Survey on Pressure Vessel Using Finite Element Method

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Abstract- *Pressure vessels are a commonly used device in marine engineering. Until recently the primary analysis method had been hand calculations and empirical curves. New computer advances have made finite element analysis (FEA) a practical tool in the study of pressure vessels, especially in determining stresses in local areas such as penetrations, O-ring grooves and other areas difficult to analyze by hand. This project set out to explore applicable methods using finite element analysis in pressure vessel analysis.*

Keywords- FEM, Presser vessel, Pressure, fuel, Boundary conditions

I. INTRODUCTION

The term pressure vessel referred to those reservoirs or containers, which are subjected to internal or external pressures. The pressure vessels are used to store fluids under pressure. The fluid being stored may undergo a change of state inside the pressure vessels as in case of steam boilers or it may combine with other reagents as in chemical plants. Pressure vessels find wide applications in thermal and nuclear power plants, process and chemical industries, in space and ocean depths, and in water, steam, gas and air supply system in industries. The material of a pressure vessel may be brittle such as cast iron, or ductile such as mild steel.

Pressure vessels have been in wide use for many years in chemical, petroleum, military industries as well as in nuclear power plants. They are usually subjected to high pressures and temperatures which may be constant or cycling. Factors such as vessel material, the shape, chemical composition and physical substances used in it, the environment of vessels and etc. all are factors which each can have different effects on performance of pressure vessels. The fluid being stored may undergo a change of state inside the pressure vessel as in case of steam boilers or it may combine with other reagents as in a chemical plant. The pressure vessels are designed with great care because rupture of pressure vessels means an explosion which may cause loss of life and property. The material of pressure vessels may be brittle such that cast iron or ductile such as mild steel. Cylindrical or spherical pressure vessels (e.g., hydraulic cylinders, gun barrels, pipes, boilers and tanks) are commonly used in industry to carry both liquids and gases under pressure. When the pressure vessel is exposed to this pressure, the material comprising the vessel is subjected to pressure loading, and hence stresses, from all directions. The normal stresses resulting from this pressure are functions of the radius of the element under consideration, the shape of the pressure vessel as well as the applied pressure.

II. LITERATURE SURVEY

Sadanandam et al.(2017) Pressure vessel is used to carry liquids such as petrol, kerosene, aviation fuel etc and these fuel tanks are used to transport fuel. Finite element method is a mathematical technique used to design a fuel carrying vessel and performing the stress analysis. In this the geometrical model is created and the model is sub divided into smaller elements. It is subjected to internal pressure and these Boundary conditions are applied at specified points. The aim of this paper is to design a model and analysis of fuel carrying tank using finite element analysis software and also select a proper material composition for pressure vessel. Designing is validated according to maximum principal stress theory and Distortion theory by taking design factor or factor of safety. The comparisons also made between the calculation results and software results.

Santra et al.(2016),A pressure vessel is a closed container designed to hold gases or liquids at a pressure and temperature substantially different from ambient pressure and temperature. The cross-section of the pressure vessel may be circular or square with flat end covers, reinforced by a gate mechanism on both sides. In the present study the vessel has been optimized for shape for both circular and square sections by considering stress level on the shell areas and comparative heat losses for cylindrical and square cross sectional pressure vessel has also been presented. The pressure vessel designed as per the ASME code Section VIII and then checked for the stress patterns across the walls of vessel for the applied pressure and temperature. The complete analysis i.e. pressure and thermal tests are carried out using FEA based software

platform (Solidworks 3D design & Analysis platform). At first on the basis of observation it has been tried to compare the validity of pressure vessel shape. Then tried to reduce the thickness of the shell by applying the same amount of load, so as to obtain an optimal thickness of pressure vessel. Thus observing both the results we have come to a conclusion to decide the most valid shape & thickness of shell required for an optimal pressure vessel. The literature survey indicates that so far many works has been done on different topics & subjects related to pressure vessel optimization by FEA based technique of analysis, but there are very few works done to compare the optimality of shape of pressure vessel shell by FEA analysis. The discussion on the results, conclusion & the scope of further work has also been manifested at the end ofthe work.

