Design and Analysis of a Large Opening Nozzle as per ASME Design Code - A Review

Manisha A. Patel[1], Ankit D. Oza[2]

[1]*M.E. CAD/CAM Student, G.T.U/LJIET-Ahmedabad (Gujarat).*
[2] *Assistant Professor, Mechanical Engineering Department, G.T.U/LJIET- Ahmedabad (Gujrat).*

***Abstract*-This paper reviews some of current development of design and analysis of large opening nozzle on cylindrical shell. There are various parameter to design large opening nozzle on shell and check as per principal of American Society of Mechanical Engineering (A.S.M.E.) Sec VII Division – 1.Due to large opening the cylindrical shell are weakened and geometry discontinuity in the shell because of high stress distribution under the required of high steam flow rate, internal pressure, temperature, external axial loads etc. The high stress gradient such zone may cause structure changes, breakage of fibers, microcraking, delamination, changes material behaviour which may lead to fracture of structure members. The stress development is to analysis by using ANSYS, a versatile Finite Element Package.**

Keywords— Large opening nozzle, ASME code, Internal pressure, Temperature, Flow rate, Stress analysis, stress effects.

I. INTRODUCTION

In recent year the use of structure which contain a large opening nozzle on cylindrical shellas shown in fig. 1.also called two intersection of cylindrical shell has continually increasing trend. Many engineering installation now involved such as boilers, reactor pressure vessel, pipe network in chemical plants, off-shore oil drilling tower, Fluid supply system etc. Large opening nozzle in these cylindrical shellbecause of the ratio of nozzle dia. To shell dia. exceed 1/2 and 1/3 that is 0.9 > 1/2 and 0.9 > 1/3 as per ASME pressure vessel design code. The large opening nozzle on shell these geometric discontinuities alter the stress distribution in the neighborhood of discontinuity so that elementarystress equations no longer prevail. Such discontinuities are called “stress raisers” and the regions in which they occurare called the areas of stress concentrations.
There are high stress concentrations which exceed the yield stress value of shell material. In addition, because of complicated shape at the boundary, it is easy in production to form various weld defects. It is necessary to research the behavior of elasto - plastic fatigue in the area of a large opening at the working temperature.

II. STRESS CONCENTRATION

In a cylindrical shell weakened by a large opening, the stress distribution caused by an internal pressure load applied to the shell will differ considerably from that in an un-weakened shell. The maximum stress will be much larger if there is a circular hole in the shell than in the case where there is no penetration. This causes the rise in the stress distribution.
Around the hole, to study the effect of stress concentration and magnitude of localized stresses, a dimensionless factor called Stress Concentration Factor (SCF), is used to calculate the stress rising around hole. The determination of S.C.F includes basic concept of engineering like maximum stress/strain and nominal stress etc. This factor is ratio between the maximum average stress generated in the critical zone of discontinuity and the stress produce over the cross section of that zone.Ktis defined by Eq. (1) is used

$$\mathbf{K_t} = \frac{\sigma max}{\sigma nomi} \quad (1)$$

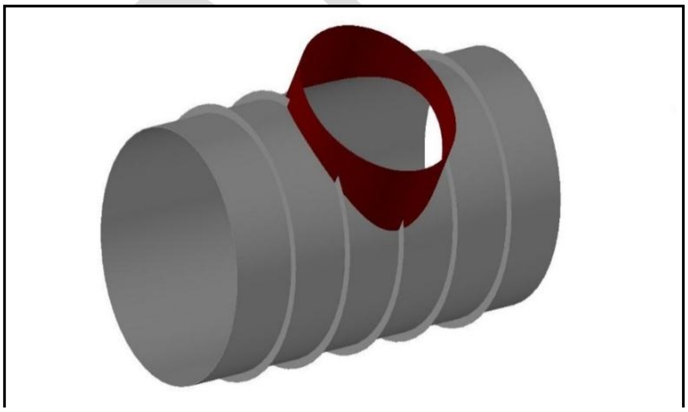


Fig. 1 Large opening nozzle on cylindrical shell

III. REVIEW

To extensive literature survey is carried out for study of large opening nozzle on shell to analysis of stress concentration.

