Finite Element Analysis of Support Designs for Road Tankers

Mr.Rohan Balasaheb Patil [1] , Prof.Dr.V.V.Kulkarni [2]

[1]Department of Mechanical Engineering, KIT's college of Engineering Kolhapur
[2]Department of Mechanical Engineering, Sanjay Ghodawat Institute ,Atigre

---

Abstract - *A pressure vessel is a closed container designed to hold gases or liquids under internal or external pressure .Pressure vessels are designed to operate safely at a specific pressure and temperature. A saddle support is used to support the horizontal pressure vessels and are welded or permanently fixed to the pressure vessel using U clamp. Generally horizontal pressure vessels supported on saddle supports are designed by zicks formula but in this method there are certain assumptions. This method is not applicable for different loading conditions. The stresses and stress concentration in vessel due to saddle support are difficult to calculate by traditional theories There are different types of saddle support used for horizontal pressure vessel for different capacity ranging from 2,500 litre to 25,000 litre. The main purpose of this work is to perform stress analysis of different parts of saddle support by using finite element analysis software ANSYS 16.*

Key Words*: Stress, Deflection,Saddle Support,ANSYS*

1. INTRODUCTION

Pressure Vessel, is a container designed to hold gas or liquid at a substantially high pressure that is usually different from the ambient pressure. Pressure vessels are dangerous, and fatal accidents have occurred in the history of the development and operation and of pressure vessels. Consequently, pressure vessel design, manufacture, and operation are regulated by engineering authorities backed by legislation. For these reasons, the definition of a pressure vessel varies from country to country. Design involves parameters such as maximum safe operating pressure and temperature, safety factor, corrosion allowance and minimum design temperature (for brittle fracture). Construction is tested using non-destructive testing, such as ultrasonic testing, radiography, and pressure tests. Hydrostatic tests use water, but pneumatic tests use air or another gas. Hydrostatic testing is preferred, because it is a safer method, as much less energy is released if a fracture occurs during the test (water does not rapidly increase its volume when rapid depressurization occurs, unlike gases like air, which fail explosively). Many pressure vessels are made of steel. To manufacture a cylindrical or spherical pressure vessel, rolled and possibly forged parts would have to be welded together. Some mechanical properties of steel, achieved by rolling or forging, could be adversely affected by welding, unless special precautions are taken. In addition to adequate mechanical strength, current standards dictate the use of steel with a high impact resistance, especially for vessels used in low temperatures. In applications where carbon steel would suffer corrosion, special corrosion resistant material should also be used.. A saddle support is used to support the horizontal pressure vessels and are welded or permanently fixed to the pressure vessel using U clamp. The appropriate location of saddle support is most important form the view point of stresses developed in pressure vessel. If the location of saddle support is not correct it will result in higher stresses at pressure vessel junction and will lead to failure of pressure vessel. Therefore, the design of saddle support and determining the stresses developed in saddle and part of pressure vessel is an important step during design of a horizontal pressure vessel. The forces acting on saddle support due to weight of horizontal pressure vessel and internal pressure, causes stresses in the saddle supports.

2. LITERATURE SURVEY

L.P.Zick (1951) presented a study on design of horizontal cylindrical vessels with dished heads to resist internal pressure by existing codes. The purpose of this paper is to indicate the approximate stresses that exist in cylindrical vessel supported on two saddles at various locations. By knowing these stresses, it is possible to determine which vessel may be designed for internal pressure alone, and to design structurally adequate and economical stiffing for the vessels which require it. Formulas are developed to cover various conditions, and a chart is developed which covers support designs for pressure vessels made of mild steel for storage of liquid. An attempt has been to produce an approximate analysis involving certain empirical assumptions which makes the theoretical analysis closely approximate the test results

Vlastimil Krupka (1991) presented work on more advanced solution of the limit state of horizontal vessel (in the region of the saddle supports),which shows the true picture of the real load carrying capacity but, at the same time provide a simpler and easier solution useful in design practice. Its help in the application of the design of vessels (which are full of liquid) under cyclic load or, if need be, to check a buckling stability and even in the possibility of its application form the point of view of a more advanced concept of design, respecting shake-down effect and categorization of stresses according to ASME code, Sections III and VIII, Division 2.

L.Yang,C.Weinberger & Y.T.Shah(1994) presented a study on finite element analysis to predict the stress distribution within a water filled horizontal vessel with hemispherical ends and two or three saddle supports. Computations where performed for various values of design parameters. The wall thickness was varied from 0.5 to 70 mm; the vessel length from 10 to 30m; and the vessel radius from 0.5 to 2.0m.The effects of the pressure and a third saddle support where investigated and the maximum tensile and shear stresses are compared with the prediction of zick's analysis. The objective of the paper was to compute the stress distribution within the vessel wall as a function of pressure and the geometric variables of the vessel shape, wall thickness and saddle location. A finite element analysis technique was used to determine the stresses within the vessel walls and the results where compared with experimental results obtained.

