An Approach for Designing of Composite Gas Cylinder Using ASME Standard

Amey N. Paradkar [1], Khan Mod. Zohaib [2], Sairaj More [3], Utkarsh Hadadare [4], Vinayak N. Patil [5]

[1] B.E Student, Department of Mechanical Engineering, Bharati Vidyapeeth College of Engineering, Navi Mumbai, ameyaparadkar@rediffmail.com
[2] B.E Student, Department of Mechanical Engineering, Bharati Vidyapeeth College of Engineering, Navi Mumbai, khanmohdzohaib17@gmail.com
[3] B.E Student, Department of Mechanical Engineering, Bharati Vidyapeeth College of Engineering, Navi Mumbai, sairajmore56@gmail.com
[4] B.E Student, Department of Mechanical Engineering, Bharati Vidyapeeth College of Engineering, Navi Mumbai, utkarsh.hadadre@gmail.com
[5] Assistant Professor, Department of Mechanical Engineering, Bharati Vidyapeeth College of Engineering, Navi Mumbai, vnpatil5@gmail.com

Abstract: This paper describes the use of ANSYS software for the replacement of the conventional stainless steel material of Liquid Petroleum gas (LPG) cylinder by a low density composite material named E Glass Epoxy for reducing the cylinders weight. In lieu of this, Finite element analysis package ANSYS has been used on composite cylinder subjected to an internal pressure. A case has been developed to study the stresses due to pressure loading inside the cylinder designed as per ASME standards. The results of stresses for steel cylinders were compared with the analytical solution available in the literature in order to validate the model and the software. The weight reductions were presented for steel, composites LPG cylinders and the variation of stresses throughout the cylinder made of steel and composites were studied.

The current Indian Gas supply system makes the transportation of cylinders arduous due to the difficulty in moving the heavy stainless steel cylinders around the house for housewives. An alternative is required, which can produce the same result with less weight, that is, for the same amount of gas stored inside the cylinder the weight of the cylinder is reduced. The above project is a small step towards an user friendly concept taking into consideration practicality, utility as well as safety.

1. Introduction

A gas cylinder is used to store gases at a pressure above atmosphere. These gas cylinders have a wide amount of applications such as chemical processes; soldering, welding and flame cutting; medical and laboratory uses; fire extinguishers; household applications etc. The gas cylinders used are widely made of different types of steel.

In this project we are concentrating on household cylinders which is made of plain carbon steel. These cylinders are heavier in weight and are very difficult to lift as their main handlers are house wives. These gas cylinders are manufactured in industries by rolling and forging which also leads to the wastage of materials overall.

The household gas cylinder weighs approximately 14 Kg. Nowadays, composite materials have been used widely which are proved to be more effective. These composite materials are wound over metal liner thus acting as over wrapped composite pressure vessel. These cylinders have high tensile strength carbon fibre which makes them lighter in weight and easier to lift.

These gas cylinders can be of a wide variety of shapes. In this project, the cylinder which we have used has a shape of cylindrical body with two hemispherical ends.

Geometrical Dimensions & Existing design of Gas Cylinder:

- We have to consider 15.9 kg of LPG gas cylinder
- Empty gas cylinder weight
  = 15.9 Kg with frame holder
  = 13 Kg without frame holder
- Gas weight = 14.2 Kg
- Volume of gas = 47.8 L
- Perimeter = 102 cm
- Diameter of cylinder = 320 mm
- Length of cylinder = 360 mm

Internal pressure

- LPG standard proportion 70% propane and 30% butane

(In Mumbai temperature is 27 ^{0}C and pressure is 0.6618 MPa)

Fig.1: Composite Gas Cylinder on the left and currently used gas cylinder to the right

(A) Problem Statement:

The existing design of Cylinder is heavier in weight which is difficult for human handling and increases the transportation cost thus obviating the need to design a cylinder of light weight. The existing cylinder is difficult to lift by house wives, reducing the weight of cylinder makes the handling comfortable. For this two materials were compared. Firstly, the commonly used material in gas cylinder which is cast iron and a composite material namely E-glass Epoxy were analyzed to get a better result.

