Structural Analysis of Pressure Vessel Using Ansys Workbench

Ahtisham Ul Haq Arain and Qadir Bukhsh Jamali

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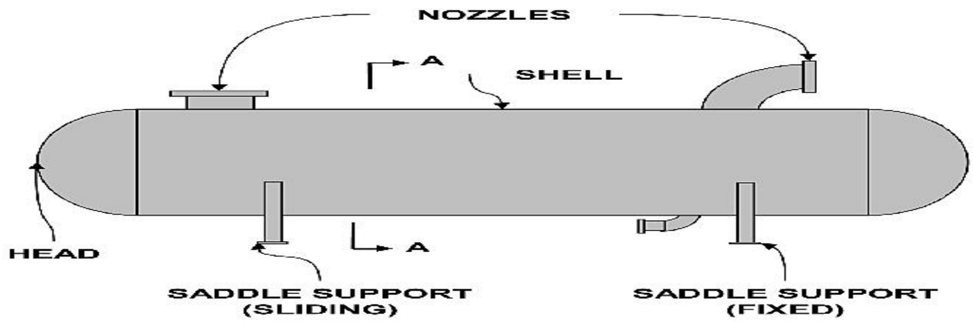
STRUCTURAL ANALYSIS OF PRESSURE VESSEL USING ANSYS WORKBENCH

*Ahtisham ul Haq[1], Qadir Bakhsh Jamali[1]
Department of Mechanical Engineering, Quaid -e- Awam University of Engineering, Science and Technology 67480, Nawabshah Pakistan
*Corresponding Author: ahtisham.arain002@gmail.com

INTRODUCTION

A pressure vessel is a container which can hold gases or liquids at a pressure substantially different from the ambient pressure. These vessels are used in various industries, including petrochemical, chemical, pharmaceutical, food processing, and power generation, to store, transport, or process fluids under high pressure or temperature conditions. Pressure vessels are designed to safely contain and control the pressure of the fluid inside them and is an essential component in many industrial processes.

General components of a pressure vessel include; head, shell, nozzle and support frame. Shell is the wall which is composed of metal plates welded together to form a circular structure and to close this cylindrical structure on both sides' heads are used. Nozzle is typically flanged to head or shell to allow for connections of pipes into and out of the vessel. Saddle or support leg supports the weight of pressure vessel and does not allow free motion in any particular direction.



Pressure vessels store fluids under pressure so they are often subjected to large internal pressures due to which induced stresses and high temperatures are generated which can lead to failure. A small fracture or a crack of these vessels can cause an explosion, so pressure vessels are dangerous. Hence it is very important to monitor stresses in the vessel. Due to this there is an increasing interest in the field of stress concentration study of pressure vessels.

METHODOLOGY

The methodology of this study was designed in following steps:

1. SELECTION OF PRESSURE VESSEL DIMENSIONS:

Through literature dimensions of pressure vessel and its type are selected on the basis of use. Most of the pressure vessels being in operation were horizontal type so this study focuses on structural failures of horizontal pressure vessels.

2. DESIGN OF PRESSURE VESSEL:

The 3D model of pressure vessel was developed in SOLIDWORKS tool by using the dimensions from literature review.

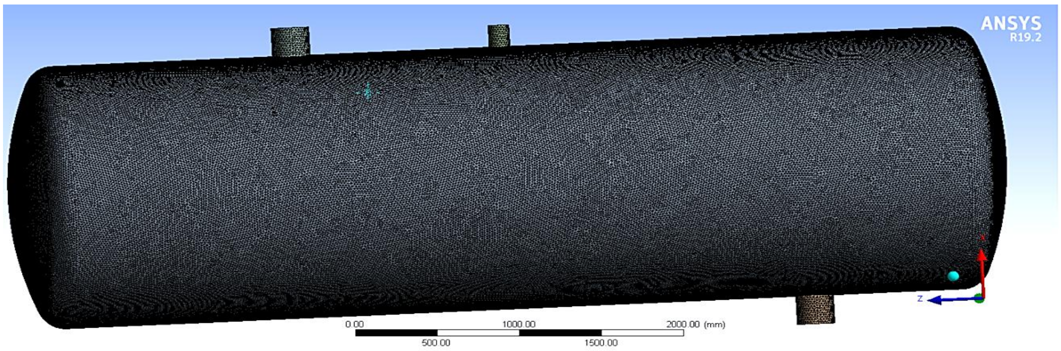
S. No.	Parts	Thickness (mm)	Length (mm)	Diameter (mm)	
				Inside	Outside
1	Shell	17	5500	1800	1834
2	Head	17	900	1800	1834
3	Nozzle (Inlet and Outlet)	20.6	203	189	219
4	Manhole	20.6	254	466	508
5	Drain nozzle	22.2	152.4	82.54	127

