DESIGN AND ANALYSIS OF PRESSURE VESSEL OF 1MeV DC ACCELERATOR

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ABSTRACT:-A pressure vessel is a closed container which is designed to store liquid or gas at a pressure or temperature,which is different from the ambient pressure and temperature.During operation,the pressure vessel has to withstand several induced stresses due to internal or external pressure.Thus,for the safety purpose storage vessels has to be designed according to ASME standards and rules.The design mainly concerned with two chambers mounted concentrically out of which one experiences internal pressure and other experiences external pressure with proper fixture and connecting arrangement. This project work deals with a detailed study of various parts of pressure vessels like shell, torrispherical head.Design is carried according to rules of ASME code section VIII, Division I and calculate the stresses induced in the various part of the vessel by using ASME CODE AND STANDARDS and compare these results with the ANSYS results.

Keywords-Pressure Vessel, ASME CODE,ANSYS ,Joint Efficiency, Structural analysis (Displacement, Hoop stress &Longitudinal stress), Pressure component (shell, head, and nozzle).

1.1 INTRODUCTION : Pressure vessels are leak proof containers may be of any shape and size ranges from cold drink bottles to high-pressure steam boilers, used in engineering construction. The word 'design' means to create, to innovate and used not only for the calculation of the detail dimensions of the vessels but also to find out the mode of failure or damage, and selection of materials type and its environmental behavior. Accelerator vessel is a main body of the 1 MeV industrial Electron Beam Accelerator in which high voltage capacitors, rectifier columns, RF electrodes, corona shields, high voltage terminals, electron gun, accelerating tube etc. are housed. Sulpher hexafluoride (SF_6) is a gaseous insulator for high voltage pressure. The inside wall of the accelerator tank and RF electrodes forms the tank capacitor of the 120 kHz power oscillator. Hence the design of accelerator tank acts as a component for the efficient performance of the electron accelerator.

1.1. BRIEF DESCRIPTION OF PROJECT:-The pressure vessel for 1MeV Accelerator is designed for a 10 kg/cm^2 of internal pressure, 1 atmosphere of external pressure, and a maximum working temperature of 70 degree Celsius. It is a thin,closed and vertical type of pressure vessel. Pressure vessel is the main

body of the accelerator. It will be filled with SF_6 gas at an operating pressure of 6 kg/cm^2 for insulation of high voltage components. The height of the vessel is 3450 mm, inside diameter 1600 mm and shell thickness is 14 mm.

1.2. THE PROBLEM DESCRIPTION

This project work deals with a detailed study of various parts of pressure vessels like shell, torrispherical head, flanges and nozzles.Design is carried according to rules of ASME code section VIII, Division I and calculate the stresses induced in the various part of the vessel by using ASME CODE AND STANDARDS and compare these results with the ANSYS results.

1.3. OBJECTIVE

The main objective of this report is to design the standard cylindrical pressure vessel and calculate the stresses induced in the various part of the vessel by manually and compare these results with the ANSYS results. Efforts are made in this report to design the pressure vessel using ASME codes and standards.

1.4. STRESSES IN PRESSURE

VESSELS:-Stress analysis is the determination of the relationship between external forces applied to a vessel and the corresponding stress. The starting place for stress analysis is to determine all the design conditions for a given problem and then determine all the related external forces. We must then relate these external forces to the vessel parts which must resist them to find the corresponding stresses.In any pressure vessel subjected to internal or external pressure, stresses are set up in the

shell wall. The state of stress is triaxial and the three principal stresses are:

- **Longitudinal/Meridional stress**
- **Circumferential/Latitudinal stress**
- **Radial stress**

2) LITERATURE REVIEW

2.1)A REVIEW ON DESIGN AND ANALYSIS OF PRESSURE VESSEL:-

a)David Heckman tested three dimensional, symmetric and axisymmetric models; the preliminary conclusion is that finite element analysis is an extremely powerful tool when employed correctly. Depending on the desired solutions, there are different methods that offers faster run times and less error. The two recommended methods included symmetric models using shell elements and axisymmetric models using solid elements. Contact elements were tested to determine their usefulness in modeling the interaction between pressure vessel cylinder walls and end caps.

b)A. J. Dureli (1973) presented work on the stresses concentration in a ribbed cylindrical shell with a reinforced circular hole subjected to internal pressure, by several experimental methods and the results obtained were compared with those corresponding to a non-reinforced hole in a ribbed and un-ribbed shell and also to a reinforced hole in an un-ribbed shell. From the result it was found that the maximum value of hoop stress, and longitudinal stress, in shells always occurred at the points θ = 0° and θ = 90°, respectively, along the edge of the hole, θ being the angle measured clockwise from the longitudinal axis of the hole.

c) **R.C. Gwaltney (1973)** compared theoretical and experimental stresses for spherical shells having single non-radial nozzles. The stress distributions for radial and non-radial nozzle geometry are analyzed. Stress distributions for the non-radial and the radial nozzle attachments are quite similar but the non-radial nozzle configuration gave the maximum

normalized stress, both theoretical and experimental, for internal pressure and for axial loads on the nozzle as well as for pure bending moment loading in the plane of obliquity.