(B) Methodology:

- Studying Different Parameters of gas cylinder
- Calculating the shape of cylinder
- Working and boundary conditions of the cylinder
- Identification of suitable composite materials for the cylinder.
- 3D modelling using Solid works and ANSYS by FEA software analysis.
- Theoretical strength analysis Calibration of analysis and theoretical result, fabrication of composite material.

2 .Literature Review

- **M Dhanunjayaraju, TL Rakesh Babu** have studied the nature of LGP cylinder for internal pressure made of steel as compared to Cylinder made of FRP materials. They compared the steel with composite Glass FRP and Carbon FRP. Finite element analysis is used to calculate stresses and deformation inside. The results delineates that the weight can be saved enormously by 10Kgs of LPG cylinders by using FRP composites and the stress values are also well within the limit of capability of materials.
- **Yashraj jaywant salunke, K.S.Mangrulkar** worked towards the reduction in the weight of the LPG Gas Cylinder using Light Weight Composite material. For this they considered Glass Fiber Reinforced Plastics (GFRP) as a replacement for Steel. Analytical Method was used to calculate the Stress distribution in the cylinder made of steel and GFRP. Output results of Analytical Calculation shows that GFRP results in 77.31% saving in the material and Stress induced in GFRP are within the safe limit. This results in increasing the safety of cylinder with reduced accidents, less maintenance, rust free.
- **Pankit M. Patel1 Prof. Jaypalsinh Rana** worked for the design and optimization of LNG/CNG cylinder for optimum weight. In the literature, design and analysis of composite pressure vessel are carried, which are made of thermoplastic linear, glass fiber and polymer raisin. Analysis showed that there is a good arrangement between experimental results and elasto-plastomodelling for mechanical behavior of high density polythene linear under internal pressure. The study gives the influences of temperature and winding angle on filament wound composite pressure vessels. The result showed that the cylinder with 34 CrMo with 1.7 thickness and carbon fibre thickness of 4mm experienced stress less than the stress achieved in existing cylinders,. The weight was reduced from 19.45 to 6.16 Kg, thus the lighter weight are easy to handle and assemble.
- **Subhash N. Khetre, Arun Meshram, P. T. Nitnaware** worked towards design and analysis of composite high pressure vessel with different layers using FEA and T-Sai Wu failure criteria. It has been seen that Composite pressure vessels tend to fail in their parts. The design of these parts is most important issue for such vessels. Factors taken into account are strength of the material selected, the effect of winding stability and geometric variables. Analysis was carried out for number of layers and result showed that layers can be minimized for optimizing the design. Thus we can conclude that T-Sai Wu failure criterion can yield fairly good results with consistent accuracy for composite pressure vessels.

- **Kumar Akkimaradi, Asst Prof U.B.Khadabadi** have worked for the design and analysis of composite cylinder. The FRP composite materials have higher specific strength and modulii and tolerability characteristics which will result in reduction of weight and structure. Cylindrical composite pressure vessels constitute a metallic internal linear and a filament wound and a composite outer shell. The metalliner is necessary to prevent leaking while some of the metal liners also provide strength to share internal pressure load. Composite materials include alloys, plastic co polymers, minerals and wood. The above paper concludes that the stress carrying capacity for composite material is greater than that of normal steel along with light weight of composite material as compared to steel.
- **A.Tom, G.M. Pius, G .Joseph, J. Jose , M .J .Joseph** have worked on to reduce the weight of the LPG gas cylinder using Aluminum 6061T6 alloy and Aluminum 5052-H38 alloy for the replacement of steel, since steel is most commonly used but is heavy in weight. Analytical calculations were done for the stress distribution in the cylinder made of steel and the aluminum alloys. And the analytical calculations showed that the aluminum alloys show good results in terms of stress concentrations as compared to steel. Also the life of the cylinders would be increased by using the aluminum alloys.

- **RemyaGopi, BeenaB.R**. studied the contributions related to Finite Element Analysis and Finite Element Modeling of GFRP LPG cylinders. Steel is used as the material for the LPG cylinders but has some disadvantages like it is heavy and it does not have any accurate way for showing the level of emptiness in the cylinder. So Cylinders made from GRP composites are used as an alternative to overcome these problems .And the results obtained by the use of GFRP composites show that the stress deformations are also within the required limits. And the weight is also reduced which proves its advantage in the household applications.

