Global Journal of Enterprise Information System

DOI: 10.18311/gjeis/2017/15866

Design of Gas Cylinder using Composite Material as per ASME Standards

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Abstract

A gas cylinder or tank is a pressure vessel used to store gases at above atmospheric pressure. Many pressure vessels are made of carbon steels these material results in increase in weight and transportation cost. The Literature survey shows that gas cylinders fails due to corrosion and difficult to transporting. In this Project work, the aim is to design a gas cylinder as per ASME standards using composite material which can be used for our day today life. Solidworks 2015 is used for 3D modelling of the cylinder and Finite Element Analysis is used to test the performance of the cylinder made of composite material and compare with Cylinder made of Steel. The results shows that stress induced in the both cylinder is nearly equal but composite cylinders results in height amount of weight saving and corrosion resistance and also decrease the transportation cost.

Keywords: E Glass Epoxy, Finite Element Analysis, Solidworks

Manuscript Accepted: 12-Jan-2017; **Originality Check:** 14-Jan-2017; **Peer Reviewers Comment:** 16-Jan-2017; **Double Blind Reviewers Comment:** 18-Feb-2017; **Author Revert:** 21-Feb-2017; **Camera-Ready-Copy:** 24-Feb-2017)

1. Introduction

1.1 Introduction to Gas Cylinder

A gas cylinder or tank is a pressure vessel used to store gases at above atmospheric pressure. To store and transport any gas from one position to another position without any safety is very hazardous to human life, hence gas cylinders are used for this purpose. Gas cylinder maintains gas at desired pressure without any change due to change in temperature. Gas cylinder not only used to store liquefied petroleum gas which is used for household purpose but also other gases such as Oxygen used in hospital incase of any emergency, to store oxygen and acetylene for welding purpose, to store hydrogen, nitrogen and other gases for any industrial purpose under pressure.

2. Types of Gas Cylinders

There are three types of gas cylinders

1. High Pressure Cylinders – High pressure cylinders come in a variety of sizes. Some examples of gases supplied in High pressure cylinders include Nitrogen, Helium, Hydrogen, Oxygen and Carbon Dioxide.
2. Low Pressure Cylinders – Low pressure cylinders come in a variety of sizes. Some examples of gases supplied in low pressure cylinder are LPG and refrigerant gases.
3. Acetylene Cylinders.

Figure 1. Different sizes of Gas Cylinder.

3. Selection of Gas Cylinder

Different types of gas cylinders are studied based on application for its performance. In this project work, focus is to design gas cylinder for domestic purpose with composite material.

Perimeter = 102cm

Diameter of cylinder = 320mm Length of cylinder = 360mm

Volume of the Gas = 47.8 liters

The pressure acting inside gas cylinder is independent of volume. It is depend on ambient temperature and composition of propane and butane. The LPG inside gas cylinder consists of 70% propane and 30% butane.

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Table 1. Internal Pressure variation with temperatures

Temperature (°C)	Pressure (MPa)
16	0.4688
21	0.5653
27	0.6618
32	0.786

5. Material Selection

Generally gas cylinders are made up of steel material. Any gas cylinder made of metallic materials has a major drawback of severe bursts in worst cases. Due to safety reason now day's gas cylinder made up of composite materials such as Fiber Reinforced Plastic Composites. These Composite pressure vessels are light in weight and high strength. Fiber

Reinforced Plastic gas cylinders doesn't explode due to porosity formation of materials. In this project, E-glass FER is considered as composite material for manufacturing of gas cylinder as compared to Plane carbon Steel.

Table 2. Material Property Table of Gas cylinder

Sr. No.	Properties	E-glass FRP	Plane Carbon Steel
1	Density, Kg/ 3	2100	7800
2	Young Modules in Axial Direction, GPa	45	210
3	Young Modules in Transverse Direction, GPa	12	-
4	Poisons ratio	0.28	0.28
5	Yields Stress, MPa	1020	220.59

6. Parameters and Strength Calculation of Gas Cylinder

Gas Cylinders are designed as per Pressure vessel design of ASME standards. Gas cylinders contains three different types of end shapes i.e. Elliptical, Semi-Elliptical and