A. Literature Review of Opening on Cylindrical/Shell

Zaid Khan et al [1]they studied about the effect on large opening structure stability of vessel and its design as per ASME Code.The main objective of this paper is to design and analysis the effect on large opening and structure stability of pressure vessels. There are various parameter to design large opening pressure vessels and checked according to the principles specified in American Society of Mechanical Engineering (A.S.M.E) sec VIII Division 1. And various parameter of filter sheet designed vessels and checked according to the principles specified in American Society of Mechanical Engineering (A.S.M.E) sec VIII Division 1. The stress developed in the pressure vessels and tube sheet is to analyzed by using ANSYS, a versatile Finite Element Packageas shown in fig. 2 ANSYS model of nozzle. In this Paper, Thin pressure vessels having a large exhaust opening has been kept very near to the Filter sheet are designed according to the guideline given in ASME code Div I and Div II. Efforts are made in this paper to understand the various stresses in the large opening pressure vessels and design using ASME codes &standards to legalize the design. The ASME has established what have become internationally accepted rules for design and fabrication large openings of pressure vessels. And to determine effect present on the large opening and causes for failure and taking incorporate remedial action in the design to prevent failure.

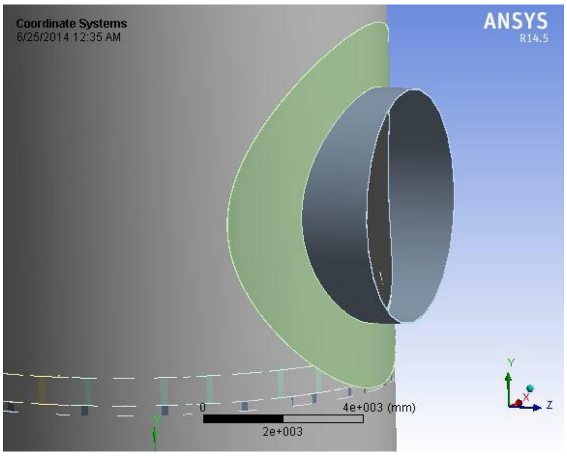
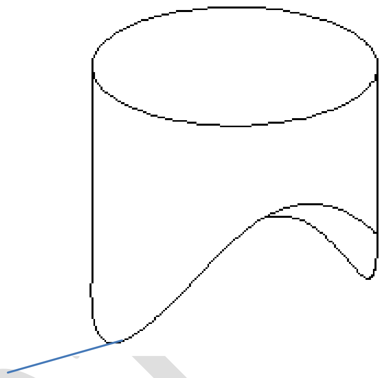


Fig.2ANSYS model of nozzle

K.I. Shnerenko et al [2]they studied about the stress distribution in a composite cylindrical shell With a large circular opening.One of the major and most difficult problems faced in the mechanics of composite shells is the determination of the stress–strain distribution near structural and manufacturing holes, inclusions, and interfaces. Because of high stress gradients,such zones may cause structural changes, breakage of fibers, microcracking, delamination, and large deformation, which may lead to fracture of structural members. Thin-walled shell structures are addressed in. The authors provide formulationsand solution methods for stress problems based on various design models [4, 7] that account for specific features in the deformation of composites. Due to the development of computer technology, the need has arisen for efficient numerical methods intended to solve a wide class oftwo-dimensional problems using the most general design models.Here we solve the stress–strain problem for a deep cylindrical composite shell with a circular opening using thevibrational difference method.This problem is solved by variational difference method and analysis the low shear stiffness region. The end of result is obtained that the stress gradient at the periphery of the increase with its radius.