- **T Ashok Harikrishna** studied an alternate material for the LPG cylinders such as FRP Composites. A comparison was made by using steel and FRP materials and the analysis was done using ANSYS software .The cylinder is subjected to internal pressure for the analysis. The basic building blocks of the fiber reinforced composites helped in understanding the arrangement of fibers that whether they should be arranged in the longitudinal direction or transverse direction to attain strength .The properties of glass fibers was also studied .The information about increase in the use of composites in the recent years has been studied .The results show that the weight of the LPG cylinders could be saved enormously by using FRP composites and the stress values were also well within the limit of capability of the materials.

Based on the challenges in the research mentioned in the previous section, present study focused on the weight savings for steel, composites LPG cylinders and the variation of stresses throughout the cylinder made of steel and composites were studied .

3. Theoretical Calculation

Parameters	Values
Weight of gas (m) kg	14.2
Volume of gas (L)	47.8
Perimeter (cm)	102
Diameter of Cylinder (mm)	320
Length of Cylinder (mm)	360
F.O.S	4

(3.1)

- Thickness , $t= (Pr)/SE1-(0.6P)$
- Hoop Stress $\sigma H=(Pw*D)/(2*t)$

Where, Pw =Working Pressure

- Longitudinal Stress

  $\sigma l = (Pw*D)/(4*t)$

- Circumferential Strain

  $\xi 1=1*(\sigma H-(\sigma l/m))$

- Longitudinal Strain

  $\xi 2= (\sigma l-(\sigma H/m))/E$

- Strain of Capacity

  $\xi v= (2*\xi 1)+\xi 2$

- Increase in Volume dV=

  $\xi v*(Vclinder)$

- Maximum Principle Stress =

$((\sigma H+\sigma l)/2)-(((\sigma H-\sigma l)/2)^2+\tau^2)^{(1/2)}$

(Neglecting Shear Stress i.e $\tau=0$)

- Maximum shear stress=$(\sigma H-\sigma l)/2$
- Total Deformation =$(P*D*L*(0.5-\mu))/(2t*E)$

4. Software Analysis

Designing of gas cylinder on Solid works -

The following are the steps given for software analysis.

Design of cylinder:

A gas cylinder is been considered with two materials to be compared which are plain Carbon Steel and E Glass Epoxy material. These are taken for the design of cylinder.

Theoretical Calculations:

On the basis of the thorough research done during the literature survey, the boundary conditions on the system were defined. Accordingly, theoretical calculations to gas cylinders with its parameters were done as calculated in (3.1).

3D Modeling of Gas Cylinder Using SOLIDWORKS:

After getting the dimensions of the cylinder, a 3-D Model of these manifolds was created on SOLID WORKS workbench as shown in (Fig 2) and (Fig 3).

Selection of Material:

After the study of composite materials, two materials were short listed which were E Glass Epoxy and S Glass Epoxy along with the existing material which is plain Carbon Steel by WRM method.(We have taken E glass Epoxy for comparison with Plain Carbon Steel.)

Simulation Using FEA:

Simulation of the design was done for the Cast Iron ASTM-30, the short-listed composite materials and Advance Material (E Glass Epoxy) using Finite Element Analysis software ANSYS WORKBENCH.

Results Calibration and Conclusion:

The simulation results were compared with theoretical values on the basis of various factors and the Design best suited was concluded according to the results. The results are calculated in (5.1) and (5.2).

Designing on Solid works :

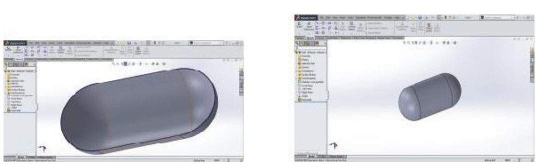

Fig:2 Plain Carbon Steel

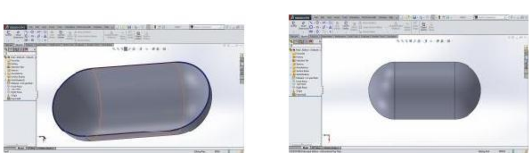

Fig 3: E Glass Epoxy

Analysis on ANSYS Software:

Defined the element type(s) to be used which is triangular mesh.

