Design And Modal Analysis Of Horizontal Pressure Vessel

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Abstract: *In Process Industries, such as chemical and petroleum industries designers have recognized the limitations involved for confining large volumes of high internal pressures in single wall cylindrical metallic vessels. In process engineering as the pressure of the operating fluid increases, which results in increment in the thickness of the vessel to hold that fluid is an automatic choice. In order to avoid the increase in thickness of a Pressure vessel an alternative is to use the Composite materials instead of Steel.*

In this thesis, the Horizontal Pressure vessel will be deigned according to the principles specified in American Society of Mechanical Engineers (A.S.M.E) Sec VIII Division 1. The 3D models of the Horizontal Pressure vessel with elliptical head will be done in CREO 2.0. Structural, Modal and Random vibration analysis will be done in Ansys for Horizontal Pressure vessel with elliptical head using carbon steel and composite materials like CFRP and Kevlar.

Key words: *Elliptical head, MAWP, MAP, EFE, Nozzle reinforcement etc.*

I.INTRODUCTION

Storage tanks are vessels that hold liquids, compressed gases or mediums used for the short- or long-term storage of heat or cold.

In the USA, storage tanks operate under no pressure, differentiating them from pressure vessels. Storage tanks are often cylindrical in shape, perpendicular to the ground with flat bottoms, and a fixed flange or floating roof. There are usually many environmental regulations applied to the design and operation of storage tanks, often depending on the nature of the fluid contained within. Above ground storage tanks differ from underground storage tanks in the kinds of regulations that are applied.

TYPES OF PRESSURE VESSELS

Based on the installation of tank the tank can be classified into two types.

1. Horizontal Pressure vessel
2. Vertical Pressure vessel

In the case of a liquefied gas such as hydrogen or chlorine, or a compressed gas such as compressed natural gas or MAPP, the storage tank must be made to withstand the sometimes immense pressures exerted by the contents. These tanks may be called cylinders and, being pressure vessels, are sometimes excluded from the class of "tanks".

Vertical storage tanks are produced by a number of manufacturers, which includes Norwesco, Ace Roto-Mold, Duracast, Snyder, and Poly-Mart. These seamless tanks are formed by rotationally molding high-density virgin polyethylene resin. Because they are made from plastic, the tanks have a natural resistance to rust, corrosion, and impact. The addition of UV inhibitors during production makes them resistant to sun degradation as well.

Vertical storage tanks have flat bottoms, so they can support themselves without the use of additional equipment. They are lightweight and can be moved manually when necessary. They have a long, useful lifespan and do not require maintenance.

II. Materials

While steel and concrete remain one of the most popular choices for tanks, glass-reinforced plastic, thermoplastic and polyethylene tanks are increasing in popularity. They offer lower build costs and greater chemical resistance, especially for storage of specialty chemicals. There are several relevant standards, such as British Standard 4994, DVS (2205, and ASME RTP-1 which give advice on wall thickness, quality control procedures, testing procedures, accreditation, fabrication and design criteria of final product.

Material	Density (g/cc)	Young's modulus (gpa)	Poisson's ratio
Steel	7.85	235	0.3
Cfrp	1.6	70	0.101
Kevlar	1.47	68	0.3

ASME CODE, SECTIONVIII, DIVISION 1

It provides the requirements applicable to the design, fabrication, inspection, testing and certification of Pressure vessels operating at either internal or external pressures, this code as established in 1925(section VIII DIV I). The pressure vessels operate between 15psi to 3,000 psi comes under ASME Section VIII div I.). The pressure vessels operate between 3,000psi to 10,000 psi comes under ASME Section VIII div II. Its requirements are more rigorous than in division I. The pressure vessels operate more than 10,000 psi comes under ASME Section VIII div III. It does not establish maximum pressure limits. Its requirements are more rigorous than in division I and division II.