3. SELECTION OF MATERIAL:

Pressure vessels are made of many different materials such as stainless steel chrome, aluminum, nickel, fiberglass, and even plastic but the best materials for the manufacturing of pressure vessels are titanium, nickel alloys, stainless steel, and carbon steel. In this study structural behavior of pressure vessels made of structural steel, stainless steel, aluminum alloy, titanium, and gray cast iron are observed because these are widely available and are easy to work with.

4. SIMULATION:

After the 3D model has been completed, the next step was to simulate the model in ANSYS workbench.The geometry was defined here for pressure inside the vessel and gravitational acceleration. Direction of pressure being applied. Head design also affected the overall stress bearing abilities of pressure vessels so hemispherical head was chosen from careful study of literature review as it was observed to give better results. Hemispherical head is a popular choice for pressure vessels due to their ideal shape, which evenly distributes the pressure in the vessel across the surface of the head. After the meshing has been done successfully, simulation takes place in which results are produced and pictures of pressure vessel's deformation and failure points are obtained.

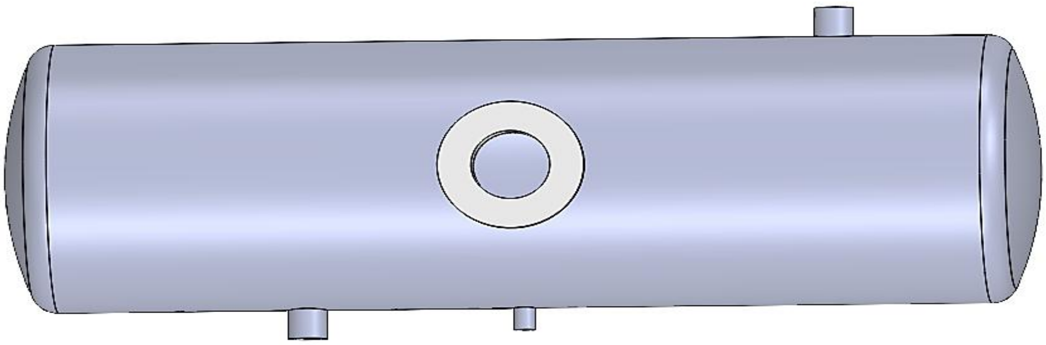


RESULTS AND DISCUSSION

The purpose of this study was to design and analyze the structural behaviour of pressure vessel by determining the equivalent stress, shear stress and deformations in the structure. This study involves analysis of pressure vessel for different materials such as Titanium alloy Ti-6Al-4V, Stainless steel SS420, Gray cast iron class 30, Aluminum alloy 6061, and Structural steel 460.

1. DESIGN OF PRESSURE VESSEL

The 3D model of pressure vessel was developed in SOLIDWORKS according to the dimensions obtained from the literature review. The model of pressure vessel was then analyzed for various design materials and under a constant pressure of 2MPa.