Defined the material properties of the elements which are-

- E Glass Epoxy-

Density=2100kg/m3
Young's Modulus in Axial DirectionE1=45GPa
Young's Modulus in Transverse Direction E2=12GPa
Poisson's Ratio μ=0.28
Yield Strength=1020MPa

- Plain Carbon Steel-

Density, ρ= 7800 kg/m3
Young's modulus, E=210 GPa
Poisson ratio, μ=1/m=0.28
Ultimate strength =399.82 MPa
Yield strength=220.59 MPa

Defined the geometric properties of the elements like length=360cm, Perimeter=102 cm and diameter=320 cm.

Defined the physical constraints (boundary conditions). Defined the pressure which is 0.6618MPa along hemisphere and dome portion of cylinder.

Post processing

Post processing contained simulation of the gas cylinder and analyzing different aspects like von misses stress, shear stress, directional deformation and comparing the two materials used to obtain best results.

As shown in Fig 4 and Fig 7directional deformation, Fig 5 and Fig 8 maximum principal stress, Fig 6 and Fig 9 maximum shear stress was calculated for the two materials which is plain Carbon Steel and E Glass Epoxy.

Plain Carbon Steel :

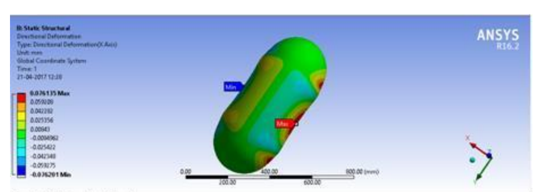

Fig 4: Directional Deformation

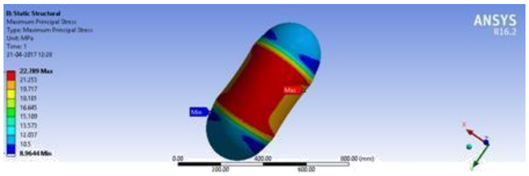

Fig 5: Maximum Principal Stress

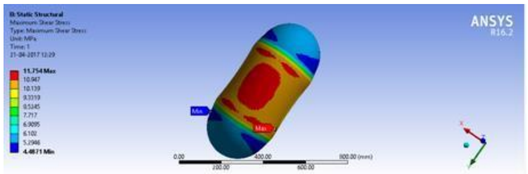

Fig 6: Maximum Shear Stress

E Glass Epoxy:

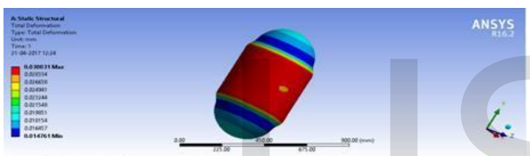

Fig 7: Directional Deformation

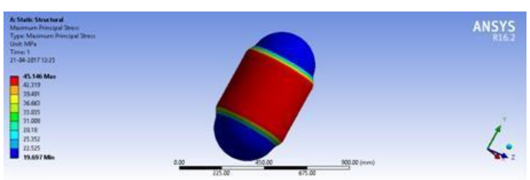

Fig 8: Maximum Principal Stress

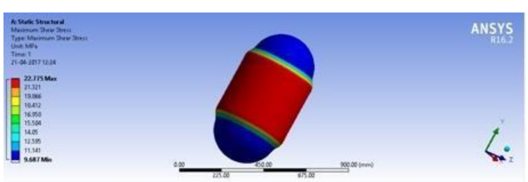

Fig 9: Maximum Shear Stress

5. Result

From the above analysis and calculations performed the results obtained are displayed in the table below as follows-

5.1: Plain Carbon Steel

Parameters	Analytical Method	FEA Method
Maximum Principal Stress (MPa)	44.30	45.0
Maximum Shear stress (MPa)	22.15	22.77

(*All Units are in Mega Pascal)

5.2: E Glass Epoxy

Parameters	Analytical Method	FEA Method
Maximum Principal Stress (MPa)	22.06	22.78
Maximum Shear Stress (MPa)	11.03	11.75

5.3: For Cylindrical Portion

Parameters	Plain Carbon Steel	E-Glass Epoxy
Thickness (mm)	2.39	4.789
Hoop Stress (MPa)	44.30	22.06
Longitudinal Stress (MPa)	22.15	11.03
Circumferential Strain	0.00018	0.000421
Longitudinal Strain	0.0000464	0.0004044
Increase in Volume mm^3	11768	36091.59