2.2) DESIGN AND ANALYSIS OF THE PRESSURE VESSEL BY USING FEM:-

a)Henry H.Bednar et al has investigated 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 overthe conventional mono block pressure vessels, it is concluded that multi layered pressure vessels are superior for high pressures and high temperature operating conditions.

b)Harold H.Wait has investigated Fatigue analysis will be carried out for entire equipment for specified regeneration cycles and we will found fatigue life more than required cycles. Accordingly we conclude that all evaluation points for fatigue are within allowable limits specified by code. The maximum fatigue damage fraction observed which less than unity as required by code.

2.3)MODELLING FOR STRUCTURAL ANALYSIS OF PRESSURE VESSEL:-

a)According to the **Ming-Hsien Lu et.al** if a simplified 2-D axisymmetric model is used to simulate the stress behaviour of the nozzle-vessel structure, the actual vessel radius can be directly used, which could obtain a conservative membrane and membrane plus bending stress intensities in the nozzle vessel junction Following work consists of literature survey, summarizing the published work on section. This simplified 2-D model could also predict conservative membrane stress intensity at the nozzle-to-pipe connection location; this paper creates three different 2-D axi-symmetric finite element models, where different vessel radii are modelled, i.e. 1, 1.5 and 2 times the actual vessel radius. Using these simplified numerical models to calculate the membrane and membrane plus bending stress intensities

along some selected sections when undergoing internal pressure loading, and comparing these results with those evaluated from the realistic 3-D model, it shows that the 2-D model with vessel radius equalling to the actual value could well represent the behaviour of a nozzle attached to the vessel.

b)Drazan Kozak et.al made numerical analysis on cylindrical pressure vessel with changeable head geometry i.e. semi-elliptical and hemispherical heads 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, insight into the stress distribution per plate thickness and obtained results which are closest to the analytical ones. This type of axisymmetric element could be recommended in such cases, when the total symmetry of model is considered. Also analysis of cylindrical pressure vessel with different head type is performed in purpose of comparison of values of maximal equivalent stresses. It is concluded that smaller values of equivalent stresses are appearing in pressure vessel with hemispherical heads, and equivalent stress distribution is advantageous too in that case of head geometry.

c)Dr. Clemens Kaminski made a study on stress analysison pressure vessel. In this he found out the stresses in cylinder and sphere, failure modes of pressure vessel under bulk yielding and buckling, stress concentration and cracking and also hoop longitudinal and volumetric strain. 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

d)Michael A. Porter made the comparison between linear and nonlinear

FE analysis of a typical vessel nozzle. In this paper he presents a nonlinear (elastic-plastic, material nonlinearly only) analysis of the same nozzle and results are compared with the results from the previous linear analysis. He concluded that nonlinear FE may not be necessary for thin wall vessels. And the results using linear FE appear to be suitably conservative.

e)Pavo Balicevic et.al has chosen a pressure vessel of elliptical head to analyze its strength and he described the method for calculating strength, and also describe the distribution of total circular forces and radial forces of the cylindrical vessel with ellipsoidal heads.

3. SELECTION OF CODE:

The American Society of Mechanical Engineers set up a committee in 1911 for the purpose of formulating standard rules for the construction of steam boilers and other pressure vessels. This committee is now called the Boilers and Pressure Vessel committee. I have used ASME Boiler and Pressure Vessel Code Section VIII, Division-1, Rules for the construction of the pressure vessel. Material selected as per ASME section- II. Material test and quality assurance plan can be carried out as per section-VIII and section-IX for design of pressure vessel for 1MeV accelerator tank.

3.1 DESIGN PARAMETERS:-

i) Working pressure: 6 kg/cm^2

ii) Design temperature: 70^{0}c

iii) Content:Sulpher Hexa Fluoride (SF$_6$)

iv) Design internal pressure: 10 kg/cm^2

v) Design external pressure:1.013 kg/cm^2

vi) Material for the tank: ASME SA 516 GR 60 Carbon Steel Plate.

vii) I.D of the pressure vessel :1600 mm

viii) Height of the pressure vessel 3450 mm

x) Mounting:Vertical type

xi)Corrosion allowance:3 mm.

xii) Ends: Toripherical head (Top) and flat cover (bottom).

3.2 MATERIAL SELECTION FOR PRESSURE VESSEL OF 1MEV ACCELERATOR TANK: -

As per A.S.M.E section -II materials for the above system are given below.

i) Plate for vessel:ASME SA516GR60

ii) Nozzle Pipe: ASME SA 312 TP GR 304L (Seamless)

iii) Main and blanking flanges: ASME SA 105 Grade II

iv) Bolt/Nut /washer: ASME SA 193 GR B8 304/SA 194 GR 8A

4.CONCLUSION

The pressure vessel is successfully designed so that it with stand all the mechanical stresses acting on it. The pressure vessel is analyzed under various conditions of operation. All forces are carried according to ASME codebook. The pressure vessel also with stand the internal pressure as well as external pressure at working conditions. The various forces analyzed are pressure exerted by gas on the shell, torrispherical head, flanges and nozzles. The stresses in above-mentioned conditions are found out and thickness of various parts is selected such that the stresses produced in each member are

within the maximum allowable range. All the selected have been successfully verified and hence the design of pressure vessel is safe.

5.REFERENCES

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