm diameter pressure vessel

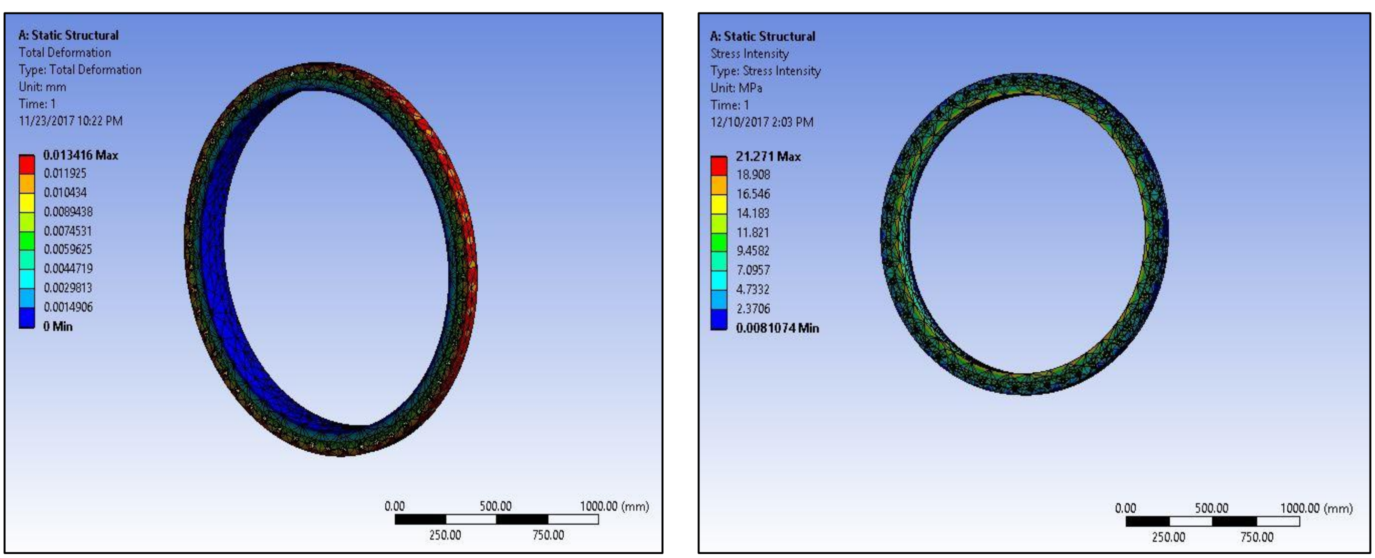

Fig. 6: ANSYS results for standard body flange of 1500mm diameter pressure vessel

