"Thermo-Mechanical Analysis of Vertical Pressure Vessel Applied for High Heating Condition"

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Abstract- **The pressure vessels are closed containers used to hold gases or liquids at a pressure substantially different from the ambient pressure. The pressure inside the vessel is different and may changes by the conditions. The vessels are too dangerous and fatal accidents have occurred in the history of pressure vessel development and operation. The pressure vessels are required to design with great care because rupture of pressure vessels means an explosion which may cause loss of life and property.**

A thermo-mechanical analysis has been carried out for the vertical shell pressure vessel operating in the high heating condition and pressure. The analysis is performed on model parts with three different materials i.e. Structural Steel, Magnesium alloy and Titanium alloy and the results are compared. A transient thermal and structural analysis has been carried out.

The stress and deformed values at high temperature application, the Titanium material pressure vessel model is better than the other two material because of the reduction of the stress values the life time of the vessel may increase.

Index Terms- Pressure Vessel, thermo-mechanical analysis, material, temperature, stresses, deformation, heat flux.

I. INTRODUCTION

1.1 Background

Pressure vessels are utilized in various ventures; for instance, the power age industry for fossil and atomic power, the petrochemical business for putting away and preparing rough oil in tank cultivates and in addition putting away fuel in benefit stations, and the concoction business (in synthetic reactors) to give some examples. Their utilization has extended all through the world. Pressure vessels and tanks are, actually, basic to the concoction, oil, petrochemical and atomic ventures. It is in this class of gear that the responses, partitions, and capacity of crude materials happen. As a rule, pressurized hardware is required for an extensive variety of mechanical plant for capacity and assembling purposes.

II-LITERATURE REVIEW

"Finite element analysis of dynamic responses of composite pressure vessels under low velocity impact by using a three-dimensional laminated media model" by B.B. Liao, L.Y. Jia, Thin-Walled Structures 129 (2018) 488–501

This paper expects to contemplate dynamic basic reactions and failure instruments of composite pressure vessels subjected to low speed affect. Initial, a three-dimensional overlaid media demonstrate in view of sub-overlay theory is presented for intra-laminar harm, where Puck's failure criteria and strain based harm advancement laws for fiber and lattice are utilized. The effect reactions of composite pressure vessels can be figured in view of sub-covers and the fiber and framework harm are anticipated in light of each employ by utilizing this approach.

"Failure analysis of a pressure vessel subjected to an internal blast load" by I. Barsouma, S.A. Lawal, R.J. Simmons, C.C. Rodrigues, Engineering Failure Analysis 91 (2018) 354–369

The goal of the ebb and flow work is to display a treated steel (SA 316L) autoclave blast and break that happened amid an exploration research facility test intended to examine the warm disintegration of ammonium tetrathiomolybdate within the sight of dimethylsulfoxide (DSMO) in the autoclave. A finite component examination is directed to more readily comprehend the reason for failure of the autoclave and with the goal to explore whether the occurrence was caused by static overpressure or an inner impact stack. The experimental CONWEP impact stacking model is utilized to demonstrate the inner impact stack.

"Parametric study of interaction effect between closely-spaced nozzles in a thin cylindrical pressure vessel", Kushan DS, Sanyal S, Bhowmick S, International Journal of Pressure Vessels and Piping (2018)

The presence of nozzle openings in process vessels gives rise to stress concentration The nearness of spout openings in process vessels offers ascend to pressure focus because of confinement of worries around openings. Presentation of second spout in region of first spout will produce its own particular pressure shapes and will interface with stretch forms of essential spout.

III-RESEARCH METHODOLOGY

Thermo-Mechnaical Analysis

Heat exchange issues and thermomechanical finite element investigations incorporates warm stacking and temperature cycling; temperature weakening; warm stun; pressurized warm stun; warm exchange examination; convective warmth and mass exchange; tempestuous constrained convection and warm radiation; warm stratification; warm striping; solidifying issues; crawl; nearby crawl; high-temperature auxiliary uprightness techniques; plan for lifted temperature benefit; warm weariness; fire execution; warm administration thinks about; parametric investigations.