Shen Naijie (1995) investigated the stresses in saddle supports of pressure vessels and piping by experimental and theoretical analysis. Electric strain gauge measurement and a double Fourier series expansion method is used to analysis the model. To determine the contact pressure distribution pattern between saddle and model a trial and error and method is used. W. M Banks, D. H. Nash, A E Flaherty, W C Fok, A S Tooth (2000) presented a study on maximum strain on glass reinforced plastic (GRP) vessel, used for unpressurised liquid storage and supported on rigid saddle support, occurs in the immediate region of the saddle horn on the outside surface. Fourier series solution have been used to conduct the parametric study and to provide the results for the maximum strain in 'closed form', an equation fitting technique has been used.

N.EL-Abbasi (2001) presented the three-dimensional finite element analysis of a pressure vessel resting on flexible saddle support. It was carried out using a newly developed thick shell element and accounts for frictional contact between pressure vessel and saddle support. The seven parameter shell element used is capable of evaluating the variation of the stresses and the strain field through its thickness. The technique used was variational inequalities based formulation for the accurate description of class of frictionless contact problems .The effect of saddle radius, saddle width, plate extension and support overhang on the resulting stress field in both vessel and support are evaluated.

K.Magnucki, P.Stasiewicz, W.Szyc (2003) presented on supporting saddle of a horizontal cylindrical pressure vessel filled with liquid. The parametric model of the saddle support was developed and the effect of geometrical parameter on the stress values arising in a structure was examined by means of finite element analysis method. The shape and location of the saddle, which gives minimum stress concentration, has been determined. Results of Numerical analyses allow the effective proportion of the geometrical parameters of the vessel.

Shafique M.A.Khan (2010) presented the analysis results of stress distribution in horizontal pressure vessel and saddle supports. He used 3D finite element analysis method for determining stresses in different parts of pressure vessel and saddle support. He used the quarter of the pressure vessel model with details of saddle supports. It provides the detail of stress distribution in pressure vessel and parts of saddle supports. He studied the effect of changing load and various geometric parameters and recommended the optimal values of ratio of the distance of support from the end of the vessel to the length of vessel and ratio of length of vessel to the radius of the vessel for minimum stresses in both pressure vessel and saddle support. He concluded that the highly stressed area beside the pressure vessel and saddle horn is the flange plate.

3. PROPOSED SYSTEM

3.1 Collection of different design of road tankers supports

The different design collections of conventional road water tankers and their CAD modeling of the same

Design: 1

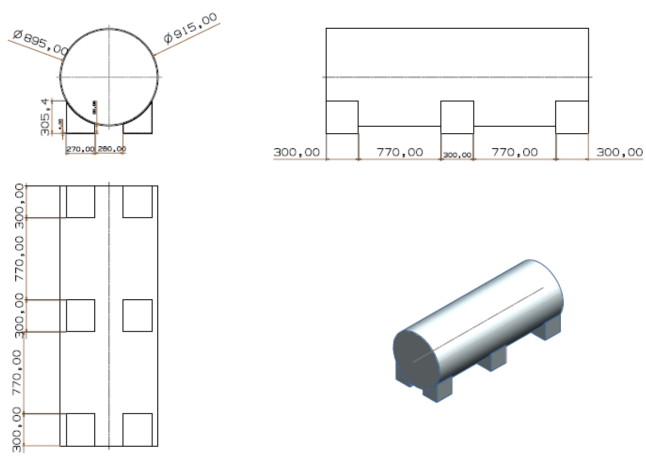

Fig.3.1- Leg Support

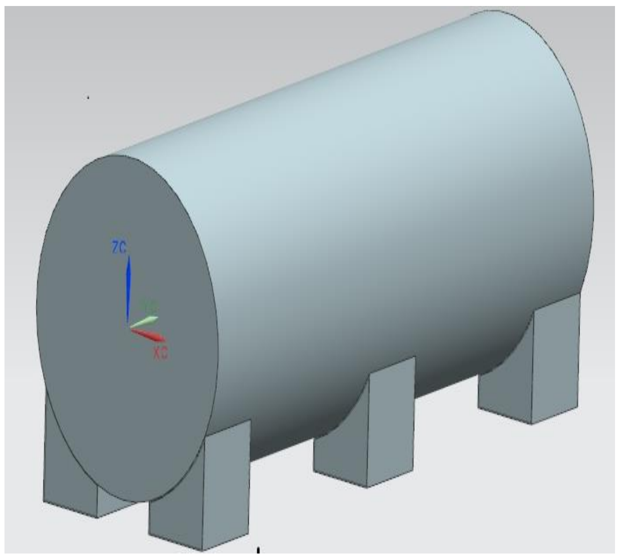

Fig.3.2-3D Model of Design 1

Fig.3.1: Shows Design collection of road tanker with leg supports that are placed at a specific distance of the vehicle chassis frame and Fig No-3.2 shows the 3D model of the Design 1, Design: 2

