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"A REVIEW PAPER ON PRESSURE VESSEL DESIGN & ANALYSIS USING FEM METHOD"

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ABSTRACT

This paper reviews some of the developments in the determination of stress concentration factor in pressure vessels at openings, stress analysis of different types of end connections and minimization stress with the help of optimize location and angle of nozzle on shell and head. The literature has indicated a growing interest in the field of stress concentration analysis in the pressure vessels. The motivation for this research is to analyze the stress concentration occurring at the openings of the pressure vessels and the means to reduce the effect of the same. Design of pressure vessels is governed by the ASME pressure vessel code. The code gives for thickness and stress of basic components, it is up to the designer to select appropriate analytical as procedure for determining stress due to other loadings. In this paper the recent and past developments, theories for estimation of stress Concentrations are presented and the scope for future studies is also presented.

KEYWORDS : *Pressure Vessel, ANSYS, PVElite Software, PRO-E, Mechanical Stresses, ABAQUS*

I. INTRODUCTION

A pressure vessel is a container designed to hold gases or liquids at a pressure substantially different from the ambient pressure. The pressure differential is dangerous, and fatal accidents have occurred in the history of pressure vessel development and operation. Consequently, pressure vessel design, manufacture, and operation are regulated by engineering authorities backed by legislation. For these reasons, the definition of a pressure vessel varies from country to country, but involves parameters such as maximum safe operating pressure and temperature, and are engineered with a safety factor, corrosion allowance, minimum design temperature (for brittle fracture), and involve nondestructive testing, such as ultrasonic testing, radiography, and pressure tests, usually involving water, also known as a hydrotest, but could be pneumatically tested involving air or another gas. The preferred test is hydrostatic testing because it's a much safer method of testing as it releases much less energy if fracture were to occur (water does not rapidly increase its volume while rapid depressurization occurs, unlike gases like air, i.e. gasses fail explosively). In the United States, as with many other countries, it is the law that vessels over a certain size and pressure (15 PSI) be built to Code, in the United States that Code is the ASME Boiler and Pressure Vessel Code (BPVC), these vessels also require an Authorized Inspector to sign off on every new vessel constructed and each vessel has a nameplate with pertinent information about the vessel such as maximum allowable working pressure, maximum temperature, minimum design metal temperature, what company manufactured it, the date, its registration number (through the National Board), and ASME's official stamp for

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pressure vessels (U-stamp), making the vessel traceable and officially an ASME Code vessel.

Figure.1

II. LITERATURE SURVEY

In this section research papers are discussed related to the present work. Published papers are highlight in this section.

Josip Kacmarcik, Nedelijko Vukojevic and Fuad Hadzikadunic[2] etc concluded that comparison show good agreement between the stress concentration factor determined with two different method, here two different method strain gauge with experimental set-up and finite element analysis with ABAQUS software are used for two different nozzle geometries investigation, here two stress concentration factor defined by maximum principal stress and maximum von-Mises stress are calculated by strain gauge measurement and compared with ABAQUS software, in this paper nozzle external radius are different C_1 Nozzle has higher radius then C_2 nozzle, but both nozzle have same thickness of vessel wall and external radius of a vessel, in this paper only 1/8 of the vessel part and ¼ of nozzle part is modeled because it is possible to defined three symmetry planes and here as a mesh generation 3D tetragonal elements are implemented, stress concentration factor is obtained by the value of stress(principal and von Mises) obtained via FEM analysis and strain gauge measurement, when compared both method it is shown that the maximum deviation of 15.5% is acceptable for engineering application of stress concentration factor and FEM analysis is very reliable enough for determining stress concentration factor in pressure vessel design. And this research also show advantages of FEM analysis in possibility to determine stresses on vessel internal side that can be greater than external stresses which is very difficult for strain gauge measurement.