5.4: For Dome Portion

Parameters	Plain Carbon Steel	E-Glass Epoxy
Thickness (mm)	2.39	4.78
Hoop Stress (MPa)	22.15	11.03

6. Conclusion

Based on the analysis of LPG cylinders made of different materials following conclusions have emerged out from the present investigations:

- The new design of Gas cylinder with composite material E Glass Epoxy resulted in a greater effectiveness in terms of stresses induced by gas on the cylinder walls even though there was slight increase in wall thickness.
- The weight of the cylinder using E Glass Epoxy plummeted efficiently as compared to plain carbon steel.
- This new designed cylinder can help for easy transportation from Industry to homes.
- These Cylinders will help the household wives to move the cylinders easily hence, reducing human efforts.

7. Future Scope

In the upcoming years, colorful, lighter and easier-to-handle cooking gas cylinders will make their way into Indian kitchens, eliminating the need for heavy and hazardous steel containers. The biggest benefit of the composite gas cylinder is risk minimization as there is no explosion in case of leaks or fire hazards. This is due to the advanced fibre glass technology used in manufacturing the composite cylinders. The new cylinder would be translucent, letting consumers see the level of gas contained in it and reducing the possibility of rigging, as is common with opaque steel cylinders. The introduction of composite cylinders is among the key initiatives by the government to improve the quality of life. Even though the major focus of the Indian government is in introducing the gas pipelines which will enable direct gas supply, this system will take years to come into effect. There are other considerations to consider as pipelines have disadvantages like maintenance of pipeline, inconvenience during installation (as it would be uprooting roads to install the gas pipeline), disposal of existing used steel cylinders etc. The gas pipeline would also not be possible for remote and undeveloped areas where there is poor infrastructure. Thus the future scope of our project can aid the government during the period when pipelines have yet to come into effect. Additional benefits of the new composite cylinders are for storage purposes as after installing the pipelines, these cylinders can be used as reserve gas suppliers during critical times. As for the other concerns, it can also be used widely in the industries where weight really matters and that these light weighted composite cylinders can be efficient for saving cost.

8. References

1. **Mr.Yashraj Jaywant Salunke, Prof.K.S.Mangrulkar. "**Stress Analysis of a Composite Cylinder for the Storage of Liquefied Gases**"**, India International Journal of Engineering Trends and Technology (IJETT) – Volume 13 Number 8 – Jul 2014 ISSN: 2231-5381

2. **T.Ashok, A. Harikrishna "**, Analysis Of LPG Cylinder Using Composite Material**s"**, India IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 9, Issue 2 (Sep. - Oct. 2013), PP 33-42

3. **Remya Gopi , Beena B R, "**Finite Element Analysis OF GFRP LPG Cylinder**"**International Journal of Engineering Development And Research,Volume 5 Issue 4.

4. **M Dhanunjayaraju, TL Rakesh Babu**," Stress analysis of LPG cylinder with composites". IJAR 2015; 1(12): 1042-1045. Accepted: 27-10-2015. International Journal of Applied Research 2015.

5. **Alok Tom , Geo Mathew Pius , George Joseph , Jacob Jose and Mathew J Joseph**," DESIGN AND ANALYSIS OF LPG CYLINDER" ,International Journal of Engineering & Applied Sciences (IJEAS) Vol.6, Issue 2(2014)17-31

6. **Pankit M. Patel Prof. Jaypalsinh Rana**, "Design & optimization of LNG-CNG cylinder for optimum weight",International Journal For Scientific Research and Development ,Volume 1, Issue 2, 2013.

7. **Subhash N. Khetre, P. T. Nitnaware, Arun Meshram**, "Design and Analysis of Composite High PressureVessel with Different Layers using FEA", International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 IJERTV3IS111412 Vol. 3, Issue 11, November-2014

8. **Kumar Akkimaradi, Asst Prof U.B.Khadabadi**, "DESIGN AND ANALYSIS OF COMPOSITE CYLINDER", International Research Journal of Engineering and Technology (IRJET) Volume: 03 Issue: 02 | Feb-2016