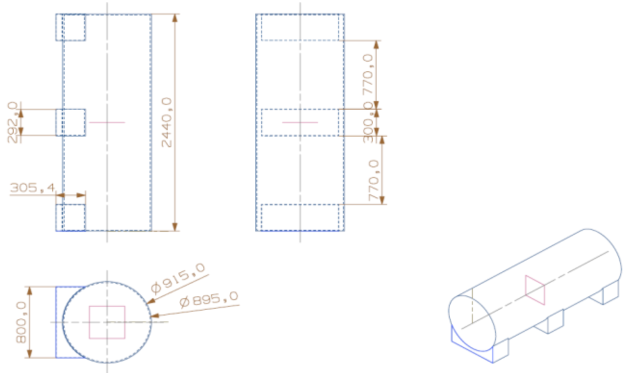

Fig.3.3-Continuous Supports

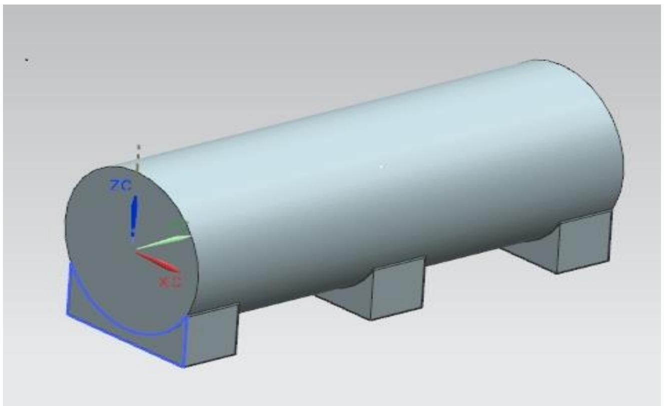

Fig.3.4- 3D Model of Design 2

Fig.3.3: Shows Design collection of road tanker with Continuous supports that are placed at a specific distance of the vehicle chassis frame and Fig.3.4 shows the 3D model of the Design 2, Design: 3

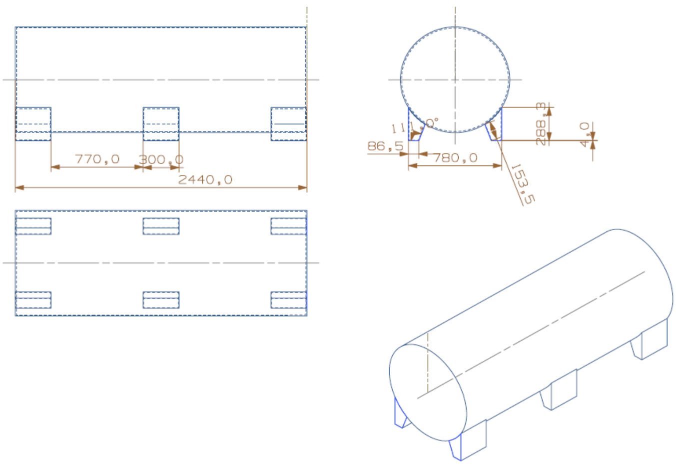

Fig.3.5-Supports for milk tankers which are placed at specific distances

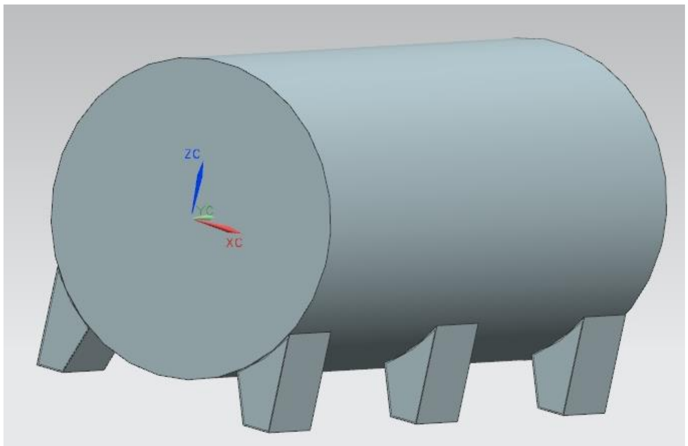

Fig.3.6- 3D Model of Design 3

Fig.3.5: Shows Design collection of road tanker with supports like milk tankers that are placed at a specific distance of the vehicle chassis frame and Fig.3.6 shows the 3D model of the Design 3

Design: 4.