Suresh et al.(2018) The improvement in the area of various types of composites revolutionized and brought many changes inthe areas of engineering products, manufacturing processes, material processing for various applications, industrial equipment manufacturing, aerospace parts and vehicles manufacturing, defense applications, etc. Due to their light weight and high strength to weight ratio, their applications in the manufacturing of pressure vessels also increased but are limited to small-scale only due to the production cost of the composites. In order to produce the composites at low cost which can meet the standards of the materials used for pressure vessel construction and to sustain at working conditions of pressure vessels such as high pressure and temperature this paper aims at developing an epoxy composite reinforced with recycled ceramics particles and analyses the pressure vessel using the properties of the prepared composite using simulation studies and by using Finite Element Analysis (FEA).The Recycled Ceramic Reinforced Composite sample is made and tested in the laboratory for its properties. These obtained properties are assigned in simulation package and the analysis is carried out. The design of pressure vessel is carried out in Solidworks Part Design and the finite element analysis (FEA) and simulations are carried out in Solidworks Simulation.

Hussain et al.(2016),A pressure vessel is a container used to store substances at more than 15 psi, it can with stand greater than m normal amounts of pressure without bursting. Those are used to contain a multitude of substances including air, water, chemicals, nitrogen, and fuel. They are used in paper and pulp, energy, chemical industries, food and beverage. The objective of present work is to design a pressure vessel whose sole purpose is to withstand the pressure of the substance stored in it. Modeling is have been arrived by analytical calculations. The shell is analyzed for the Von-Mises and the shear stresses induced in the plate, finally the analytical calculations and the values obtained by analysis are compared. The Von-Mises stress induced in the bolt material is573.04MPa, which is less than the maximum stress i.e.680MPa. Hence it is found that the design is safe. The shear stress induced in the plate is 30MPa, which is less than the allowable stress in the plate material.

Manish et al.(2013) This paper presents the work carried out for determination of stresses in an open ended pressure vessel of elliptical shape. In some situations, due to the limited space available, exit pipes are made of ellipticalor obround shape. In this study, the stresses in the elliptical pressure vessel are determined using finite element method. The material of the vessel is aluminum alloy. Internal pressure is applied to the vessel. Software ANSYS‟ is used for modeling & analysis purpose. Considering the symmetry about both axes, only quarter model is prepared. PLANE82 elements are used for the analysis. Firstly analysis of circular pressure vessel isdone. The results of the circular vessel are validated by analytical solution. Then using the same type of element& mesh density, analysis of elliptical pressure vessel is done. During the study, different parameters were varied& their effect on the stresses was observed.

Das et al.(2015) Pressure vessels have to be designed in such a way that they are able to bear high pressure and extreme level of temperature. In pressure vessels openings are required for inlet and outlet purposes. These openings can cause geometric discontinuity of the vessel wall, so a stress concentration is created around the opening. Hence a detailed analysis is required. In this study behavior of a cylindrical pressure vessel wall for increasing diameter of holes are considered to find out the diameter of opening with minimum stress concentration. The pressure vessels shall be analyzed by using PreWin, a graphical pre and postprocessor for the structural analysis software FEAST (Finite Element Analysis of Structures) and the results are compared with the analytical solutions and the results obtained using ANSYS.