III. DESIGN OF CONSIDERATIONS

Inner diameter= 96”

Length=120”

Nominal thickness=3”

Corrosion allowance= 0.125”

Allowable stress=20,000 PSI

MAWP=1150 PSI

MAP= 1204 PSI

MDMT= -24.5°F

Design of Shell

Design thickness, (at 100 °F) UG-27(c)(1)

t = P*R / (S*E - 0.60*P) + Corrosion Allowance

Maximum allowable working pressure, (at 100 °F) UG-27(c)(1)

P = S*E*t / (R + 0.60*t) - P_s

Maximum allowable pressure, (at 70 °F) UG-27(c)(1)

P = S*E*t / (R + 0.60*t)

% Extreme fiber elongation - UCS-79(d)

EFE = (50*t / R_f)*(1 - R_f / R_o)

Elliptical head

Design thickness for internal pressure, (Corroded at 100 °F) Appendix 1-4(c)

t = P*D*K / (2*S*E - 0.2*P) + Corrosion

Maximum allowable working pressure, (Corroded at 100 °F) Appendix 1-4(c)

P = 2*S*E*t / (K*D + 0.2*t) – Ps

Maximum allowable pressure, (New at 70 °F) Appendix 1-4(c)

P = 2*S*E*t / (K*D + 0.2*t) - Ps

% Extreme fiber elongation - UCS-79(d)

EFE = (75*t / Rf)*(1 - Rf / Ro)

Design of Nozzle

Nozzle required thickness per UG-27(c)(1)

trn = P*Rn / (Sn*E - 0.6*P)

Required thickness tr from UG-37(a)

tr = P*R / (S*E - 0.6*P)

IV. CREO MODELING

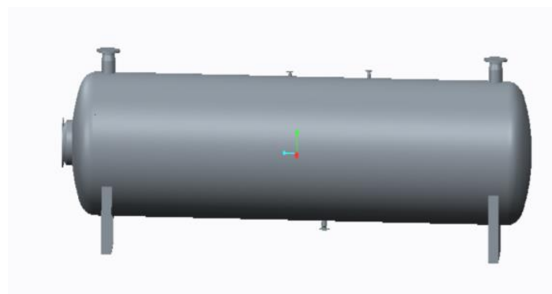


Fig.1- Assembly of Pressure vessel

V. RESULTS AND DISCUSSION

Static, Modal and Random Vibration Analysis for Horizontal Pressure Vessel by Using ANSYS 14.5.