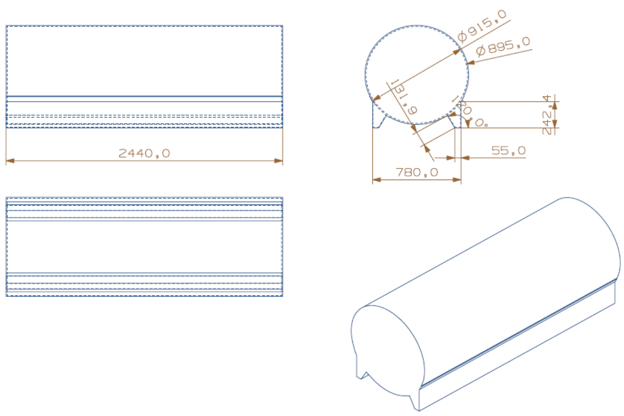

Fig.3.7- Supports for milk tankers along the length

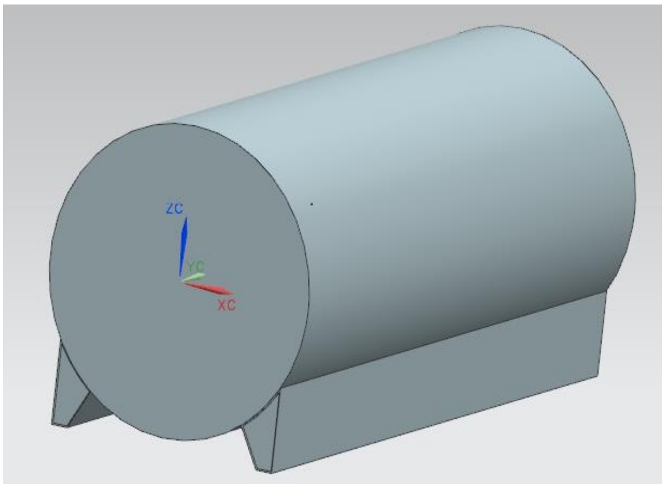

Fig.3.8- 3D Model of Design 4

Fig.3.7: Shows Design collection of road tanker with supports like milk tankers that are placed along the length of the vehicle chassis frame and Fig.3.8 shows the 3D model of the Design 4

FEA mesh model's

The following Fig.3.9 to Fig.3.12 shows various design collection of road tankers i.e. Design 1 to Design 4 model meshing,

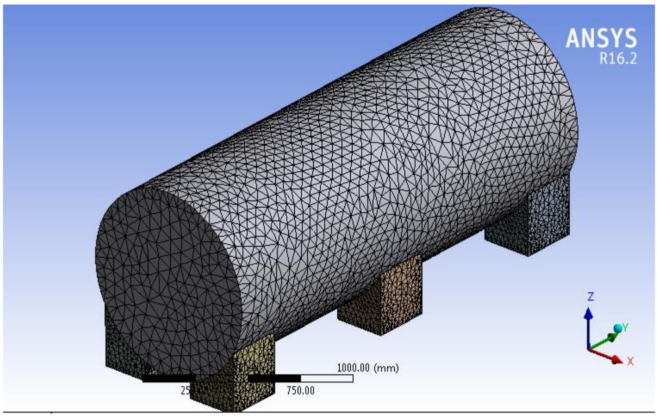

Fig.3.9: Mesh Model of Pressure Vessel of design 1

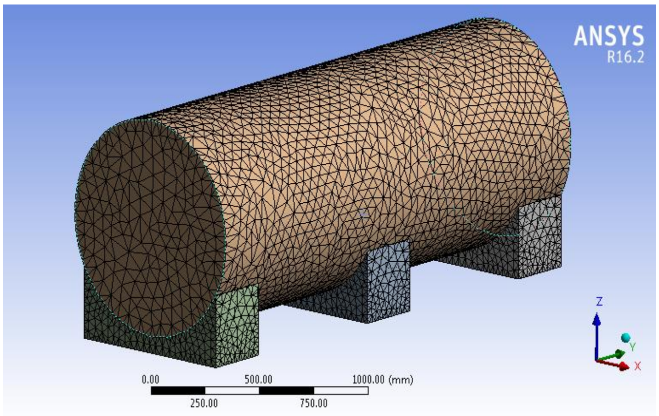

Fig.3.10: Mesh Model of Pressure Vessel design 2

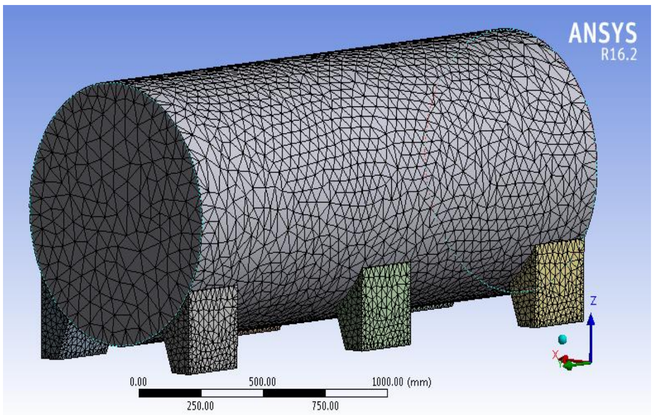

Fig.3.11: Mesh Model of Pressure Vessel Design 3

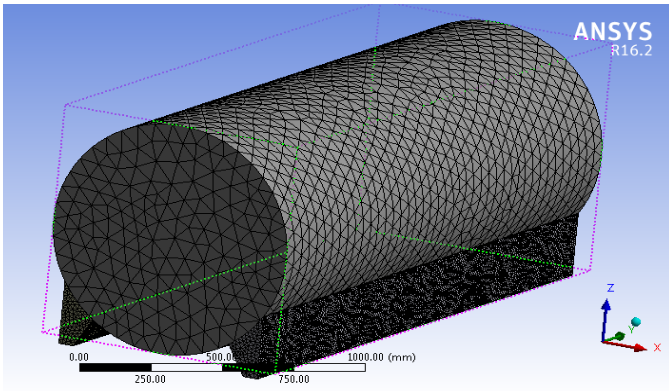

Fig.3.12: Mesh Model of Pressure Vessel of design 4

Boundary condition

Boundary Conditions: Internal pressure is applied red color indicates that internal pressure is been applied to the vessel and base plate of saddle supports is fixed in all directions.