Patel et al.(2014) Pressure vessel contains with different inlet & outlet openings called nozzle or valves. The design parameter of these valves may different in one pressure vessel. These valves cause geometric discontinuity of the pressure vessel wall hence stress concentration may occur around the valve or nozzle. Since due to the high stress concentration there may be the chances of failure of vessel junction. Hence detail stress distribution analysis needs to be done for pressure vessel. Determination of limit pressure at different location on pressure vessel by using finite element method is less time consuming and it avoid complex mathematical work at difficult geometries. So, it is essential to validate the result. Experiments are conducted on oblique nozzle (450 with shell

axis) &result obtained is used to validate the finite element results. Distortion measurement test by measuring change in diameter of vessel after vessel is pressurized using water. Twice elastic slope method & Tangent intersection method are used to find out limit load estimation of cylindrical vessel with oblique (450) nozzle.

III. HIGH PRESSURE VESSELS

The application of high pressure to the chemical process industries opened a new field to the design engineer. High pressure vessels are used as reactors, separators and heat exchangers. This relatively new technique originated in the industrial synthesis of ammonia from its elements and with the process for the cracking of oil. Now the high pressure vessels are extended up to 350 MPa. In mono block vessels as the internal pressure in the shell increases, the required shell thickness also increases. Jasperand scudder describes the limitations encountered with convention formulae used in the design of single walled vessel of large volunes of high internal pressures.

Construction of High Pressure-Vessels:

- A solid wall vessel produced by forging or boring a solid rod of metal.
- A cylinder formed by bending a sheet of metal with longitudinal weld.
- Shrink fit construction in which, the vessel is built up of two or more concentric shells, each shell progressively shrunk on from inside outward. From economic and fabrication considerations, the number of shells should be limited to two.
- A vessel built up by wire winding around a central cylinder. The wire is wound under tension around a tension around a cylinder of about 6 to 10 mm thick.
- A vessel built up by wrapping a series of sheets of relatively thin metal tightly round one another over a core tube, and holding each sheet with a longitudinal weld. Rings are inserted in the ends to hold the inner shell round while subsequent layers are added. The liner cylinder generally up to 12mm thick, while the subsequent layers are up to 6mm thick.

Types of High Pressure Vessels:

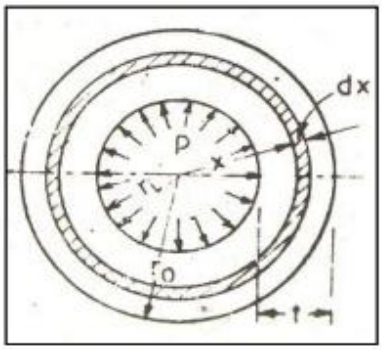

Fig.1 Solid Wall Vessel

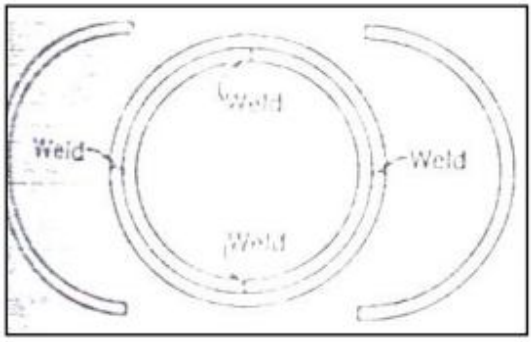

Fig.2 Multi-Layered Cylindrical Vessel

Factors Considered in Designing High Pressure Vessels:

- Dimensions-Diameter, length and their limitations.
- Operating conditions – Pressure and temperature.
- Available materials and their physical properties and cost.
- Corrosive nature of reactants and products.
- Theories of failure.
- Types of construction i.e. forged, welded or casted.
- Method of Fabrication.
- Fatigue, Brittle failure and Creep.
- Economic consideration.

IV. CONCLUSION

Finite element analysis is an extremely powerful tool for pressure vessel analysis when used correctly.Theoretical calculated values by using Different formulas are very close to that of the values obtained from ANSYS analysis is suitable for multilayer pressure vessels. Owing to the advantages of the multi layered pressure vessels over the conventional mono block pressure vessels, it is concluded that multi layered pressure vessels are superior for high pressures and high temperature operating conditions.

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