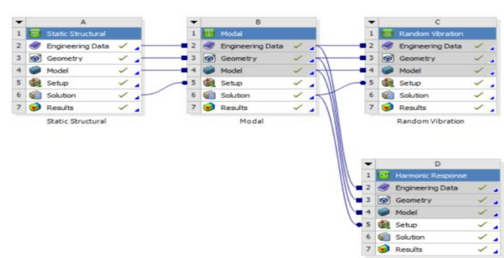


Fig.2- Analysis in Ansys workbench

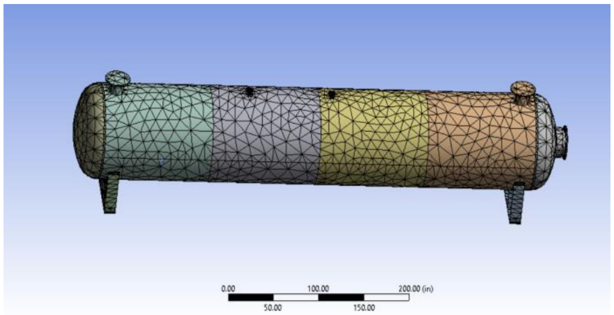


Fig.3- Meshed Model in Ansys workbench

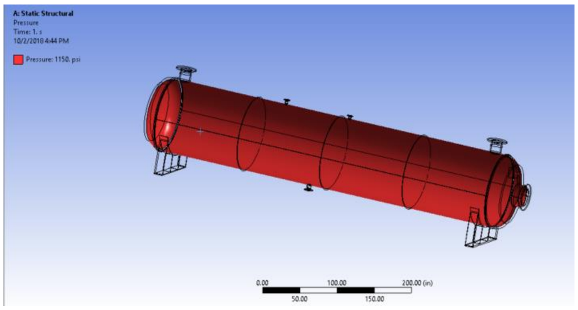


Fig.4- Apply Pressure on shell

Material:-Steel

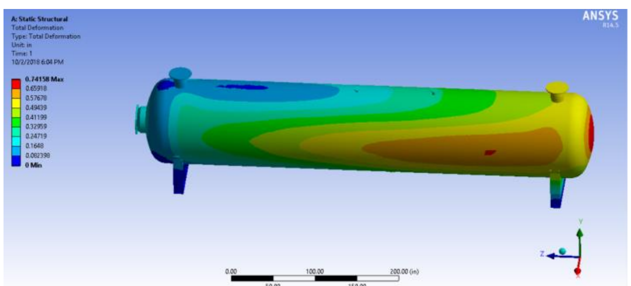


Fig.5- Total deformation

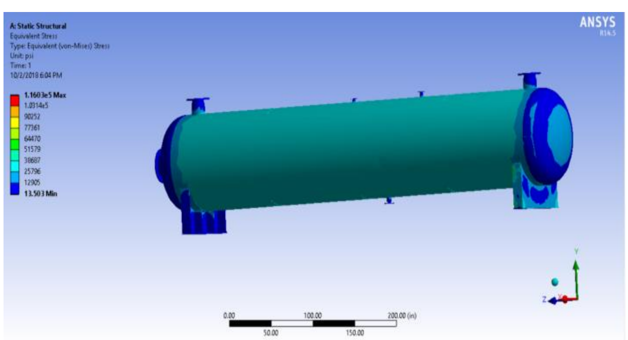


Fig.6- Equivalent stress

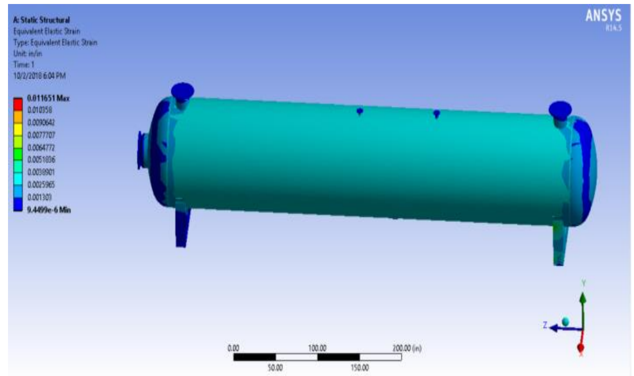


Fig.7- Equivalent strain

Material: - CFRP

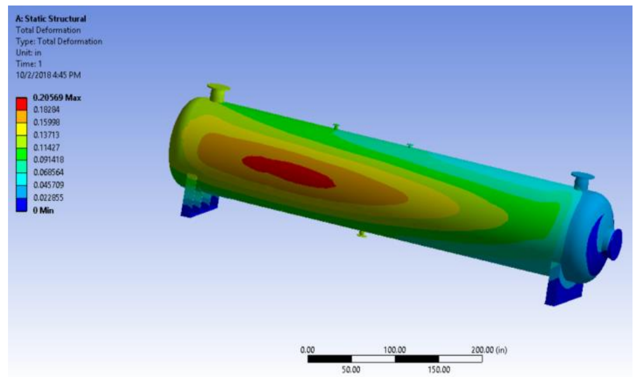