7. Plane Carbon SteelGas Cylinder

1. Thickness of cylindrical shell

Assuming Internal Pressure, P = 0.6948 MPa and Radius, r = 160 mm

As per ASME Standard for Pressure vessels made of metals,

<Eq Problem in MS word>

Where, S = Max Allowable Stress

Pressure inside the cylinder is P = Design pressure = 1.05 × Working pressure

Take, Working pressure = 0.6618 MPa = 1.05 × 0.6618

P = 0.6948 MPa

E1 = Joint Efficiency Take, E1 = 0.85

R = Radius of cylinder = 160mm

<Eq Problem in MS word>

2. Thickness of Cylinder head Select hemispherical head

Thickness of head is same as that of cylindrical shell Thickness = 2.39 mm

Length of straight flange = 3t

= 3 × 2.39

= 7.17 mm

Radius of curvature = 160mm

8. E-Glass Epoxy Gas Cylinder

ASME standards are different for Design of Pressel vessel made of Composite materials. Assuming Internal Pressure, P

= 0.6948 MPa and Radius, r = 160 mm

1. Thickness of cylindrical shell made of Minimum thickness of cylindrical shells under internal pressure should be greater of (a) and (b)

(a) Longitudinal Stress

<Eq Problem in MS word>

As grater thickness is 4.798 mm hence thickness of cylindrical shell equal to 4.798 mm.

2. Thickness of Cylinder head

Select hemispherical head

Thickness of head is same as that of cylindrical shell Thickness = 0.5138 mm

Radius of curvature = 160mm

9. Theoretical Strength Calculation of Gas Cylinder

When cylinder is subjected to internal pressure "P",

Stresses and Deformation will be produced in both cylindrical and Head portion of the cylinder. Two types of stresses are induced in the Cylinder i.e. circumferential stress or Hoop Stress and Longitudinal stress.

1. Plane Carbon SteelGas Cylinder

Cylindrical portion

<Eq Problem in MS word>

2. E-Glass EpoxyGas Cylinder

Cylindrical portion

<Eq Problem in MS word>

Hoop Stress

<Eq Problem in MS word>

10. 3D Modeling of Gas Cylinder

Modeling of gas cylinder is done by using Solidworks 2015. Since cylinder made of plan carbon steel and E Glass epoxy has different thickness, two 3D models are created using solid works part modeling feature.

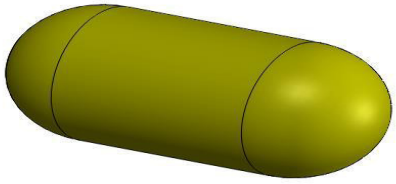

Figure 2. 3D model of gas cylinder.

FEA is carried out by using ANSYS Workbench 15.0 to find equivalent stress, shear stress and total deformation. Assuming Boundary and Loading conditions as follow, Pressure: 0.668MPa,

Frictionless Support,

Automatic meshing with 16792 Elements and No. of nodes 33497

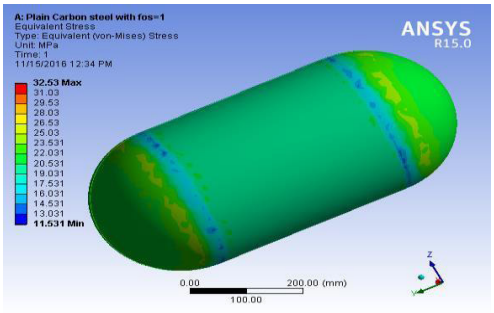

Figure 4. Equivalent stress on steel gas cylinder.

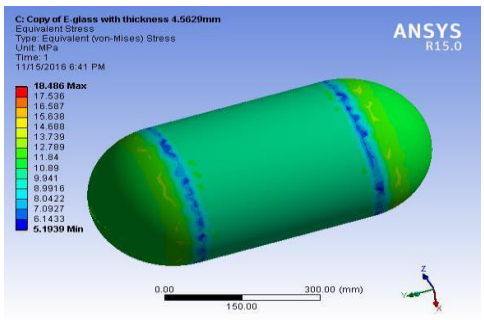

Figure 5. Equivalent stress on E-glass gas cylinder.

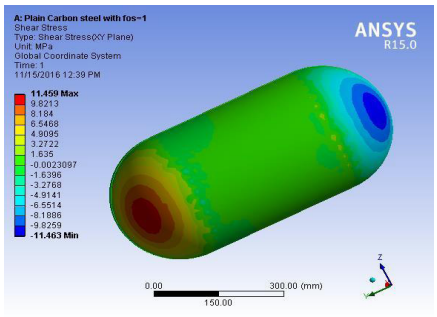

Figure 6. Shear stress distribution of steel gas cylinder.