1: Force

Tanker Capacity = 2500 Litre
Density of Water1000 Kg / m3 or 1.00 Kg / L

$$\text{Density} = \frac{mass}{volume} = \frac{Kg}{m3}$$

$$1.000 = \frac{Kg}{2500}$$

Kg = 2500
Force in N = Kg x Gravitational Acceleration
= 2500 x 9.81
Force = 24525 N

2. Pressure

Water Tanker work at atmospheric Pressure
Atmospheric Pressure = 1 bar
Pressure Value required for Analysis in ANSYS Software in MPA
1 bar =0.1 MPa

Element type

The elements used for the meshing of the full and ventilated disc are tetrahedral three-dimensional elements with 10 nodes (solid187) the meshing was refined in the contact zone (saddle support). This is important because in this zone, the total load acting on support and it varies significantly. Indeed, in this strongly deformed zone. That is why the correct taking into account of the contact conditions involves the use of a refined mesh

4. RESULTS AND DISCUSSION

We have checked the result of designs collected of tanker 1 to tanker 4 their FEA results with von-miss stress and deflection in the pressure vessel. The details is shown in the figures from Fig 4.1 to Fig 4.12

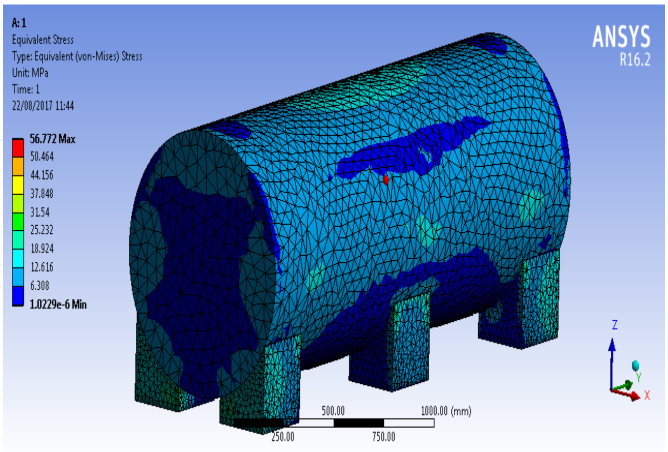

Fig.4.1- Static Structural Analysis of Design 1 Model Color Code shows Von-misses stresses over Pressure vessel body and Supports

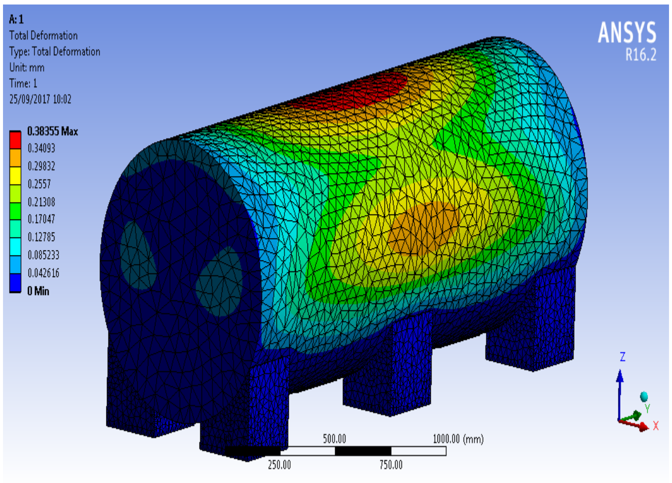

Fig.4.2 –Shows the deflection in body of design 1 pressure vessel

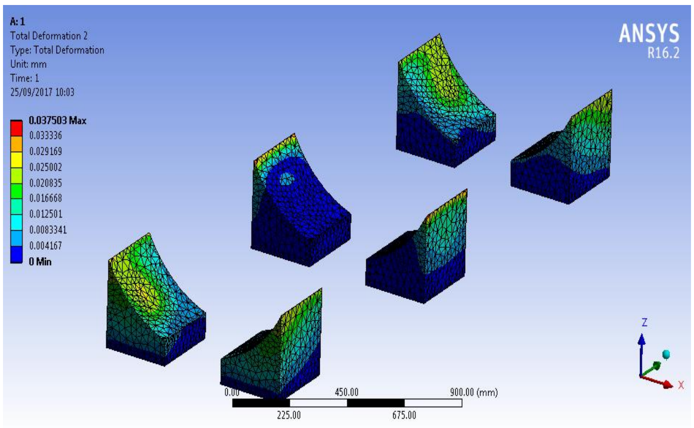

Fig.4.3Shows the deflection in support design of design 1 pressure vessel

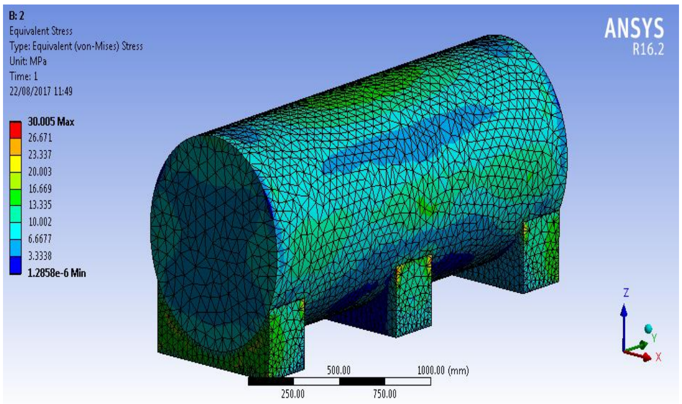

Fig.4.4 Static Structural Analysis of design 2 Model Color Code shows Von-misses stresses over Pressure vessel body and Supports

Saddle support used for Model 2 is a continues member and most of the pressure vessel surface is supported by saddles. But material requirement for this type of support is more than model 1 support. According FEA Analysis result both conditions are safe, but model 2 saddle supports is heavy and costly.