B. Difference Between the Result of Non-Standard and Standard Flanges

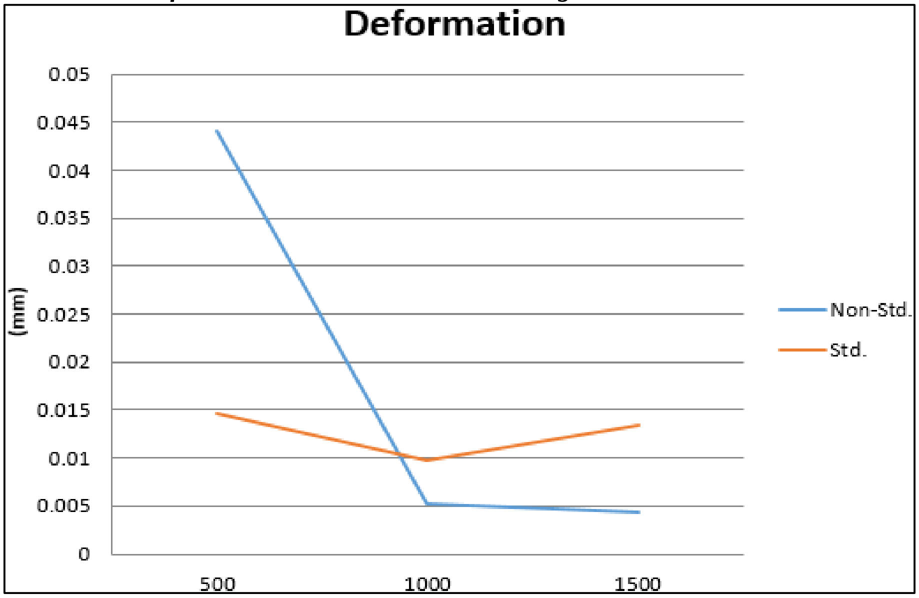

Fig. 7: Difference between the deformation of non-standard and standard flanges

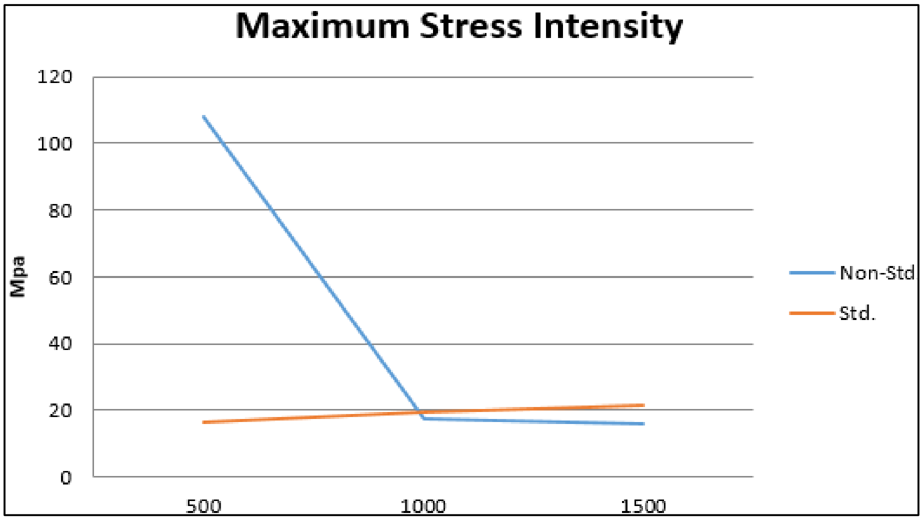

Fig. 8: Difference between the maximum stress intensity of non-standard and standard flanges

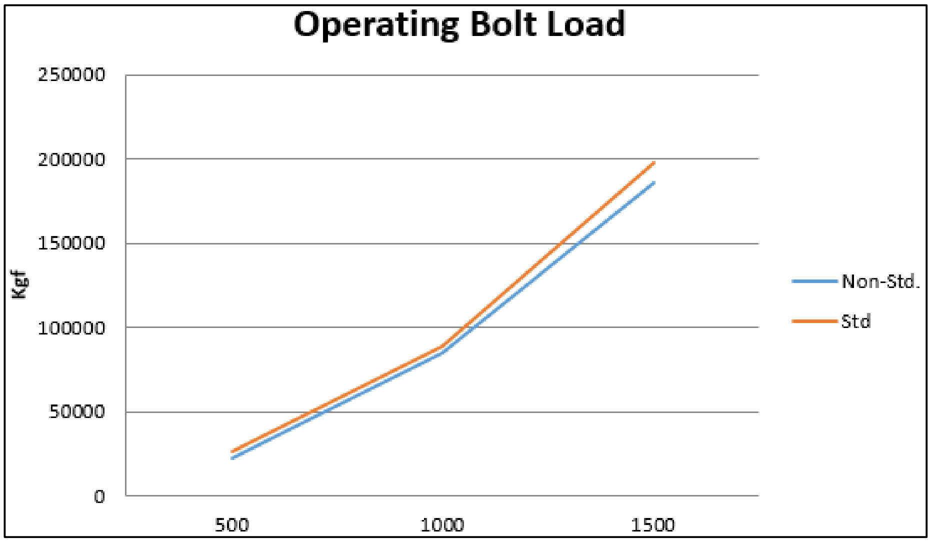

Fig. 9: Difference between the operating bolt load of non-standard and standard flanges

