

Design and Analysis of Pressure Vessel Using Finite Element Method

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Abstract: 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.

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

I. INTRODUCTION

Pressure vessels are leak proof containers used to hold gases or liquids at a pressure different from the ambient pressure. The end caps fitted to the cylindrical body are known as heads. Pressure vessels are used in various fields such as chemical industry, pharmaceutical industry, oil and fuel industry, and plastic industry. Other example of pressure vessels are diving cylinder, recompressed chamber, distillation towers, nuclear reactor vessel, hydraulic reservoir and storage vessels for liquefied gases such as ammonia and chlorine.

Pressure vessels are boilers and storage tanks that contain liquid or gases and are designed to operate at pressure above 15 psig. A boiler is defined as a welded container or a pipe arrangement in which steam or hot water with a temperature exceeding 120°C is generated by the application of heat, resulting from the combusting of fuel (solid, liquid or gaseous) or from hot combustion gases. The mechanical design of most pressure vessels is done in accordance with the requirements contained in the ASME Boiler and Pressure Vessel Code.

II. PRESSER VESSEL SHELL

The shell is the primary component that contains the pressure. Pressure vessel shells are welded together to form a structure that has a common rotational axis. Most pressure vessel shells

are cylindrical, spherical, or conical in shape. Horizontal drums have cylindrical shells and are fabricated in a wide range of diameters and lengths.

III. SELECTION OF MATERIALS BASED ON THE CARRYING LIQUID AND CORROSION FACTOR

Selection of materials in design process requires deep knowledge about different properties of the material and Many factors have to be considered when selecting engineering materials, but for chemical process plant the overriding consideration is usually the ability to resist corrosion .The process designer will be responsible for recommending materials that will be suitable for the process conditions the material selected must have sufficient strength and be easily worked.

The most economical material that satisfies both process and mechanical requirements should be selected; this will be the material that gives the lowest cost over the working life of the plant, allowing for maintenance and replacement. The most important characteristics to be considered when selecting a material of construction are:

1. Mechanical properties
2. The effect of high and low temperatures on the mechanical properties
3. Corrosion resistance
4. Any special properties required; such as, thermal conductivity, electrical resistance, magnetic properties
5. Ease of fabrication-forming, welding, casting.
6. Availability in standard sizes-plates, sections, tubes
7. Cost

Depending up on the above mechanical properties & for fluid medium the material we select the stainless steel 18Cr/8Ni (304) minimum thickness of (3mm) type because it has good yield strength, tensile (UTS) strength, good fracture toughness, good resistance of temperature, good corrosion resistance and it can be fabricated in different methods except casting.

IV. DETERRING THE DIAMETER AND LENGTH OF A PRESSURE VESSEL

$$V=2V_h+V_s$$

V_h = volume of the head

V_s = volume of the shell

The standard internal diameter is determined 1m Then $L=3 \times 1=3$ m

V. CALCULATE THE SHELL THICKNESS

5.1. Circumferential Stress (Longitudinal Joints)

$$t = PR / (SE - 0.6P) + C.A$$

t=min required thickness of vessel

R=internal radius of vessel

S = max. Allowable stress, Pa

E = joint efficiency (min)

C.A=corrosion allowance, mm

5.2. Longitudinal Stress (Circumferential Joints)

$$t = PR / (2SE + 0.4P) + C.A$$

VI. FINITE ELEMENT ANALYSIS RESULTS USING ANSYS MECHANICAL APDL

A variety of specializations under the umbrella of the mechanical engineering discipline (such as aeronautical, biomechanical, and automotive industries) commonly use integrated FEM in design and development of their products. Several modern FEM packages include specific components such as thermal, electromagnetic, fluid, and structural working environments. In a structural simulation, FEM helps tremendously in producing stiffness and strength visualizations and also in minimizing weight, materials, and costs.

FEM allows detailed visualization of where structures bend or twist, and indicates the distribution of stresses and displacements. FEM software provides a wide range of simulation options for controlling the complexity of both modeling and analysis of a system. Similarly, the desired level of accuracy required and associated computational time requirements can be managed simultaneously to address most engineering applications. FEM allows entire designs to be constructed, refined, and optimized before the design is manufactured.

6.1 FEA Implementations

1. Preprocessing (build FE model, loads and constraints)
2. FEA solver (assemble and solve the system of equations)
3. Post processing (sort and display the results)

6.2. Pressure Vessel Analysis using FEA:

ANSYS will be used to analyze the stresses and deflections in the vessel walls due to the internal pressure. Since the vessel is subjected to internal pressure using two-dimensional, 8-

node quadrilateral elements (Plane 82). In order to validate the stress analysis results, the calculation were done and compare with ansys results by taking minimum thickness value 5 mm. The report gives the maximum displacement, principal stress and shear stress distribution under the operating pressure. The purpose of this analysis is to ensure that the results of the finite element analyses were compared to the analytical findings values and the error of acceptance

Table I: INPUT PARAMETERS

S.No	Parameters	Values
1	Diameter of Vessel	1m
2	L/D Ratio	3
3	Length of Vessel	3 m
4	Internal Pressure (P_i)	1.7225 MPa
5	Design Pressure (P_d)	1.895 MPa
6	Thickness	5 mm
7	Outer Diameter of Vessel	1.01 m
8	Maximum Stress Induced	203 MPa
9	Poison's Ratio	0.27

FEA Results:

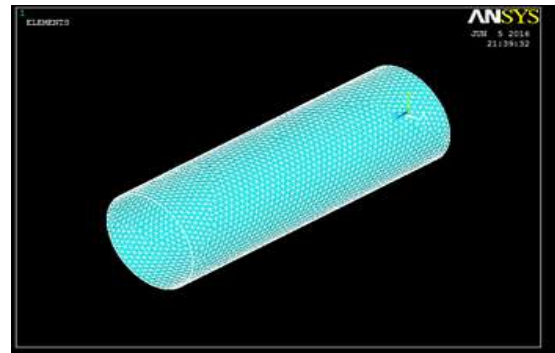


Fig:1. Meshing of Pressure Vessel

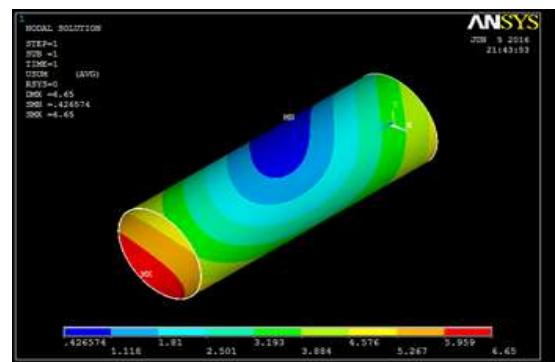


Fig: 2.Total Displacement

According to maximum principal stress theory and maximum distortion theory the design is safe for the maximum stress 203 MPa and a factor of safety is 1.01

Maximum displacement is 6.65 mm and minimum displacement is 0.42657 mm

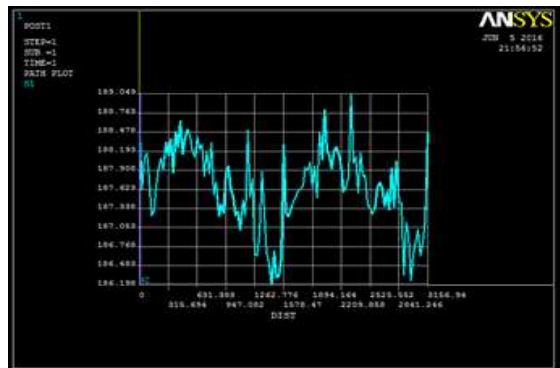
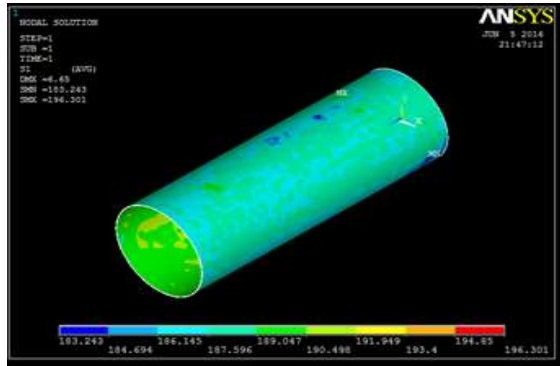


Fig:3. Principal Stress

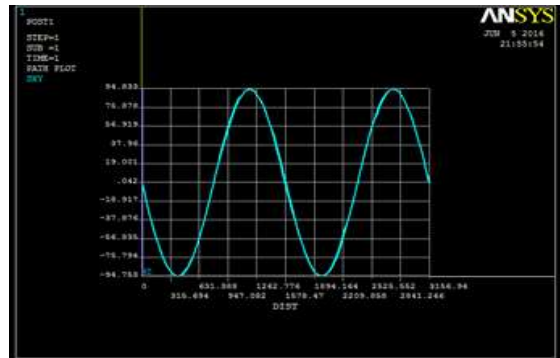
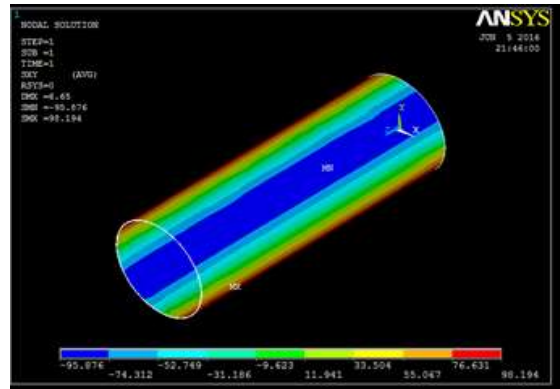


Fig: 4. Shear Stress In X Plain Y-Direction

According to the Maximum Principal Stress the hoop stresses (σ_1) induced is 196.301 N/mm² occurs at a distance 2309.858 mm and the minimum Principal stress or hoop stresses induced is 183.243 N/mm² at 1420.623 mm.

Maximum shear stress (τ_{max}) induced is 98.194 N/mm² at a distance 1261 mm, 2840 mm and the minimum shear stress is 95.876 N/mm² at a distance 316 mm, 1895 mm.

Comparison of Results:

S.No	Parameters	Calculation Results	FEA Results	Difference
1	Maximum principal Stress	189.5 MPa	196.301 MPa	6.801 MPa
2	Maximum shear Stress	94.8 MPa	98.194 MPa	3.394 MPa

VII. CONCLUSION

The finite element analysis is more accurate than any other mathematical techniques. The pressure vessel is subjected to hoop stresses and longitudinal stress the variation of stresses can be analyzed by the ANSYS results hence the design is safe under the operating conditions. Results are plotted that were the maximum hoop stress and minimum hoop stresses are induced as well as the maximum shear stress and minimum shear stresses are induced in the pressure vessel.

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