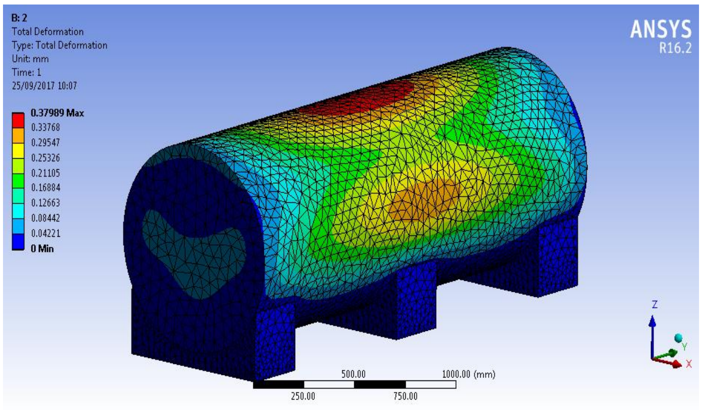

Fig.4.5 shows the deflection in body of design 2 pressure vessel

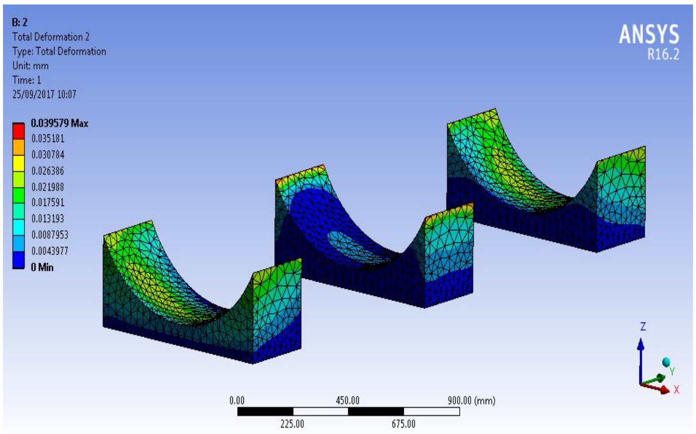

Fig.4.6 shows the deflection in saddle support of design 2 pressure vessel

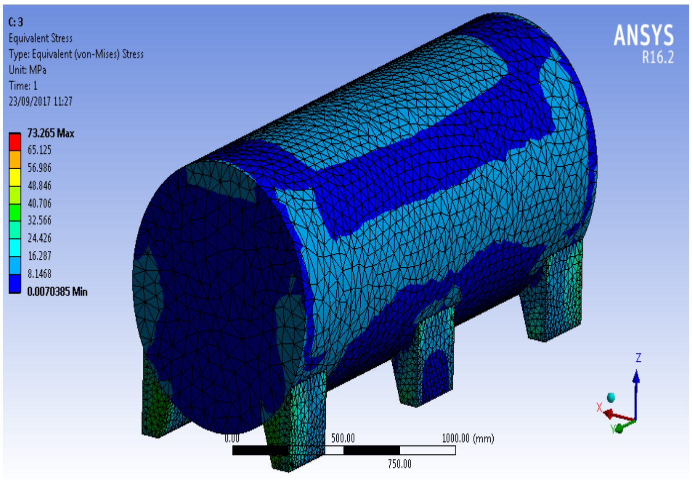

Fig..4.7 Static Structural Analysis of design 3 Model Color Code shows Von-misses stresses over Pressure vessel body and Supports

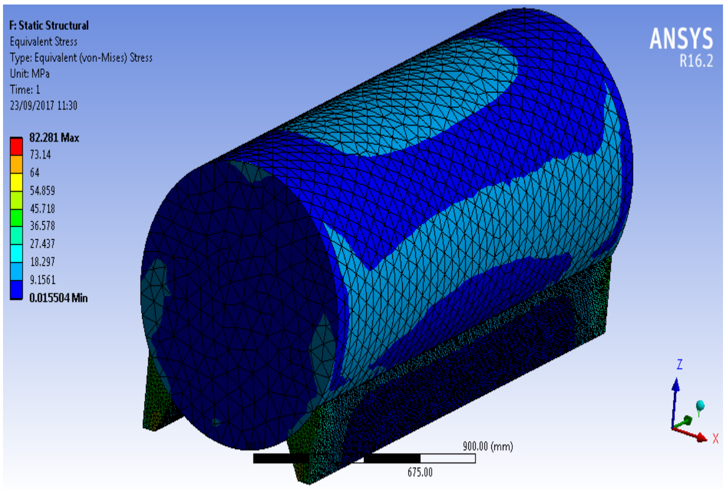

Fig.4.10 Static Structural Analysis of design 4 Color Code shows Von-misses stresses over Pressure vessel body and Supports