Fig.8- Total deformation

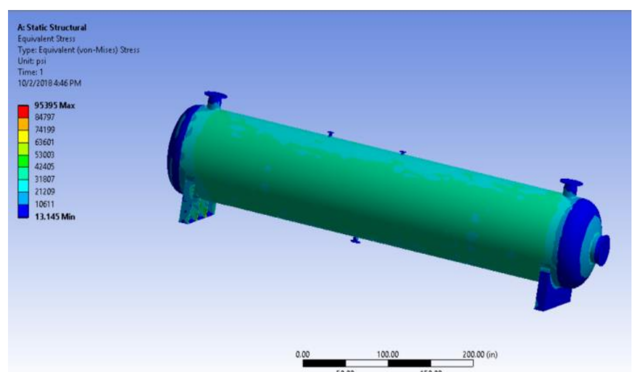


Fig.9- Equivalent stress

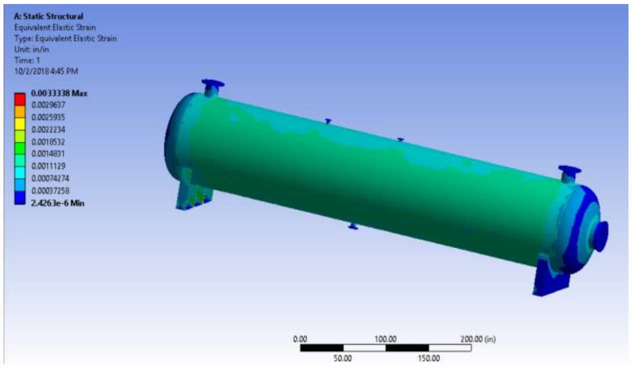


Fig.10- Equivalent strain

Material: - Kevlar

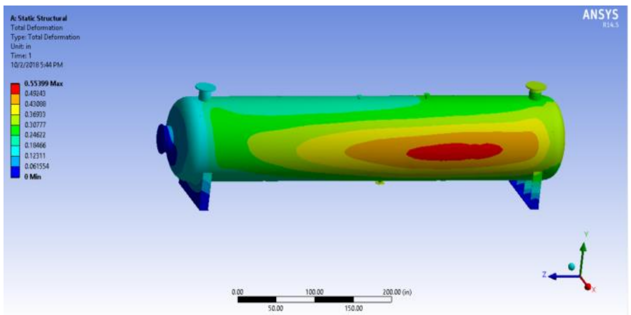


Fig.11- Total deformation

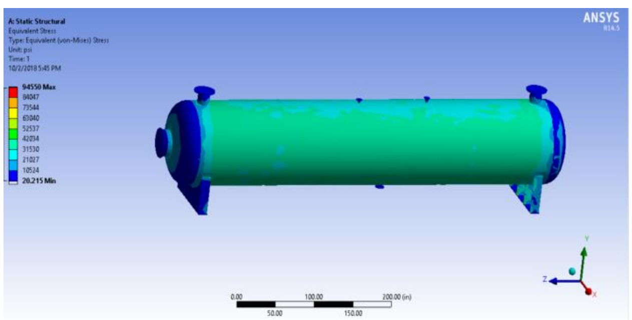


Fig.12- Equivalent stress

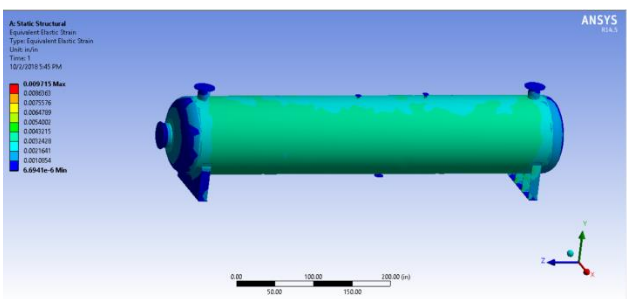
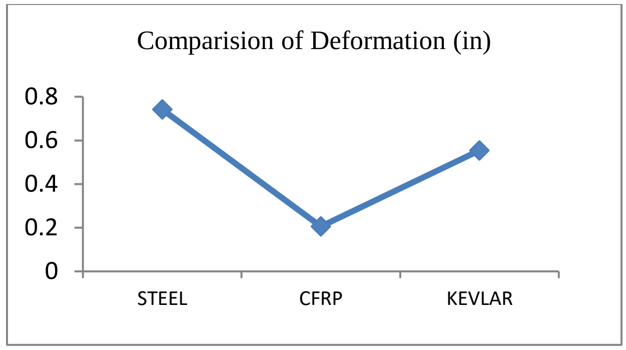
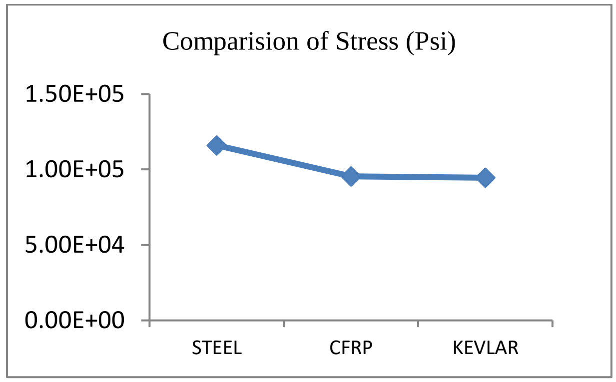


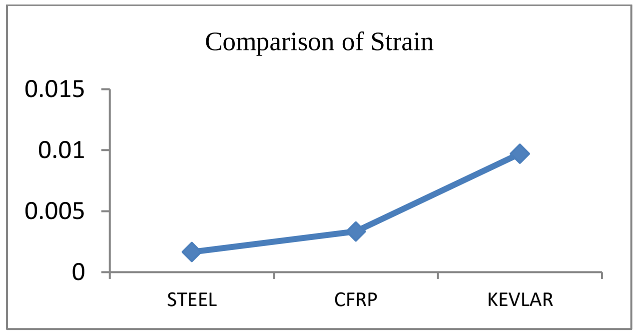
Fig.13- Equivalent strain



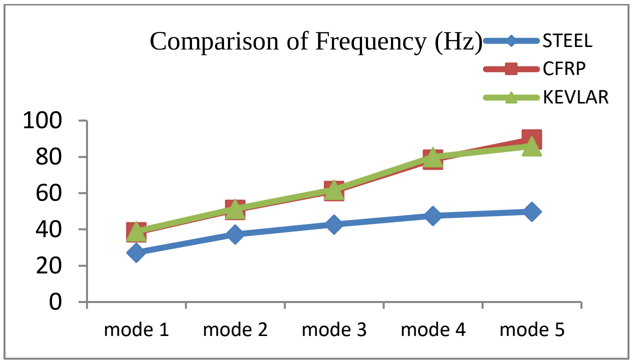
From the above graph it is indicated that the comparison of deformation for the three different materials when the operating pressure is applied to the pressure vessel and the deformations is less for CFRP while compare to other materials



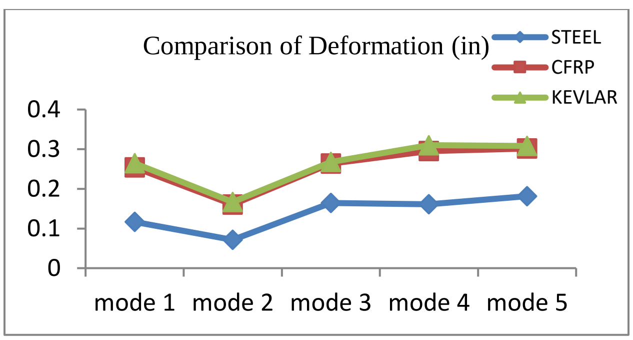
From the above graph, It is shown that the comparison of stress for the three different materials when the operating pressure is applied to the pressure vessel and the stress is less for CFRP while compare to other materials.



