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A COMPARATIVE STUDY BETWEEN STEEL AND POLYETHYLENE PRESSURE VESSEL DESIGN BY FEA ANALYSIS

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ABSTRACT

In this project our main focus on build a pressure vessel using two different types of material. The ANSYS FEA software was used to create a Structural Steel FEA model and also create Polyethylene pressure vessel compares to structural steel. There is using high operating pressure (22 N/mm^2) so, safety factor is main point. The Tensile Ultimate Strength (Map) , burst pressure, Hydrostatic Pressure , the pressure vessel are optimized using ANSYS and several 3D failure happen. Model creation and compare between two different material pressure vessels (design same) results are in good and comparison successful.

Keywords: Design, Analysis, Solid & Multilayer Pressure vessel, Burst Pressure, Pressure Vessel.

1. INTRODUCTION

INDIA is now fastest growing country in the world. Because we have good infrastructure and technology. For that we need energy. Over population and extra consuming is a cause of energy crises so we need to know importance of engineering research related to nuclear power plants. In nuclear power plant most important type of reactor is Pressurized water reactor (PWR). In mechanical engineering application pressure vessels is one of the most important considerations. As in PWR plants, change of state may occur inside the pressure vessel in the case of steam boilers. A wide application of pressure vessels in industries like air and gases supply systems nuclear and thermal power plants, fuel tanks, rocket motor cases, Pipes, are some of the examples of pressure vessels. The technical improvement one of the main cause of increased the use of pressure vessels. Pressure vessels are many types, but we mainly used two types are Vertical and Horizontal pressure vessels. Pressure vessels are capable of under their braking point to contain gases and liquid. Pressure vessels have a High pressure range greater than 15psi. So that's why the design of pressure vessels is one of the most important factors of mechanical engineering. In this paper we study and developing a design and predict to behavior aspect of pressure vessels with hydrostatic loading and mechanical loading. Pressurized water reactor (PWR) is one of the common names in the nuclear power plants field. PWR pressure vessels are complex geometries and have openings, nozzles, and other accessories which create breaks. The effect of concentration of stresses due to geometric breaks is one of the main issues in the design of pressure vessels. A wide application of pressure vessels Power plants industries, in ocean and oil patch, gas and air supply systems. For that pressure vessels considered as the hub of storage for fluid. Hence, some series of tests pressure vessels designed was created. Using ANSYS software analysis the strength and stability of pressure vessels are obsessed.

The objective of this research work is to compare two materializing two approaches called 'design by analysis' (DBA) and 'design by formula' (DBF) [1].ANSYS Workbench has been used for DBA here which is finite-element-based commercialized software. After year of 2000, finite element analysis (FEA) was introduced as a standard practice in most of pressure vessels design. The root of studies about the analysis of pressure vessels is being found from Lethnitskii's approach [2].The use of two dimensional and three dimensional shell element models is very usual in the finite element stress analysis of pressure vessels [3-7].In this study we had done progress an analytical procedure to predict a design of pressure vessels with a union of mechanical and hydrostatic loading.

2 METHODOLOGY

2.1 ABOUT ANSYS SOFTWARE

ANSYS is an analyzing program there finite-element modeling package for numerically solving a wide variety of mechanical problems like dynamic analysis, fluid analysis, structural analysis, and heat transfer. There is a study of pressure vessel basic size analysis by ANSYS software. In this software for same design (1) multiple solution created, (2) you can utilize material, (3) also use modification. In general way some of people group together and work it takes long time duration. But in simulation software there is no need to hard work just create a designed and go for simulation as you need. If there is some problem occur you just change some parameters or design and go for solution. So, for ideal design its more benefits than traditional way and easy.

2.2 **(Table 1.)** Material Used And Its Properties

	Properties	Value
Materials Structural Steel	Density (1000 kg/m3)	7850
	Melting Point (° c)	250
	Tensile yield Strength (MPa)	200000
	Poisson's ratio	0.3
	Tensile Ultimate Strength (MPa)	460
	Compressive yield strength (Mpa)	250
Polyethylene	Tensile yield Strength (MPa) (Yt)	25
	Compressive ultimate Strength (MPa) (Xc)	0
	Ultimate Tensile Strength (MPa)	33
	Poisson's ratio	0.42
	Density (1000 kg//m3)	950 kg/m³
	Young modules	1100

2.3 DESIGN OBJECTIVE

1. To determine the two different material pressure vassals (same design) at high operating pressure which is the best.
2. To demonstrate that there may be a uniform stress distribution across the entire shell, indicating the most efficient use of the material in the shell.
3. To determine the suitability of employing different materials for the Liner shell and remaining layers in order to reduce the vessel's construction costs.
4. To ensure that the stresses do not approach the yield point value during testing and to verify the theoretical stress distribution induced by internal pressure at the shell's exterior surface.
5. Finally, using the ANSYS package, validate the design parameters with FEM analysis to ensure that FEM analysis is suitable for different material.