V.N. Skopinsky, A.B. SMETANKIN[3] presented work on modeling and stress analysis of nozzle connection in Ellipsoidal head of pressure vessel under external loading, in this paper he used Timoshenko shell theory and the finite element method, the effect of stress concentration in external loading has more effect than in the internal pressure, there is an appreciable increase of the maximum stress for shell in the interaction region even at the small level of nominal stress, non-radial and offset connection have non-uniform distribution of stress on the interaction curve between the nozzle and the head, the influence of angular parameter α for non-radial nozzle connection is shown in this paper, a decrease of maximum effective stress as an angle α increase is more significant for non-central connection, and in case of torsional moment loading, the angle affects the stress in opposite manner, the stress in the shell increase as alpha angle increase.

J. Fang,Q.H.Tang[4] etc presented work on a comparative study of strength behavior for cylindrical shell interaction with and without pad reinforcement under out-of-plane moment loading on nozzle, three pairs of full-scale test vessel with different mean diameter of nozzle to mean diameter of cylindrical vessel ratio were designed and fabricated for testing and analysis ,the material of the cylinder, reinforcement pad and the nozzle are low carbon steel, result from this research indicate that the maximum elastic stress and stress ratio are reduced by pad reinforcement, they found that in test reduction rate is 20-60% and in finite element analysis reduction rate is 28-59% and its rate of reduction depend upon structure and dimension of the vessel for example D/d ratio, and result also indicate that the plastic limit of nozzle in cylinder vessel is increased by pad reinforcement, generally rate of increase is about 40-70% from test and its larger than 40% from finite element analysis, so the conclusion given from the result that the reinforcement structure are useful under static external load on nozzle.

Pravin Naral and P S Kachare[5] presented work on structural analysis of nozzle attachment on pressure vessel design, they said if the nozzle is kept on peak of the dished end it do not disturb the symmetry of the vessel, but if it is placed on the placed on the periphery of the vessel, it may be disturb the symmetry of the vessel. Size, diameter, angle, etc of nozzle connection may significantly vary even in one pressure vessel, these nozzle cause geometric discontinuity of vessel wall, so a stress concentration created around a opening, the junction may fail due to high stress ,so detailed analysis is must be required, in this paper conduct a study analysis, what will be the effect of the nozzle angle and increase number of nozzle on the periphery of pressure vessel until the symmetry is achieved, and find out optimum angle such that the stress are maintained within limits. in this paper first one nozzle placed on top on shell and calculated stresses with finite element analysis, then two nozzle placed with angle 60 degree from each other, then again two nozzle placed at angle 90 degree from each other, then also again two nozzle placed at angle 180 degree from each other ,then three nozzle placed at angle 60 degree from each other, then again three nozzle placed at angle 90 degree from each other, then four nozzle placed at angle 60 degree and again four nozzle placed at 90 degree from each other and calculated stress from ANSYS software ,from this study they found the result that peak stresses for symmetrical nozzle attachment is lowest than the others and stress increment factor for symmetric nozzle attachment is lower than other, here the stress value is minimum at two nozzle which is placed at angle 180 degree and four nozzle placed at angle 90 degree from each other, this state that the symmetry nozzle attachment had always lower stress than others.

James j Xu, benedict C. Sun, Bernard Koplik[6] had did work on local pressure stress on lateral pipe-nozzle with various angle of interaction, this paper report variation of local pressure stress factor at the junction of pipe-nozzle when its angle varies from 90 to 30 degree, the circumferential and longitudinal stress at four symmetric points around the pipe-nozzle junction are plotted as function of an angle, the ALGOR finite element software was employed to model for the true pipe-nozzle geometry, the numerical stress result come from parameters beta and gamma which are the nozzle mean radius and pipe thickness, at angle 90 degree at this angle result had low value local stress, these stress increase as angle of interaction is decrease from 90 degree and stress value more decrease when angle is decrease from 45 degree, the inside crotch point B has worst circumferential stress value, and concluded that angle 90 degree local pressure stress are same at point A and B as same as point C and D due to symmetry. And it had low stress value than other angle