Finite Element Analysis

The finite element examination is one of the numerical investigation methods that used to pick up the goals of incomplete differential conditions. The iterative scientific procedures like as Galerkin's weighted leftover strategy and Raleigh-Ritz methods castoff to pick up the finite element detailing of the incomplete differential condition.

Specification of the Problem and Part Definitions

The objective of the present study is to carry out the thermo mechanical analysis of a vertical shell pressure vessel used for high temperature application with the different material.

For modelling of the pressure vessel Autodesk Inventor software is opted. Then model imported in ANSYS 15.0 for analysis through applying the thermal and normal load conditions.

Figure 3.1 shows the geometry of the vertical shell pressure vessel. After the modelling the meshing desritization has been carried out. Figure 3.2 shows the meshed model. About 362902 Nodes and 133608 Elements have been generated.

Figure 3.1 Geometry of Vertical Shell Pressure Vessel

Figure 3.2 Meshing of Vertical shell pressure vessel geometry

Material

Currently the material used for the transporting pressure vessel are A709M Grade 345w structural steel, which is known as structure steel in simple words with the varying chemical composition leading to changes in names. Apart of this material the two other material i.e. Magnesium alloy and Titanium Alloy has been considered for the study. The material property for all the three alloy is tabulated in table 3.1

Table 3.1 Material property for Structural Steel.

Property	Structural Steel	Magnesium Alloy	Titanium Alloy
Density	7.85	1.8	4.51
Hardness	217(Brinell)	60 (Brinell)	250 (Brinell)
Tensile Strength ultimate (M Pa)	74.5	220	241
Yield Strength (M Pa)	470	130	206
Modulus of Elasticity (G Pa)	205	45	125

IV-RESULT ANALYSIS

4.1General

There are three different material has been considered for the study i.e. Structural Steel, Magnesium Alloy and Titanium Alloy. The analysis is based on the variables like Total deformation, directional deformation, stresses and strain generated and for thermal analysis Heat flux generated. The following results have been obtained.

4.2 Results for Structural Steel Pressure Vessel

Figure 4.1, 4.2 and 4.3 shows the Total Deformation, Radial Deformation and Longitudinal Deformation in vertical shell pressure vessel of Structural Steel material. The maximum value of Total, radial and longitudinal deformation obtained is about 38.81, 12.3 and 38.22 mm respectively.

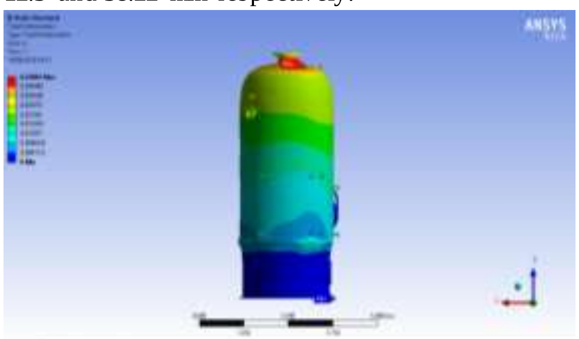

Figure 4.1 Total Deformation in vertical shell pressure vessel of structural steel material

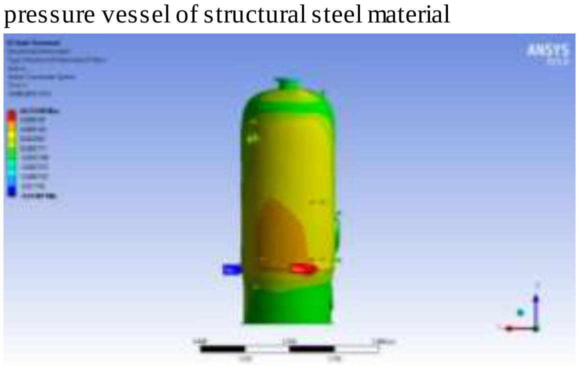

Figure 4.2 Radial Deformation in vertical shell pressure vessel of structural steel material