Ying-Zeng Guo et al [3]they studied about the reliability analysis of the reinforcement of a large opening in pressure vessel.This paper was Experimental results of strain gauge measurements on full scale vessel with large openingare reported. Opening in the cylindrical shell are larger than one-half of the inside diameter of the shells; that is their nozzle radius to shell radius ratio exceed 0.5.In opening deformation located at the tongue root of the nozzle intersecting on shell. The nozzle tongue rootas shown in fig. 3Perspective drawing of the nozzle showing open dermation of tongue root are the main cause of high gradient stress concentration in the area of large opening. The local strain approach is used to predict the fatigue life of a pressure vessel with a large opening. The nominal stress value of all the measuring point can be computed from actually measured strain value.



Tongue root

Fig. 3Perspective drawing of the nozzle showing open dermation of tongue root

M.D. Xue et al [4] authors told about the stresses at the intersection of two cylindrical shells. The stress analysis based on the theory of a thin shell is carried out for two normally intersecting cylindrical shells with large diameter ratio. Here in this paper the modified Morley equation instead of Donnell shallow shell equation which is applicable to$\boldsymbol{\rho_0} = (\boldsymbol{R}/\boldsymbol{T})^{\boldsymbol{1/2}} \gg \boldsymbol{1}$ is used for the analysis of the shell with cut out. In since 1960s Eringen et al. obtained analytical solution based on Donnell shallow shell equation for $\boldsymbol{\rho_0} = (\boldsymbol{r_0}/\boldsymbol{R}) \le \boldsymbol{0.25}$ and $\boldsymbol{\rho_0} = (\boldsymbol{R}/\boldsymbol{T})^{\boldsymbol{1/2}} < 1$, where r_0 and R are radii Of the nozzle and the vessel respectively and T is the thickness of the vessel. In this equation the error was present so in this paper the solution shell with cut – outs has been improved and extended to the

case of shell with attached nozzles. The results obtained by present method are in agreement with those from the finite element method (FEM) and experiments for $\boldsymbol{\rho_0} \le \boldsymbol{0.8}.$ the results have been verified upto **d/D = 0.8.**

Mani N Thanigaiyarasu et al [5]in this paper authors represent the **s**tress analysis of Steam Generator shell nozzle junction for sodium cooled fast breeder reactor. The Steam Generators (SG) decides the capacity factor in Sodium cooled Fast breeder Reactor (SFR) plants and hence they are designed with high reliability. One of the critical locations in SG is the shell nozzle junction. This junction is subjected to an end bending moment and internal pressure. Since the shell nozzle junction is the critical location of SG a double-ended guillotine rupture will result in leakage of large quantity of sodium, which is not desirable. safetyrequirements demand that Leak Before Break criteria with assumed initial flaw have to be demonstrated. To demonstrate LBB, the basic requirement is topredict the state of stress precisely in the shell nozzle junction under various loading conditions. An efficient finiteelement modeling for shell nozzle junction has been presented in which shell elements are employed to idealize thewhole region. These results are used for the analysis of leak before break concept. The shell nozzle junction model is analyzed with three load cases as given in table 1. Three locations are considered like extrados, crown and intrados and for each location, three layer stresses are calculated. The von mises stress values are plotted in the form of graph by taking von mises stress in y-axis and the angles around the circumference in x-axis. Half symmetry model is taken for analysis. 0o indicates the value in the extrados and 90o indicates the values in the crown and 180o indicates the value in the intrados. From the results of analysis, it can be observed that the maximum stress occurs at the junction of pull out region and the nozzle and maximum displacement occurs in the middle of pullout region. High stress concentration is developed at this location due to abrupt change in the geometry and the consequent change in stress flow. In this location, the crack is formed and can do further analysis.