Amran Ayob[7] worked on stress analysis of torispherical shell with radial nozzle, in this paper experimental reading was taken with help of 0.0625-inch foil string gauge which was bonded to the outer and inner surface of the shell, the model was instrumented with 39 pairs of 0.0625-inch foil strain gauge, these gauge was located between S=-0.1 to S=0.5 in the meridional direction. The experimental result used here is the part of test programmer carried out by drabbles to determine the shakedown behavior of a torispherical vessel with nozzle, under action of internal pressure, thrust and bending moment applied to the nozzle. There are three interacting geometric location which could influence stress field, the maximum stress could occur any of sphere-nozzle, sphere-knuckle and cylinder-knuckle junction the graph of the elastic stress factor distribution along meridional plane due to four load case shown in this paper, the crotch corner and the weld-crown region are the highest stress area with ESF approximately 2,

V. N. Skopinsky[8] had worked on stresses in ellipsoidal pressure vessel heads with noncentral nozzle, the objective of this paper is more investigation of shell intersection problem, the shell theory and finite element method are used for stress analysis of nozzle connections in ellipsoidal heads of the pressure vessel, here nozzle is considerably displaced on ellipsoidal head from head axis is considered in this paper, the feature of numerical procedure, structural modeling of nozzle-head shell intersections and SAIS special-purpose computer program are discussed. The result of stress analysis and parametric study of ellipsoidal vessel head with a noncentral nozzle under internal pressure loading are presented, in many practical design, the nozzle is placed at a relatively large distance from the head axis. Special consideration of these case is given in this analysis, this stress analysis result better understanding of this poorly investigated problem and give the possibility of achieving a more reliable design of nozzle connections on the pressure vessel heads, also the SAIS program can be used for design optimization purpose e.g. nozzle location finding.

Jaroslav Mackerle[9] had worked on bibliographical review of finite element method(FEMs) applied for the analysis of pressure vessel structural/components and piping from the theoretical as well as practical points of view, he searched paper contains 856 reference to papers and conference proceeding on the subject that were published in 2001-2004, he found papers those are classified in the following categories: linear and nonlinear, static and dynamic, stress and deflection analysis, stability problem, thermal problem, fracture mechanics problem, contact problem, fluid-structure interaction problem: manufacturing pipe and tube: welded pipe and pressure vessel components: development of special finite element for pressure vessel and pipes, finite element software and other topics, and he found that linear and nonlinear, static and dynamic, static and deflection analysis and fracture mechanics problem had various topic in pressure vessel and piping.

Balicevic, D Kozak, D. Karlievic[10] presented work on ANLYTICAL and NUMERICAL solution of internal forces by cylindrical pressure vessel with semi-elliptical heads, in this paper the solution for internal forces and displacement in the thin-walled cylindrical pressure vessel with ellipsoidal head using general theory of thin walled shell of resolution have been proposed, distribution of the forces and displacement in thin walled shell are given in mathematical form, finite element analysis of the cylindrical vessel with semi-elliptical head has been done by using ANSYS 10 code for to confirms analytical solution, here ellipsoidal head model made as axi-symmetric problem to avoid bending effect on the contact between heads and cylinders and author concluded principal stresses calculated analytically are very close to the finite element result(the difference is less than 3%)

M F hsieh, D G Moffat, J mistry[11] had worked on nozzle in the knuckle region of a torispherical head, in this paper limit load interaction plot for pressure Vs nozzle axial force, in-plane moment, out-of-plane moment and for in-plane moment versus out-of-plane moment are also present, here six model included with nozzle offset location nozzle offset/vessel outer diameter in present study, model 1 is the ax symmetric case with nozzle located in the center of the crown, the model 3 offset the outermost weld location is at crown/knuckle junction and in this work FE model was created with using PATRAN mesh generation program and stress analysis work was done by using ABAQUS program, they concluded that the nozzle has very little influence on the limit pressure of the head, even when it is located in the knuckle region of the head, for external load applied to the nozzle, the effect of increasing the offset is to increase the limit loads.