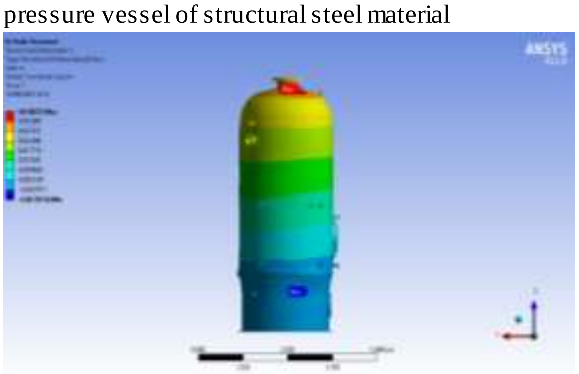

Figure 4.3 Longitudinal Deformation in vertical shell pressure vessel of structural steel material

Figure 4.4 Equivalent Elastic Strain in vertical shell pressure vessel of structural steel material

Figure 4.5 Equivalent Stress in vertical shell pressure vessel of structural steel material

Figure 4.6 Maximum Principal Stress in vertical shell pressure vessel of structural steel material

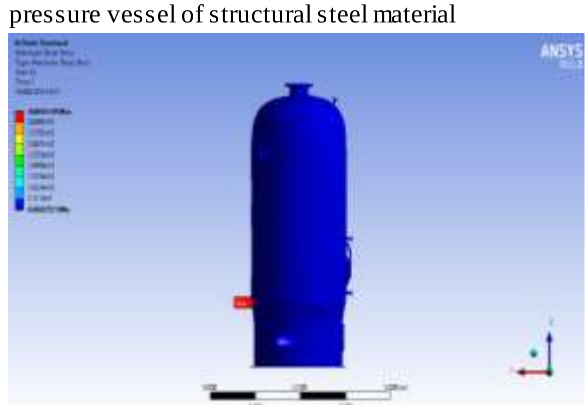

Figure 4.7 Maximum Shear Stress in vertical shell pressure vessel of structural steel material

Figure 4.8 Heat Flux in vertical shell pressure vessel of structural steel material

4.3 Results for Magnesium Alloy Pressure Vessel

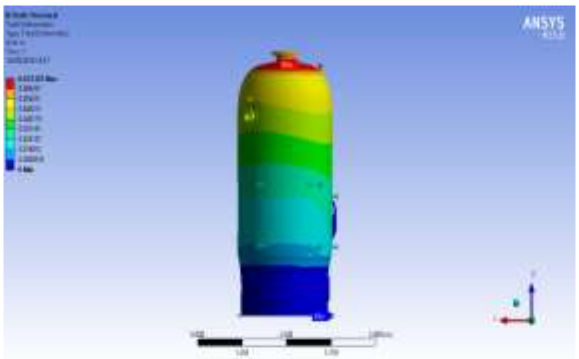

Figure 4.9 Total Deformation in vertical shell pressure vessel of Magnesium Alloy material

4.4 Results for Titanium Alloy Pressure Vessel

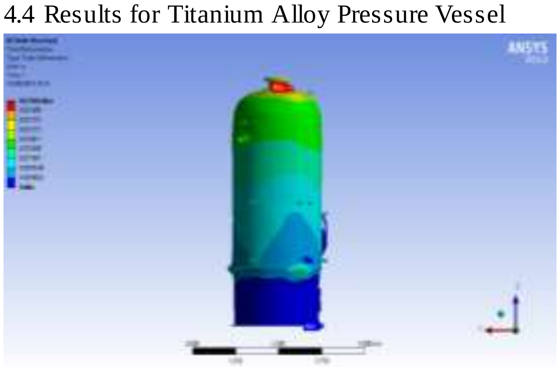

Figure 4.10 Total Deformation in vertical shell pressure vessel of Titanium Alloy material

4.5 Discussion

4.5.1 Deformation

There are three types of deformation in the structure has been considered for the study i.e. Radial, Longitudinal and Total Deformation. If we consider the total deformation the magnesium alloy shows high deformation. The radial as well as longitudinal deformation both are also high in Magnesium Alloy material.