2.4 DESIGN CONSIDERATIONS

1. ASME Code Section VIII division I is used to build a pressure vessel.
2. Only in the design of the one-layer shell is a Safety Factor of on Ultimate Tensile Strength considered. Other parts should be kept at room temperature.
3. For longitudinal seams, a joint efficiency of 100 % is required. It is taken from the liner shell.
4. For longitudinal seams, a joint efficiency of 100 % is required. It is taken from the liner shell
5. Dished end plates are subjected to a full ultrasonic examination.
6. After attaching the boss, nozzle, and other components, the dish ends will be tension eased.
7. In a one-layered shell, the longitudinal welds were staggered.

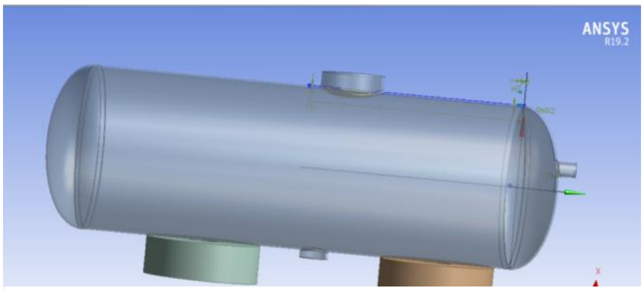

Figure 1 Drawing of Pressure Vessel in ANSYS

2.5 DESIGN DATA OF THE VESSEL

Inner diameter (Di) = 2134mm
Outer diameter (DO) =2188mm
Design Pressure, P = 22 N/mm^2
Design Temperature, T = 26 °C
Hydrostatic Pressure PH = 28.6 N/mm^2
Thickness= 27mm
Safety factor = 3

2.6 CALCULATION OF BURSTING PRESSURE

Ultimate tensile strength of material (Structural Steel) = 460Mpa

K= Outer diameter / Inner diameter (K)= 1.025

Structural Steel bursting pressure = U.T.S × $[\left[\frac{k^2-1}{k^2+1}\right]]$ =11.21

Ultimate tensile strength of material (Polyethylene) = 33

Polyethylene bursting pressure = U.T.S × $[\left[\frac{k^2-1}{K^2+1}\right]]$ =0.814