B.S.Thakkar and S.A.Thakkar [12] did a case study and put efforts to design the pressure vessel using ASME codes & standards to legalize the design. The performance of a pressure vessel under pressure can be determined by conducting a series of tests to the relevant ASME standard in future scope they have mentioned Design of pressure vessel in PVELITE software can be accrue. Further FEA analysis can be done to verify the above design procedure, they concluded that the design of pressure vessel is more of a selection procedure, selection of its components to be more precise rather designing of every components, pressure vessel components are selected on the basis of available ASME standard and the manufactures also follow the ASME standard while manufacturing the components so that leaves designer free from designing the components. This aspect of design greatly reduce the development time of new pressure vessel, it also allows the designer to keep free from multiple prototype for pressure vessel before finalizing the design, here standard part are used so it reduce time for replacement so less overall cost.

Shaik Abdul Lathuef and K.Chandra Sekhar [13] discusses some of the potential unintended consequences related to Governing Thickness of shell as per ASME. Here have a scope to change the code values by take the minimum governing thickness of pressure vessel shell to the desired requirements and also relocate of nozzle location to minimize the stresses in the shell. In this paper nozzle located at five places and analysis with ANSYS here nozzle locates at shell left end, at the shell middle, at the shell right end, at dished end of both side and calculate stress. And they found from result that the stress would be Minimum at the dished end with hillside orientation. A low value of the factor of safety results in economy of material this will lead to thinner and more flexible and economical vessels. Here we evaluated the stress in the vessel by Zick analysis approach.

Binesh P Vyas, R. M. Tayade[14]concluded that Design of pressure vessel by using PVElite gives accurate analysis result and also reduces time .A vertical pressure vessel has been designed using graphical based software named PVElite. For designing of vertical leg supported pressure vessel some input parameters like volume, inside diameter, design pressure (either inside pressure or external pressure), temperature, material, processing fluid. Etc. is required. PVElite gives thickness of shell, thickness of head, height of head, thickness of nozzle, manhole, PVElite calculate local stress according to welding research council. (WRC) 107, further research need to explore environmental parameter such as earthquake, thermal load, fluctuation load and so on.

Dražan Kozak Ivan Samardžić [15] etc had worked on stress analysis of cylindrical vessel with changeable head geometry, The main objective of this paper is numerical analyses of cylindrical pressure vessel with changeable head geometry (semi-elliptical and hemispherical heads) and comparison of results in means of precision and time needed for getting the solution, comparison of analytical and numerical results for pressure vessel with hemispherical heads is shown, In this paper a numerical analysis of pressure vessel with hemispherical and semi-elliptical heads is performed, with three types of elements: SOLID 95, PLANE 183 and SHELL 181. It is concluded that in both cases of pressure vessel heads, using of PLANE 183 element presents the best approach, because of minimal number of elements for meshing, shortest calculation time, this type of axsymmetric element could be recommended in such cases, when the total symmetry of model is considered.

V. CONCLUSION

From the literature review it is seen that ASME and other code are providing solutions for more general cases and required higher factor of safety, also limit load and stress concentration formulae are not available for non standard shape and intersection and geometrical discontinuity, most of researcher have worked in thin-pressure vessels and there is scope in studying the opening in thick pressure vessel, from above discussion it 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, the position and location of the opening on cylinder is not studied in past by researcher, Finite element analysis is an extremely powerful tool for pressure vessel. A structural analysis of the high pressure vessel will be implemented. The maximum load on a saddle may be conservative or liberal, depending upon the value of the ratio A/L used. Furthermore, the design of the saddle structure. Stress concentration is one the important of opening, factors to be studied in the pressure vessel A review of the literature related to the stress concentration at opening in pressure vessel is presented, also the effect of the end cover on the

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position and size of the opening needs to be studied.

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