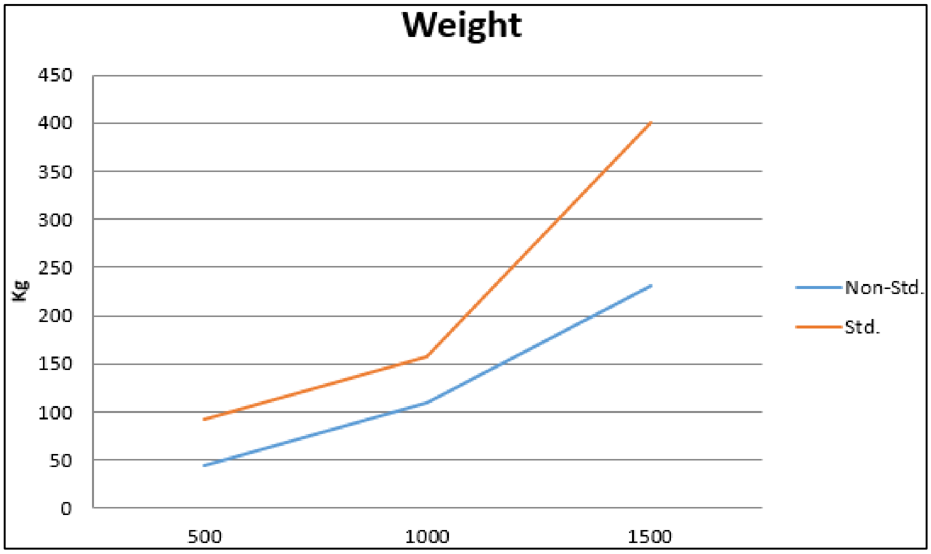

Fig. 10: Difference between the weight of non-standard and standard flanges

V. Conclusion

The objective of the paper is to design, analysis and optimization of non-standard weld neck flange. We developed three practical vessels designs with 500mm, 1000mm, and 1500mm diameter. Complete design was done by Pv-Elite software with both standard and non-standard flanges. After the designing, we analyze all design in ANSYS to figure out local stresses and deformations. We found that at almost same operating bolt load in non-standard flange with diameter 500mm has considerable deformation and stress intensity. Whereas in standard flange, in the same case, there is less deformation and stress intensity. The value of deformation and maximum stress intensity in 500mm diameter non-standard flange was 0.044043mm and 107.8 Mpa respectively and in standard flange value of deformation and maximum stress intensity was merely 0.014641mm and 16.548 Mpa respectively. In other two cases, in both standard and non-standard flanges, there is very small difference in deformation and stress intensity. The operating bolt load is slightly higher in standard flange due to greater bolt circle diameter, which results as the slightly higher deformation and stress intensity in both 1000mm and 1500mm diameter flange. In non-standard flange we required more thickness as compared to standard flange. But if we compare the weight of standard and non-standard flange, we found standard flange is almost double in weight.

VI. Future scope

Pressure vessels always considered as the most crucial and sensitive equipment in industries. Continuous study of all parts of pressure vessels is required to get the optimum and safe design. In future, study can be conducted by taking different pressure and different flange type. Material of flange also effects the flange size, so study can be done on different material also.

References

[1] M. Jadav Hyder, M Asif, "Optimization of Location and Size of Opening in a Pressure vessel Cylinder Using ANSYS". Engineering Failure Analysis .Pp 1-19, 2008.
[2] Joship Kacmarcik, Nedelijko Vukojevic, "Comparison of Design Method for Opening in Cylindrical Shells under Internal Pressure Reinforced By Flush (Set-On) Nozzles". 2011
[3] V.N. Skopinsky and A.B. Smetankin, "Modeling and Stress Analysis of Nozzle Connections in Ellipsoidal Heads of Pressure Vessels under External Loading." Int. J. Of Applied Mechanics and Engineering, Vol.11, No.4, Pp.965-979, 2006
[4] J. Fang, Q.H. Tang, Z.F.Sanga, "Comparative Study of Usefulness for Pad Reinforcement in Cylindrical Vessels under External Load on Nozzle". International Journal Of Pressure Vessel And Piping 86,Pp 273-279, 2009
[5] Pravin Narale, P.S. Kachare , "Structural Analysis Of Nozzle Attachment On Pressure Vessel Design," International Journal Of Engineering Research And Application,Vol.2,Pp 1353-1358 , 2012
[6] James J. Xu, Benedict C. Sun, Bernard Koplik, "Local Pressure Stress on Lateral Pipe-Nozzle with Various Angles of Intersection," Nuclear Engineering and Design 199, Pp 335-340, 2000
[7] Arman Ayobstress , "Analysis Of Torispherical Shell With Radial Nozzle", The Institution Of Engineers, Malaysia, Vol. 67, 2006
[8] V.N. Skopinsky, "Stress in Ellipsoidal Pressure Vessel Heads with Noncentral Nozzle," Nuclear Engineering and Design 198, Pp 317-323, 2000
[9] Jaroslav Mackerle , "Finite Element In The Analysis Of Pressure Vessels And Piping, An Addendum: A Bibliography(2001-2004)," International Journal Of Pressure Vessel And Piping 82, Pp 571-592, 2005
[10] P. Balicevic, D.Kozak, D. Kralievic, "Analytical and Numerical Solution of Internal Forces by Cylindrical Pressure Vessel with Semi-Elliptical Heads". First Serbian Congress on Theoretical and Applied Mechanics Kopaonik, Pp 10-13, 2007
[11] M. F. Hsieh, D.G. Moffat, J. Mistry, "Nozzle In The Knuckle Region Of Torispherical Head: Limit Load Interaction Under Combined Pressure And Piping Loads", International Journal Of Pressure Vessel And Piping 77,Pp 807-815, 2000