V.N. Skopinsky et al [6]Modeling and stress analysis of nozzle connections in ellipsoidal heads of pressure vessels under external Loading. Timoshenko shell theory and the finite element method are used. The features of the structural modeling of ellipsoid-cylinder shell intersections, numerical procedure and SAIS special-purpose computer program are discussed. A parametric study of the effects of geometric parameters on the maximum effective stresses in the ellipsoid-cylinder intersections under loading was performed. The results of the stress analysis and parametric study of the nozzle connections are presented. Results show that it is necessary to pay more attention to the effective stresses in the shells in these loading cases. Although the stresses due to the external loadings are secondary stresses with respect to primary stresses from the internal pressure, these stresses should be taken into consideration in a complete stress analysis for nozzle connections of a pressure vessel.

B. Literature Review of Stress Concentration Factor aroundOpening

Avinash Kharat1 et al [7] Stress Concentration at Openings in Pressure Vessels. From this paper is cleared that study of the effect of change in size, position, location of the opening in pressure vessel to study the stress concentration is essential. Such problem was suggesting use of DBA (Design By Analysis) that includes no-linearity. This approach is helpful seen that the Finite Element Method is efficient method to use as compare the analytical and experimental results to use for simulating the effect.

Aleksandar petrovic [8]Stress analysis in cylindrical pressure vessel with load applied to the free end of nozzle.Author applied a finite element method was determine the state of a stress in the cylindrical shell.The purpose of this paper is to investigate and determined the influence of forces that can act on a nozzle , in cylindrical pressure vessel . The case when nozzle , in the form of cylindrical pipe is fixed to the cylindrical shell in such a way that the nozzle axis forms an angle between 0° to 90° with a tangent to the cylindrical shell was investigated. the envelopes use to algebraic function were determination of these maximum stress value. And also used to comparison of as experimental method of strain gauge as strip used to determined a maximum stress region. The stress value obtined from the algebric function were within -12.5 and +12.8% of those from finite elements. The defference between stresses deduced from strain guage reading on experimental and calculated stresses was maximum of 12%.

P Makulsawatudom et al [9] presented work on elastic stress concentration factors (SCFs) for internally pressurized thick cylindrical vessels with radial and offset circular and elliptical crossholes. Three forms of intersection between the crosshole and main bore are considered: plain chamfered and blend radius. The minimum SCF was found to occur for the plain intersection configuration, with the peak stress at the crotch corner between the main bore and crosshole on the longitudinal plane of symmetry. Incorporating a chamfer or blend radius at the intersection reduces the stress concentration at the main bore but introduces higher peak stress elsewhere in the chamfer or blend region. The finiteelement analysis parametric investigation confirmed the well-known result that the SCF is reduced when the intersection between the crosshole and main bore surface has an elliptical profile. The radial elliptical crosshole reduces the SCFs significantly but in general leads to greater manufacturing cost. The offset circular crosshole, which is cheaper and easier to construct, also reduces the stress concentration effect although the reduction is less than that of an elliptical crosshole. The investigation considered two relatively small openings, typical of instrumentation tapping, bursting caps or fluid entry/exit ports in thick high-pressure vessels. Overall, the stress concentration effect was greater for the smaller hole, although the difference was only about 5%. When the effect of crosshole end-cap thrust was considered, the SCF did not change significantly but was slightly alleviated.

IV. SUMMARY OF THE LITERATURE REVIEW

Form the literature review it is seen that ASME providing solutions for more general cases and requires higher factor of safety. Also limit load and stress concentration formulae are not available for nonstandard shapes and intersections and geometrical discontinuity. The code does not consider for openings in thin shell but some researchers have shown that openings in thin shell are changing stress concentration value by considerable amount.

Most of research is study about evaluatedmaximum stress concentration factor region and effect of geometry discontinuity around the intersection of neighborhood region with help analysis of finite element method used. Some paper was analysis the limit of opening size on shell with cut-outs. Most of them have used parametric method to study the effect of the different design parameter like thickness, diameter of the nozzle and cylindrical/shell, opening size. Most of the research have used experimental method(stain gauge strip) in which the results are obtained directly.