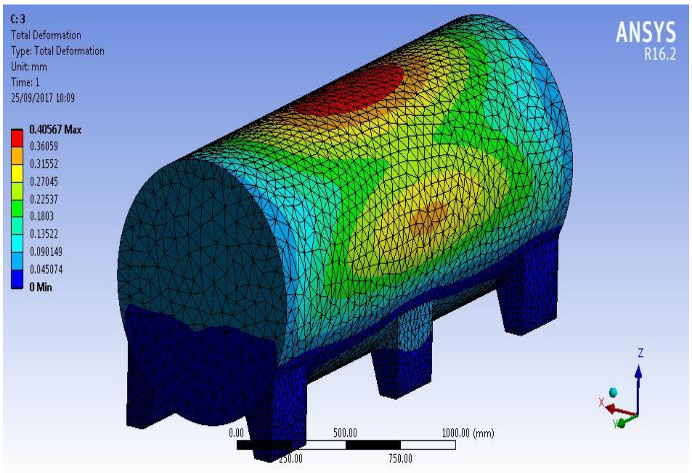

Fig.4.8–Shows the deflection in body of design 3 pressure vessel.

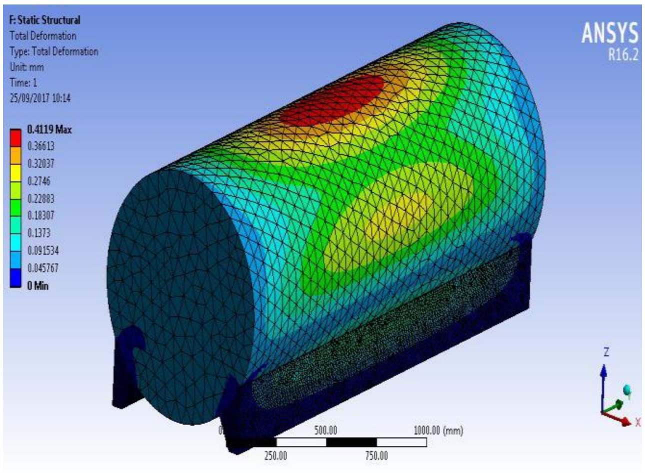

Fig.4.11 shows the deflection in body of design 4 pressure vessel

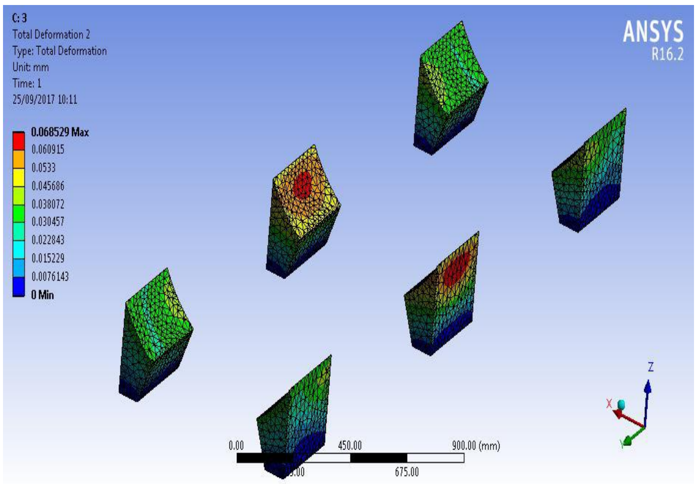

Fig .4.9 Shows the deflection in saddle support of design 3 pressure Vessel.

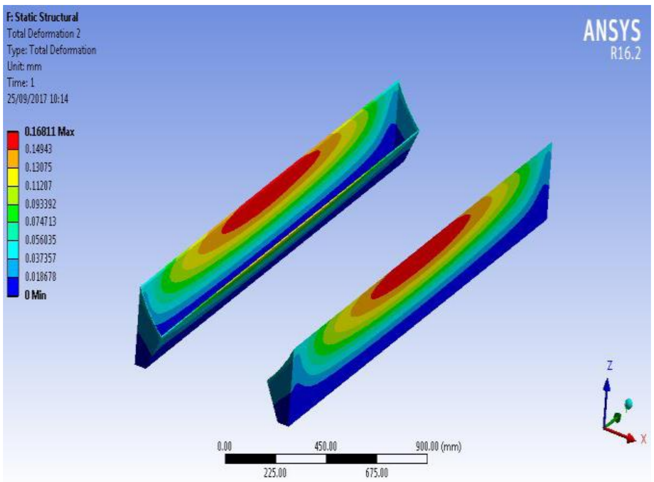

Fig.4.12 shows the deflection in saddle support of design 4 Pressure vessel

Saddle support of Model 3 and Model 4 is little bit similar. In Model 3 saddle support is placed at fixed distance and both side of pressure vessel. In model 4 saddle support is placed continuously both side of pressure vessel. According to FEA result Von-misses stress distribution is 100% same over the pressure vessel body and 80% similar saddle support, but both supports are safe and capable taking a load.