2.7 CALCULATION OF HYDROSTATIC PRESSURE

Design pressure × 1.3 = Hydrostatic Pressure = 28.6 N

3 MODELING AND ANALYSIS

3.1 STRUCTURAL ANALYSIS AND RESULTS (Structural Steel)

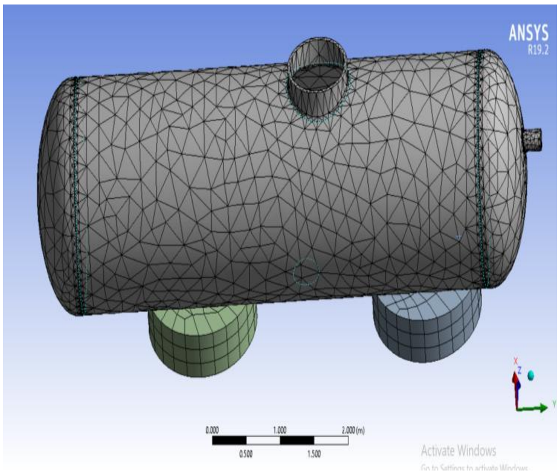

Figure 2. Finite Element meshed Model of solid wall vessel

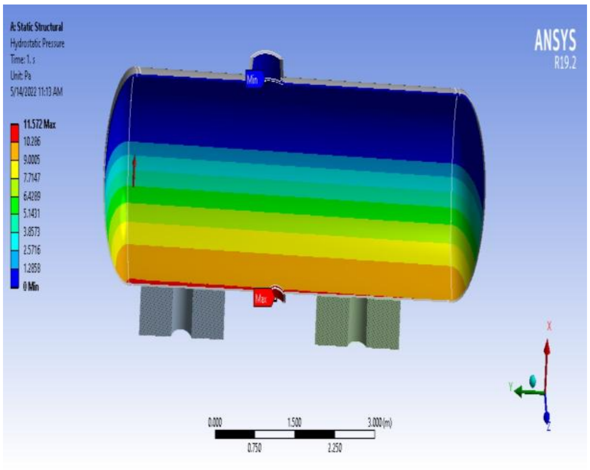

Figure 3. Application of hydrostatic pressure_Pressure

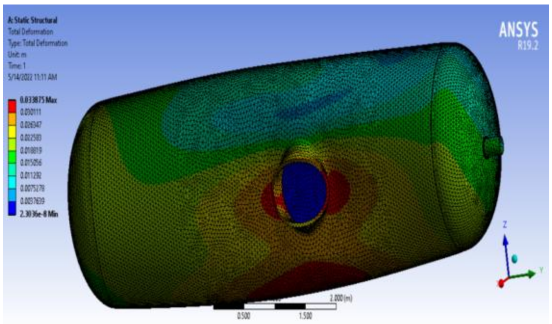

Figure 4. Vector sum displacement

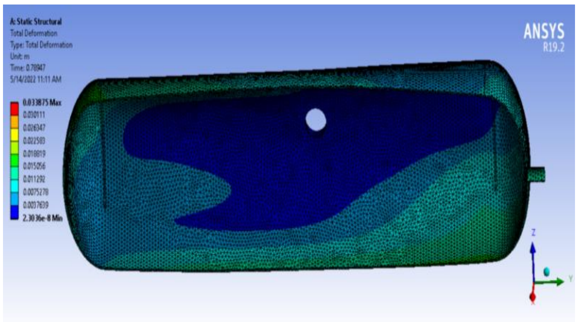

Figure 5. Von - Mises Stresses

(Table 2.) Deformation over three axes

Deformation	Minimum in m	Maximum in m
Vector sum deformation	2.3035e-005 mm	33.875 mm
X – axis deformation	-25.679 mm	17.832 mm
Y – axis deformation	-1.1401 mm	10.768 mm
Z – axis deformation	-33.458 mm	6.7328 mm

(Table 3.) Equivalent Von Mises stresses over three axes

Stresses	Minimum, Pa	Maximum, Pa
Von Mises Stresses	1.1744 MPa	1605.7 MPa
X – axis deformation	-462.94 MPa	493.68 MPa
Y – axis deformation	-1414.3 MPa	1146.8 MPa
Z – axis deformation	-1369.9 MPa	1383.3 MPa