11. Finite Element Analysis

FEA is carried out by using ANSYS Workbench 15.0 to find equivalent stress, shear stress and total deformation.

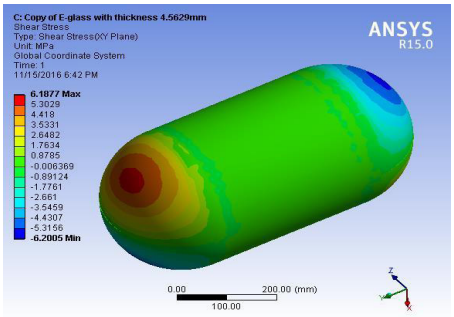

Figure 7. Shear stress distribution of E-glass gas cylinder.

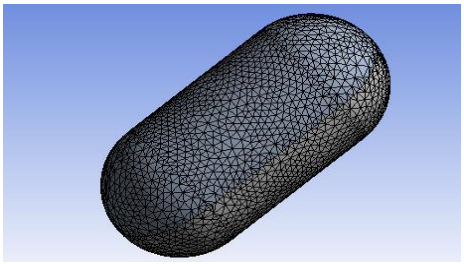

Figure 5. Meshing of gas cylinder.

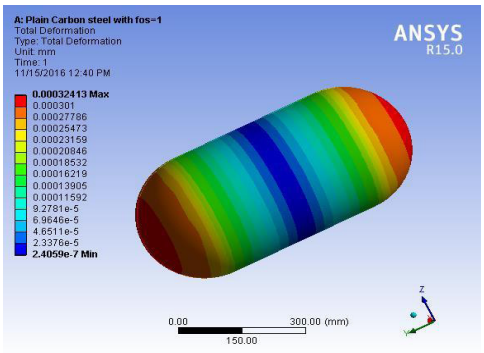

Figure 8. Total deformation of Steel gas cylinder.

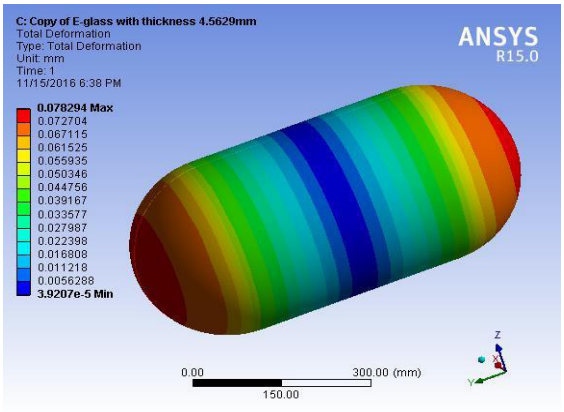

Figure 9. Total deformation of E-glass gas cylinder.

12. Result and Conclusion

Table 3. Theoretical and Analytical comparison

Sr. No	Parameters	Plain Carbon Steel		E-glass Epoxy	
		Theoretical	Analytical	Theoretical	Analytical
1	Equivalent Stress	22.15 MPa	26.53 MPa	11.03 MPa	13.79 MPa
2	Max. Shear Stress	11.07 MPa	11.45 MPa	5.15 MPa	6.187 MPa
3	Max. Deformation	0.0322 mm	0.000324 mm	0.0735 mm	0.0782 mm

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Based on analysis result of LPG cylinder made up of two different materialshave stress and deformation values within the limit. The uses of composite will also results in corrosion resistant and Increase in life of the component. Hence it is conclude that gas cylinder made up of E-glass Epoxy can be used for household purpose.

The weight of LPG gas cylinder can be saved enormously by using E-glass Epoxy composite.

Weight of the Plain Carbon Steel cylinder shell = 13.15 kg Weight of the E-glass Epoxy cylinder shell = 6.6886 kg Weight saving = 6.46 kg

Citation:
Sangram Bandpatte, Khushal Shede, Rohit Chavan, Nikhil Katkar, Balbheem Kamanna and Bibin Jose
"Design of Gas Cylinder using Composite Material as per ASME Standards",
Global Journal of Enterprise Information System. Volume-9, Issue-1, January-March, 2017. (http://informaticsjournals.com/index.php/gjeis)
Conflict of Interest:
Author of a Paper had no conflict neither financially nor academically.