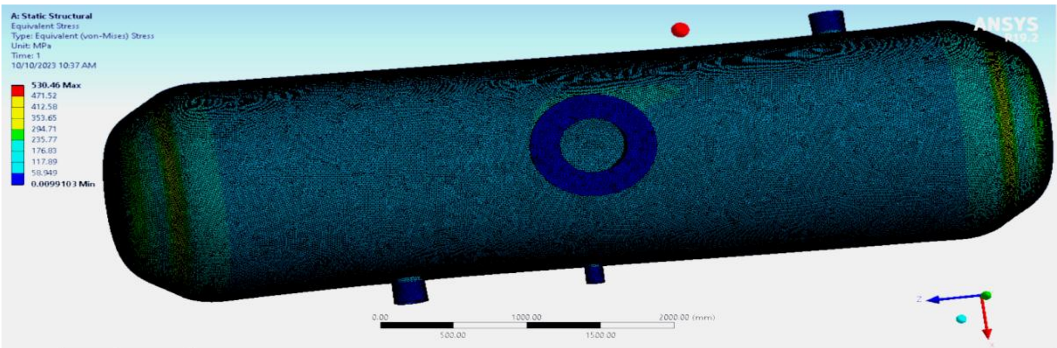


2. STATIC STRUCTURAL ANALYSIS

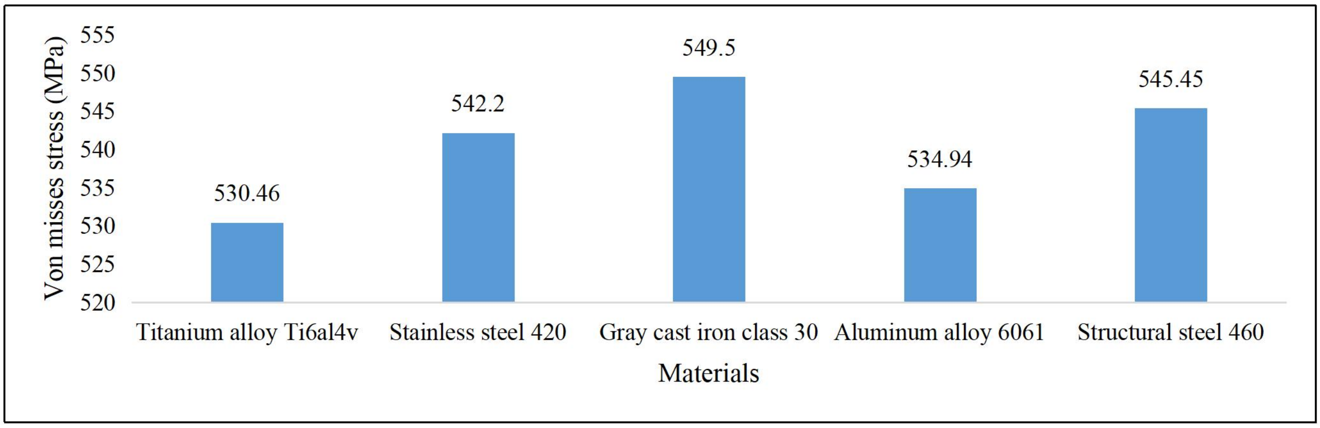
A static structural simulation determines the effect of steady loading on a structure. Stress, strain, and deformation of a structure can be studied under a range of loading conditions. Here Von misses stress, Shear stress and Total deformation on the pressure vessel have been analyzed for five materials.
It can be seen in the pictures that some points are green while some are red. The green region indicates safe design and the red region indicates region where failure has happened. While the orange lies in between the failure and safe design.

Von misses stress on pressure vessel

The figure below clearly illustrated the von misses stress in the vessel under 2MPa pressure.



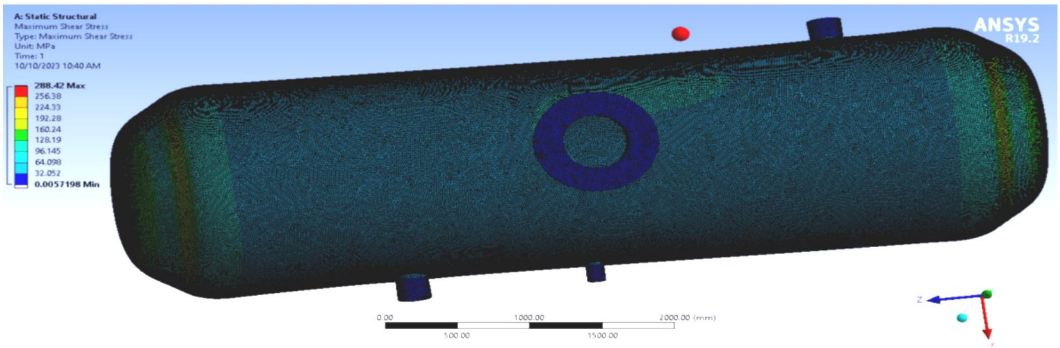
The table and chart provides comparative data of von misses stress that is experienced by all five materials.