Table.5.1 The limiting stress and deflection in FEA analysis of design 1 to design 4

Model Type	Limiting Stress in Mpa	Deflection in mm
Design 1	56.722	0.03750
Design 2	30.005	0.03957
Design 3	73.265	0.06852
Design 4	82.281	0.16811

Table 5.2 Total material cost of saddle support for different designs

Model Type	Weight	Cost per Kg Weight	Total Cost in Rs
Design 1	71.609 Kg	Rs. 85	6086.765
Design 2	85.249 Kg	Rs. 85	7246.165
Design 3	48.355 Kg	Rs. 85	4110.175
Design 4	93.549 Kg	Rs. 85	7951.665

From the Table 5.1 and 5.2 a graph of limiting stress and total cost versus designs cases is plotted and is shown in Fig.4.13

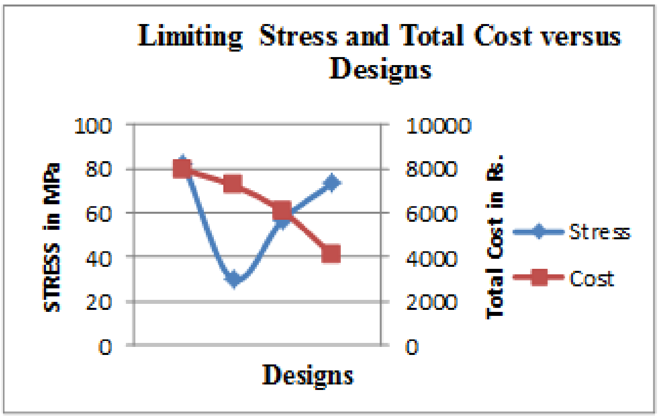

Fig.4.13 .Limiting Stress and Total Cost versus Designs

From the graph of Limiting Stress and Cost v/s design cases, it is seen that the cost of material of design case 3 is less as compared to design cases 1, 2 and 4 but the stress value for Design 3 is more but it is still below the yield limit, so as per the material cost point of view the cost of the saddles in design case 3 is suitable for tanker applications.

5. CONCLUSION

According to the FEA results of design 1, 2, 3 and 4 it is concluded that the stress value over all saddle support is under the yield limit, so every design model of saddle supports will sustain the pressure vessel load but cost of material for the saddle support is most important and these saddle support material also increase load over the vehicle.

1. Shape of design 1 and design 2 is similar and both are under the stress limit but difference is that design 2 is continuous member so more material is required for design 2 and its weight is approximately 19 % more than design 1. So here it is suggested that design 1 is better that design 2 according to material cost and weight.

2. Shape of design 3 and design 4 is similar and both are under the stress limit but difference is that design 4 is continuous member along the pressure vessel length so more material is required for design 4 and its weight is approximately double times more than design 3 (93 % More). So here it is suggested that design 3 is better that design 4 according to material cost and weight.

3. According to the Table 5.1 all the stress value over the saddle support is under the yield limit so design is safe ,also the deflection values varies from 0.03 mm to 0.16 mm.(not considerable because it can't affect over the saddle support design).

4. According to the Table 5.2 and Fig. 4.13 it is concluded that materials required for design 3 is less than other designs and approximate cost required for that design is less from material requirement. (Design 3 Material Cost Approx. Rs. 4110/-)

ACKNOWLEDGMENT

We would like to thank the researchers as well as publishers for making their resources available and teachers for their guidance. We are also thankful to reviewer for their valuable suggestions. We also thank the college authorities for providing the required infrastructure and support. Finally, we would like to extend a heartfelt gratitude to friends and family members.

REFERENCES

[1] Lin Seng Ong., 1988.Analysis of twin saddle supported vessel subjected to non-symmetric loadings. International Journal of Pressure Vessels and Piping, 35 , pp. 423-437

[2] Krupka, V., 1991. The background to a new design proposal for saddle supported vessels. International

Journal of Pressure Vessels and Piping, 46, pp. 51-65.

[3] Lin Seng Ong., 1991.Parametric study of peak circumferential stress at the saddle support. International Journal of Pressure Vessels and Piping, 48, pp. 183-207.

[4] L.S.Ong & G.Lu.,1993.Optimal support radius of loose-fitting saddle support. International Journal of Pressure Vessels and Piping, 54, pp. 465-479.

[5] L.Yang, C.Weinberger and Y.T.Shah, 1994.Finite element analysis on horizontal vessels with saddle supports. Computer & Structure,52,pp.387-395

[6] Shen Naijie, 1995.Stress state in the saddle zone of pressure vessels and piping. International Journal of Pressure Vessels and Piping, 63, pp.155-164

[7] W. M Banks, D. H. Nash, A E Flaherty, W C Fok, A S Tooth, 2000.A simplified design approach to determine the maximum strains in a GRP vessel supported on twin saddles. International Journal of Pressure Vessels and Piping, 77,pp.837-842

[8] N.El-Abbasi ,S.A.Meguid, A.Czekanski, 2001.Three-dimensional finite element analysis of saddle supported pressure vessels. International Journal of mechanical sciences,43, pp.1229-1242

[9] K.Magnucki, P.Stasiewicz, W.Szyc, 2003.Flexible saddle support of a horizontal cylindrical pressure vessel. International Journal of Pressure Vessels and Piping, 80, pp. 205-210

[10] David H Nash and Alwyn S Tooth, The influence of the flexibility of the dished end on twin saddle supported pressure vessels.University of Strathclyde Glasgow, Scotland