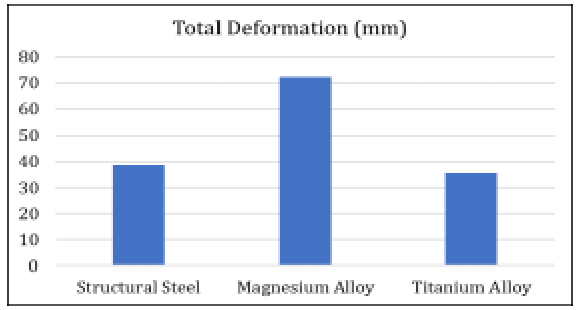

Figure 4.11 Total deformation comparison in all the three material

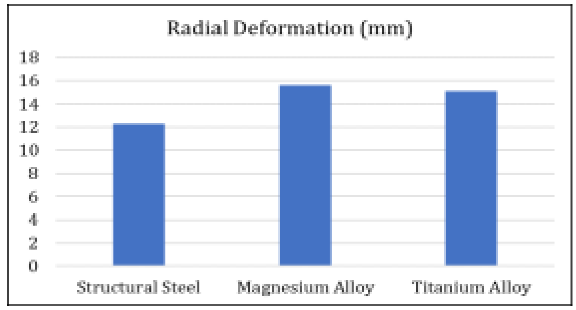

Figure 4.12 Radial deformation comparison in all the three material

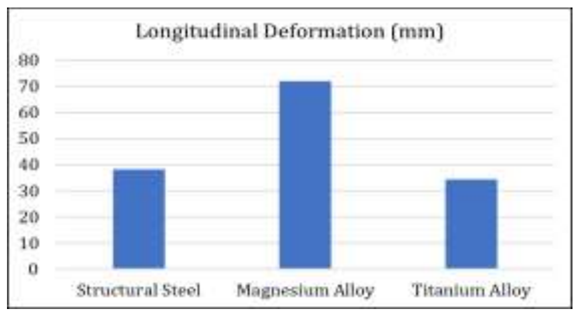

Figure 4.13 Longitudinal deformation comparison in all the three material

4.5.2 Elastic Strain

Elastic Strain is the property by which a deformed body returned to its original shape when the load is removed. The Elastic Strain is maximum in Titanium Alloy material pressure vessel.

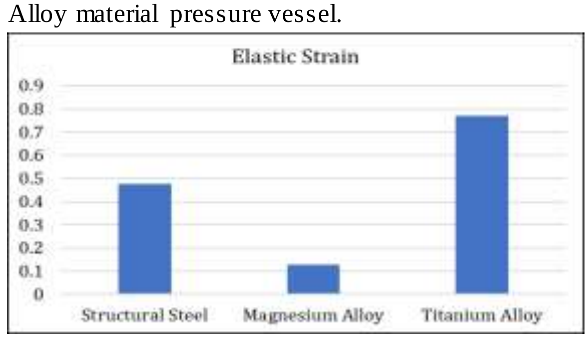

Figure 4.14 Elastic Strain comparison in all the three material

4.5.3 Stresses

There are three types of stress has been considered for the comparative analysis i.e. Equivalent Stress, Maximum Principal Stress and Maximum Shear Stress.