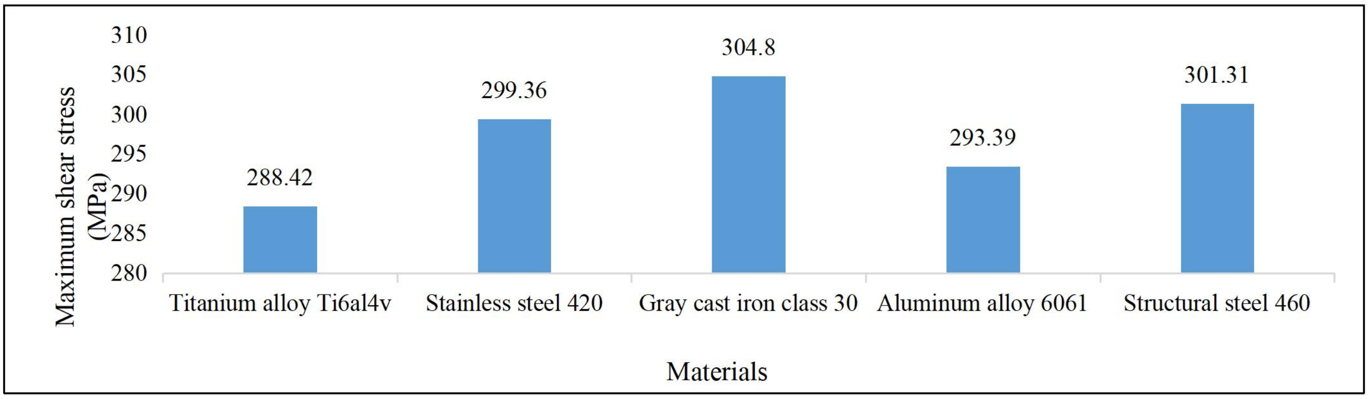
It has been observed from the simulation results that the pressure vessels of different materials have experience maximum von misses stresses in the location at inlet nozzle and at head and shell joint. Only the Aluminum alloy 6061 pressure vessel experience maximum equivalent stress on the head.

Maximum shear stress

The figure below clearly illustrated the maximum shear stress in the vessel under 2MPa pressure.



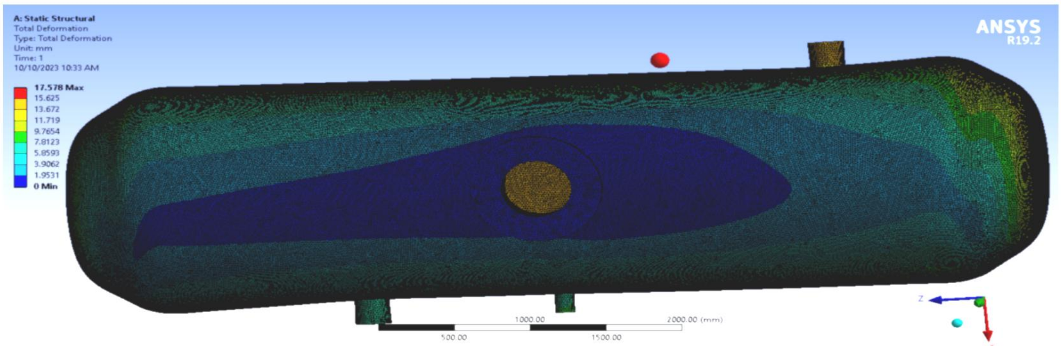
The chart provides comparative data of maximum shear stress that is experienced by all five materials .