3.2 STRUCTURAL ANALYSIS AND RESULTS (Polyethylene)

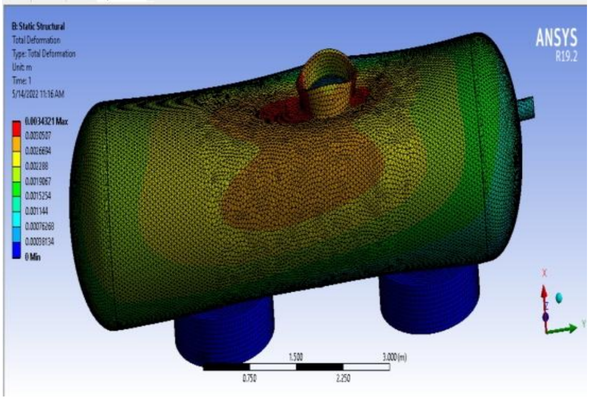

Figure 6. Von - Mises Stresses

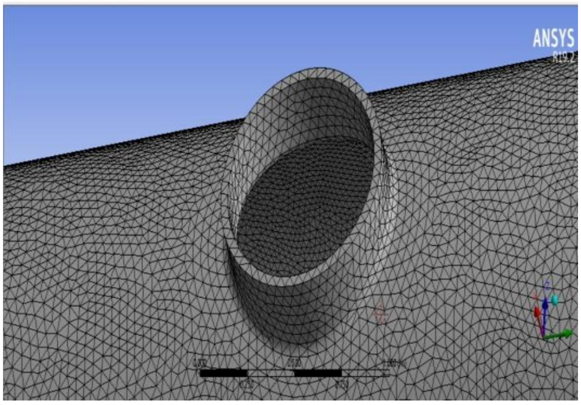

Figure 7. Finite Element meshed Model of solid wall pressure vessel

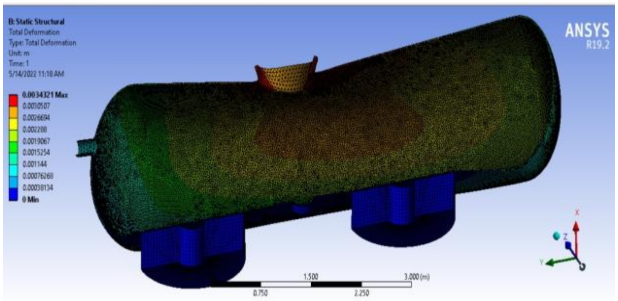

Figure 8. Vector sum displacement

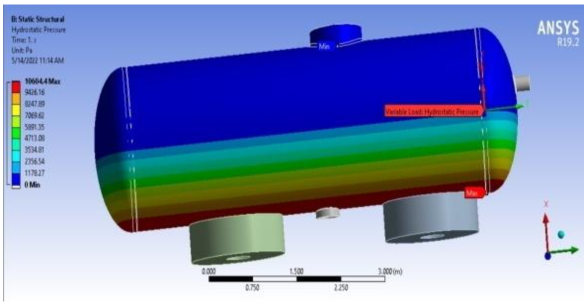

Figure 9. Application of hydrostatic pressure

(Table 4.) Deformation over three axes

Deformation	Minimum in mm	Maximum in mm
Vector sum deformation	0. mm	541.09 mm
X – axis deformation	-451.41 mm	79.964 mm
Y – axis deformation	-91.454 mm	44.342 mm
Z – axis deformation	-484.22 mm	91.457 mm

(Table 5.) Equivalent Von Mises stresses over three axes

Stresses	Minimum, Pa	Maximum, Pa
Von Mises Stresses	9.0517e-005 MPa	98.138 MPa
X – axis deformation	-40.619 MPa	43.153 MPa
Y – axis deformation	--65.423 MPa	84.691 MPa
Z – axis deformation	-54.629 MPa	107.87 MPa

4 RESULTS AND DISCUSSION

In this project work, we are mainly used two types of materials; Structural Steel and Polyethylene. After that we have analyzed all these two materials on Ansys workbench and find out the best suit for making of a high-pressure vessel. As shown in Figures 3 and 5, Structural Steel is generally delicate materials with very strong strength and low elasticity. For a 27mm thick pressure vessel, the Tensile Ultimate Strength (MPa) of Structural Steel in 460 MPa, Compressive yield strength (Mpa) of 250 MPa and blasting pressure of 11.21 N /mm2. Hydrostatic Pressure is the same for both vessels of 28.6N / mm2. Due to the strong strength of Structural Steel we build a pressure vessel design with the help of ANSYS and analyzed the same pressures of the Polyethylene. In the solid pressure vessel it has a pressure of 1605.7 MPa, and a burst pressure of 0.814 N/ mm2. The work proposes a method for analyzing such vessels exposed to internal stress. The speed of the explosion of the ship is expected using the maximum pressure condition. There is a high correlation between model prediction and test evaluation.

5 CONCLUSION

1. Today, different different material pressure vessels are now widely used in many fields. Due to the large differences in the weight of the vessel and the distribution of the same pressure throughout the strength of the vessel wall.

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2. This not only reduces the total weight of the part, but also the cost of the materials used to make the pressure vessel. This is one of the most important parts of a designer to keep the weight and cost as low as possible.
3. Pressure containers are designed for safety. A safety feature that we think is valid and the design is considered safe. Explosive pressure is less than allowable pressure, which prevents the design from failing. And because the analysis is very close to the analysis design, data are validated, the design is considered safe, and no failures occur on the pressure vessel.
4. The use of CFRP compounds provides a positive effect and strong energy and enhances the material life. It provides good stability and good durability as well as small modification of the pressure vessel.
5. It concludes that multi-horizontal pressure vessels are higher than high pressures and higher operating temperatures due to the advantages of multi-horizontal pressure vessels over traditional single-wall pressure vessels.
6. After this experiment, we came to the following conclusions: first, Structural Steel is the best metal to make a high-pressure vessel. It cost is also reliable. We compared two material Structural Steel and Polyethylene but the polyethylene does not work properly this kind of design because of low density and low tensile strength. So, as we say that Structural Steel is the best for making high pressure vessel.

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