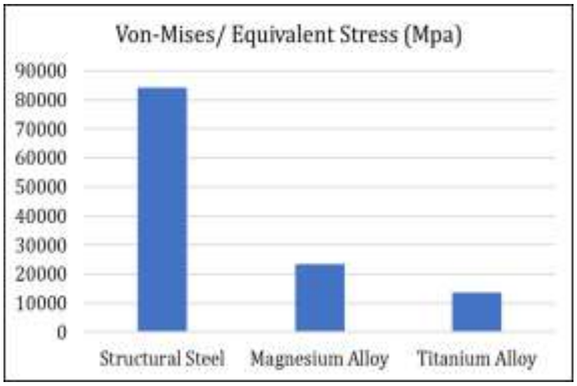

Figure 4.15 Equivalent Stress comparison in all the three material

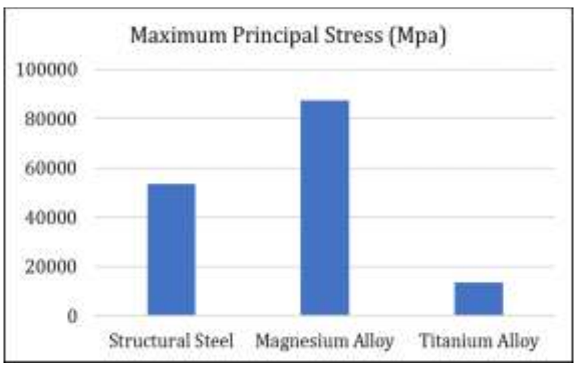

Figure 4.16 Maximum Principal Stress comparison in all the three material

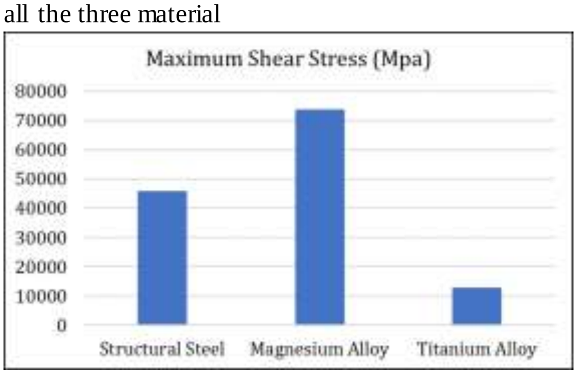

Figure 4.17 Maximum Shear Stress comparison in all the three material

4.5.4 Heat Flux

Heat flux can be defined as the amount of heat transfer per unit area per unit time from the surface of any object. As per the results obtained the Titanium Alloy shows the less heat flux and Magnesium alloy shows the high heat flux (Figure 4.32)

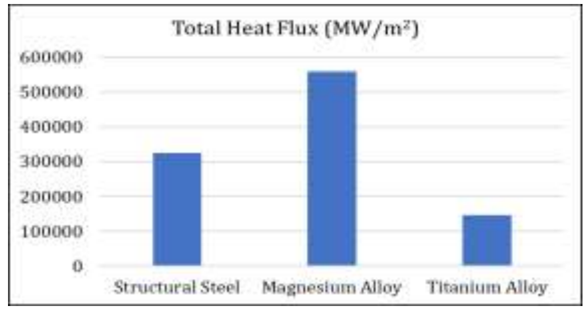

Figure 4.18 Total Heat Flux comparison in all the three material

Table 4.1 Summary of results obtained after FEA of vertical shell pressure vessel

	Structural Steel	Magnesium Alloy	Titanium Alloy
Total Deformation (mm)	38.81	72.32	35.66
Radial Deformation (mm)	12.3	15.58	15.07
Longitudinal Deformation (mm)	38.225	71.968	34.46
Elastic Strain	0.47668	0.129	0.77
Von-Mises/ Equivalent Stress (Mpa)	84219	23490	13510
Maximum Principal Stress (Mpa)	53424	87360	13696
Maximum Shear Stress (Mpa)	46007	73831	12770
Total Heat Flux (MW/m2)	324617	558880	145670

V-CONCLUSION

A Finite Element Analysis has been carried out. The following results have been obtained which shows the more applicability of Titanium Alloy material for the high heating and normal load application compare then other two materials i.e. structural steel and Magnesium alloy.

[1] Total Deformation, Radial Deformation, Longitudinal Deformation, Elastic Strain, Von-Mises/ Equivalent Stress, Maximum Principal Stress, Maximum Shear Stress and Total Heat Flux are the basic criterion that has been considered for the analysis. After the Finite Element Analysis following results have been carried out:

[2] There are three types of deformation in the structure has been considered for the study i.e. Radial, Longitudinal and Total Deformation. If we consider the total deformation the magnesium alloy shows high deformation. The radial as well as longitudinal deformation both are also high in Magnesium Alloy material. In Titanium alloy material Total deformation and longitudinal deformation both are minimum.

[3] The Elastic Strain is maximum in Titanium Alloy material pressure vessel. As the

deformation is less in Titanium alloy material the ability to regain its original shape is also high. With higher deformation magnesium alloy shows less ability.

[4] The Equivalent, Maximum Principal and Maximum Shear Stress generated is minimum in Titanium Alloy material pressure vessel. Titanium material pressure vessel shows less Maximum principal stress and Maximum Shear Stress will be more suitable for the application.

[5] Titanium Alloy shows the less heat flux and Magnesium alloy shows the high heat flux.

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