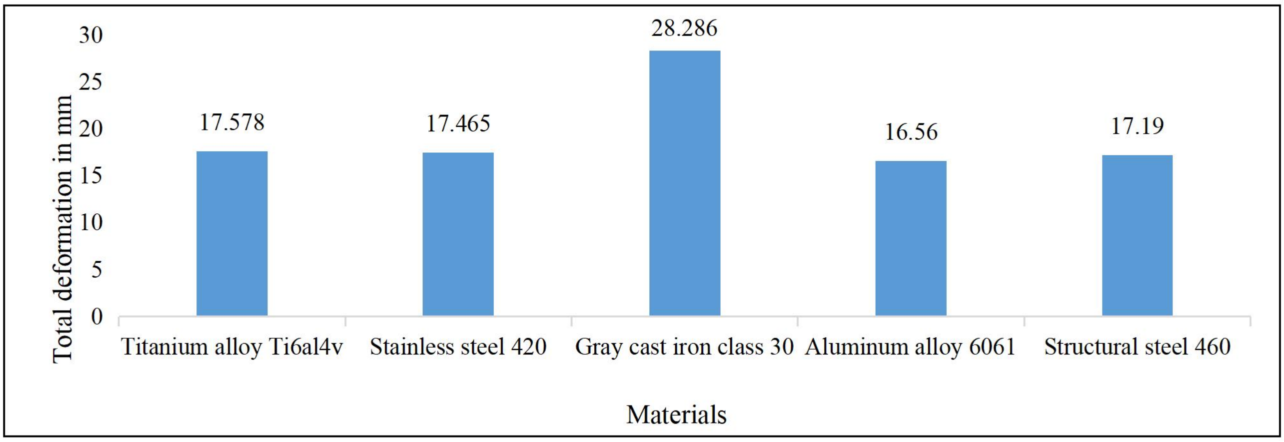
It has been observed from the graphs that most of the pressure vessels experience most amount of shear stresses below the inlet nozzle and head and shell joints. Only the Aluminum alloy 6061 pressure vessel experience the most amount of shear stress on the head.

Total Deformation

The figure below clearly illustrated the total deformation in the vessel under 2MPa pressure.



The chart provides comparative data of maximum shear stress that is experienced by all five materials .



CONCLUSION

The work presented in this thesis provides a comprehensive assessment of the most recent design guidelines for pressure vessels. By using the Finite Element Analysis (FEA) method and with the assistance of SOLIDWORKS software, it was possible to analyze the equivalent stresses, shear stresses and total deformations in pressure vessels made of different materials under constant pressure of 2MPa from varied aspects such as failure analysis which saves time and cost for developing a vessel made of metals. Finite Element Analysis requires static analysis of pressure vessels when boundary conditions are applied.

The simulation results of all selected materials is given as under;

1. **Von-misses stresses:**
   a. Titanium alloy Ti6al4v material has maximum von misses stress value of 530.46MPa.
   b. Stainless steel 420 material has the maximum von misses stress value of 542.2MPa.
   c. Gray cast iron class 30 has the maximum von misses stress value of 549.5MPa.
   d. Aluminum alloy 6061 has the maximum von misses stress value of 534.94MPa.
   e. Structural steel 460 has the maximum von misses stress value of 545.45MPa.

2. **Shear stresses:**
   a. Titanium alloy Ti6al4v material has maximum shear stress value of 288.42MPa.
   b. Stainless steel 420 material has the maximum shear stress value of 299.36MPa.
   c. Gray cast iron class 30 has the maximum shear stress value of 304.8MPa.
   d. Aluminum alloy 6061 has the maximum shear stress value of 293.39MPa.
   e. Structural steel 460 has the maximum shear stress value of 301.31MPa.

3. **Total deformation:**

a. Titanium alloy Ti6al4v material has maximum deformation stress value of 17.578mm.
b. Stainless steel 420 material has the maximum deformation stress value of 17.465mm.
c. Gray cast iron class 30 has the maximum deformation stress value of 28.286mm.
d. Aluminum alloy 6061 has the maximum deformation stress value of 16.56mm.
e. Structural steel 460 has the maximum deformation value of 17.19mm.

As per the objectives of this study, the selected design materials would be compared in all parameters or values for the recommendation of a suitable and appropriate design material. It is therefore concluded in this study by considering the results for all five kind of materials, the Gray cast iron class 30 bears the higher von-misses stress value of **549.5MPa**, Shear stress value of **304.8MPa** and total deformation value of **28.286mm**.

Therefore, from this finite element analysis it can be recommended that the gray cast iron class 30 is the suitable material at production of 2MPa pressure for the design of pressure vessel.

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