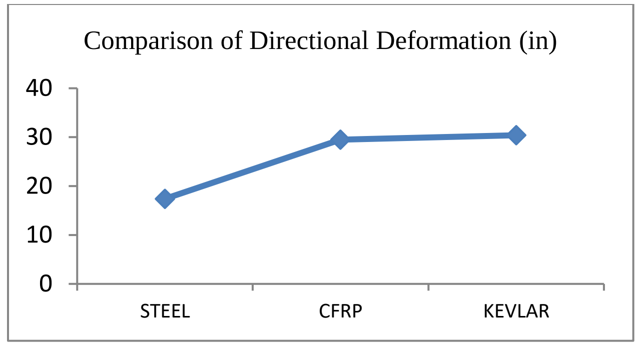
From the above graph It is indicated that the comparison of strain for the three different materials when the operating pressure is applied to the pressure vessel and the strain is less for steel while compare to other materials.



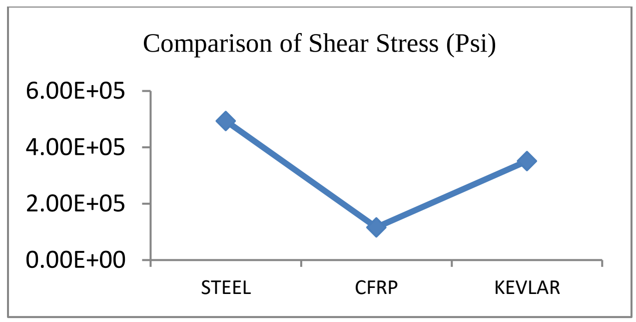
From the above graph, it is indicated that the comparison of frequency for the three different materials and all modes when the operating pressure is applied to the pressure vessel and the frequency is less for steel while compare to other materials.



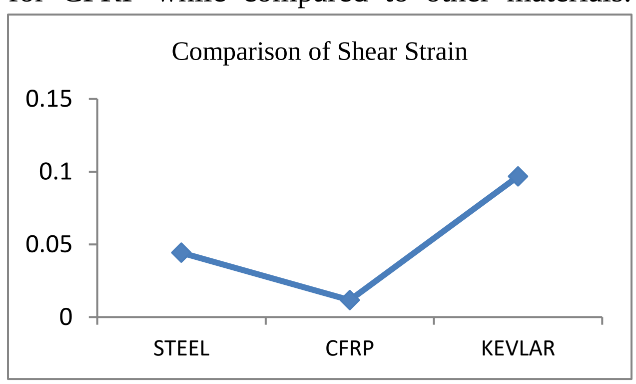
From the above graph, it is indicated that the comparison of deformation for the three different materials and all modes when the operating pressure is applied to the pressure vessel and the deformation is less for steel while compare to other materials.



From the above graph it is indicated that the comparison of directional deformation for the three different materials when the operating pressure is applied to the pressure vessel and the directional deformation is less for steel while compare to other materials



From the above graph, it is indicated that the comparison of shear stress for the three different materials when the operating pressure is applied to the pressure vessel and the shear stress is less for CFRP while compared to other materials.



From the above graph, it is indicated that the comparison of shear strain for the three different materials when the operating pressure is applied to the pressure vessel and the shear strain is less for CFRP while compare to other materials.

CONCLUSION

By observing the static analysis results, the deformations and stresses are increasing by increasing the pressure. The materials Steel, CFRP and Kevlar are used in this analysis with respective allowable stress value 1150 Psi. The results are observed from the ansys are following.

- The stress and deformation values are less for CFRP in structural analysis.
- By observing the modal analysis results, the deformation and frequency values are less for Steel. so vibrations will be less,.
- By observing the random vibration analysis, the shear stress values are less when CFRP is used.
- By observing the harmonic response the amplitude is less for the CFRP

The values are better for CFRP in all analysis, but by considering strength to weight ratio, composite materials are more advantageous than Steel.

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