From above discussion it is cleared that study of the effect of change in size, position, location of the openings in pressure vessel to study the stress concentration is essential. The position and location of the opening on cylinder is not studied in past by researchers and there is no code provision for such design. For such problems codes are suggesting use of DBA (Design by analysis) that includes non-linearity. Majority of research have preferred design by analysis than design by code. This approach is helpful in simulating the exact mode of failure in pressure vessel. From the above literature it is also seen that the finite element method was used by most of the researchers to compare the analytical and experimental results. So it is clear that finite element method is the efficient method to use for simulating the effect.

V. CONCLUSIONS

Stress concentration is one of the most important factors to be studied in the cylindrical shell opening. Form this critical literature review we can conclude that there is wide applicability of finite element analysis in ANSYS 14.5 and design calculation as per ASME codeand inPVElite 2014 software validation the calculations ofthe large opening nozzle on cylindrical shell. This evaluated the maximum effected region to induced stress concentration factor and reducing effect same and quality will be increase.

ACKNOWLEDGMENT

Behind every achievement lies an unfathomable sea of gratitude to those who actuated it, without them it would never have into existence. To them we lay the word of gratitude imprinted within us.

- First and foremost, I am grateful to God for giving me good health throughout the period I was working on my project.
- I owe my thanks to the Mr. Ankit D. Oza for providing with all facilities to work on my project successfully. For his encouragement, support and time for guiding me throughout this work. I am very much grateful to him for his constructive criticism and suggestions throughout the duration of my work.
- Also, I take this opportunity to convey my sincere thanks to the Head of the Department Prof.Prexa H. Parikh, M.E., Ph.D.(Pursuing) and Mr. R. S. Khanna, M.E. without whom mywork would have been a distant reality. I would like to express my warm acknowledgement and my sincere thanks to my industrial guide Mr. Nirav Gajjar, (Design Engineer) Chem Process System Pvt Ltd, Ahmedabad. Throughout this work and my respects and love to my mom and allother family members and friends for their love and encouragement.

REFERENCES

[1]. Zaid Khan, Kadam G.A, V.G Patil (Jun 2014). Review on effect on large opening structure stability of vessel and its design as per ASME Code.*International Journal of Engineering Trends and Technology (IJETT)*, **12 (8)**.

[2]. K.I. Shnerenko, V.F. Godzula, (2003).Stress Distribution ina Composite Cylindrical Shell with a Large Circular Opening.*International Applied Mechanics*,**39 (11)**.

[3]. Ying-Zeng Guo, Zaho-Jing Zeng, (1994).A reliability analysis of the reinforcement of a large opening in a pressure vessel.*Int. J. Pres. Ves. & Piping*, **57**, 85-89.

[4]. M.D. Xue, W. Chen, K.C. Hwang (1995).Stresses at the intersection of two cylindrical shells.*Nuclear Engineering and Design*, **154**, 231-238.

[5]. Mani N Thanigaiyarasu, G Chellapandi P. (2010). Stress Analysis of Steam Generator Shell Nozzle Junction for Sodium cooled Fast Breeder Reactor. *International Journal of Engineering Science and Technology*, **2 (7),** 2690-2698.

[6]. V.N. Skopinsky and A.B. Smetankin (2006). Modeling and stress analysis of nozzle connections in ellipsoidal heads of pressure vessels under external loading.*Int. J. of Applied Mechanics and Engineering*, **11 (4)**, 965-979.

[7]. AvinashKharat, V. V. Kulkarni2 (March 2013). Stress Concentration at Openings in Pressure Vessels – A Review. *International Journal of Innovative Research in Science, Engineering and Technology*, **2** (3).

[8]. Aleksandarpetrovic (2001). Stress analysis in cylindrical pressure vessel with load applied to the free end of a nozzle. *International Journal of Pressure Vessel and Piping*, **78**, 485-493.

[9]. P Makulsawatudom, D Mackenzie and R Hamilton (2004). Stress concentration at crossholes in thick cylindrical vessels. The Journal of StrainAnalysis for Engineering Design, Vol. 39, PP 471-481.