[12] 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 ,Vol I , Pp 228-234,(2012)
[13] Shaik Abdul Lathuef, Chandra Sekhar, "Design and Structural Analysis of Pressure Vessel Due To Change of Nozzle Location and Shell Thickness", International Journal of Advanced Engineering Research and Studies, Vol. I, Pp 218-221, 2012
[14] Binesh P Vyas, R M Tayade, "Design Of Vertical Pressure Vessel Using Pvelite Software," International Journal Of Engineering Research And Technology, Vol. 2, Issue 3.
[15] Drazan Kozak, Ivan Samardzic, "Stress Analysis Of Cylindrical Vessel With Changeable Head Geometry," Science Bulletin, Serie C, Vol. XXIII Yogesh Borse, Avadesh Sharma, "Modeling Of Pressure Vessel With Different End Connections Using Pro-Mechanica", International Journal Of Engineering Research And Application, Vol. 2,Pp 1493-1497
[16] Vikram V.Mane, Vinayak H.Khatawate, "Finite Element Analysis of Ellipsoidal Head Pressure Vessel", International Journal Of Engineering Research And Application, (2012)
[17] Ugur Guven, "A Comparison on Failure Pressures Of Cylindrical Pressure Vessels", Mechanics Research Communications 34 466–471, (2007)
[18] Pavo Balicvic, Drazan Kozak, "Strength of Pressure Vessel with Ellipsoidal Heads", Journal Of Mechanical Engineering 5410, 685-692, (2008)
[19] Shafique M.A. Khan, "stress Distributions In A Horizontal Pressure Vessel And The Saddle Supports", International Journal Of Pressure Vessels And Piping 87,Pp 239-244, , (2010)
[20] Bandarupalli Praneeth, T.B.S.Rao, "Finite Element Analysis Of Pressure Vessel And Piping," International Journal Of Engineering Trends And Technology- Volume 3, Issue 5,, (2012)
[21] Drazan Kozak, Ivan Samardzic, "Overloading Effect on the Carrying Capacity of Cylindrical Tank with Tori spherical Heads For The Underground Storage Of Petrol"
[22] M. Pradeep Kumar, K. Vanisree, "Design and Implementation of Circular Cross Sectional Pressure Vessel Using Pro-E and ANSYS", International Journal of Morden Engineering Research, Vol 3, Pp 2350- 2355
[23] L. P. Zick , "Stress In Large Horizontal Cylindrical Pressure Vessel On Two Saddle Support", .The Welding Journal Research Supplement
[24] Nishant M. Tandel, Jignesh M Parmar, "A Review on Pressure Vessel Design and Analysis, - Indian Journal of Research", Vol 3, Issue 4, 2013
[25] Modi A J, Jadav C.S, "Structural Analysis of Different Geometry Heads For Pressure Vessel Using Ansys Multiphysiscs", the 5th International Conference on Advance in Mechanical Engineering. 2011
[26] Hardik B Nayak, R R Trivedi, "Stress Analysis of Reactor Nozzle to Head Junction", International Conference on Current Trend in Technology, Nirma University, 2011
[27] M J Mungla, K N Srinivasan, V R Iyer, "Design and Analysis of A High Pressure Vessel Using ASME Code", Journal of Engineering and Technology, Vol-6, 2013

