# Design and Analysis of GFRP-Al Composite Material for the Replacement of LPG Cylinder

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***Abstract:** Composites are being used as an effective alternate replacement of various traditional metals and alloys. They possess very high mechanical properties and high corrosion resistance. With high strength to weight ratio, the composites are widely used to withstand high stress. GFRP are the composites having Glass fibers as reinforcements and epoxy resin as matrix. With the addition of Al alloy powder to the epoxy matrix, an enhanced mechanical property is observed. The existing domestic LPG cylinders are made up of low carbon steel with suitable heat treatment. It is used to store the mixture of Butane and Propane under high pressure. However, the gross weight of the cylinder is very high which makes handling difficult. The aim of this paper is to replace the traditional LPG cylinders with GFRP- Al composite which is less dense than the traditional steel, however having significant mechanical properties that satisfy the safety standards.*

***Keywords:** Composite cylinder, composite materials, glass fiber reinforced plastics.*

## I. INTRODUCTION

The current method used to contain LPG gas is by using steel cylinders. It is a challenging task to sustain the gas at enormous pressure (2200 KPa) under normal room temperature. Hence this requires the manufacturing of steel cylinders with suitable thickness to sustain the pressure. The commonly used steel for manufacturing LPG cylinder is the low carbon steel, due to its machinability and high strength. This typically leads to a minimum weight of 14.2 kg per cylinder which when combined with the gas stored yields an enormous weight of 29.5 kg [1].

By using a less dense material such as GFRP-Al when compared to steel, the net weight of the empty cylinder is drastically reduced (ie. It reduces to nearly half the value) which makes the handling, storage and transportation very easy. Less human effort is now required to carry the cylinder which minimizes the risk of injuries.

## II. MATERIALS AND METHOD

The cylinder was prepared with glass fiber epoxy laminates with Aluminum alloy. A mould of plaster of paris was used to obtain the product by considering all the standard dimensions of the cylinder. The final component is then subjected to Hydro-static test and Leak test before distribution in the market.

### 2.1 MOULD PREPARATION AND APPLICATION OF GFRP- AL COMPOSITE

The first step towards the manufacturing of the composite cylinder is to obtain a mould. This is done by applying plaster of paris mixture over an empty cylinder of standard dimension. After it is completely dry it is then removed to yield the mould [2]. Before the composite is laid over the mould it is very important to keep the mixture of catalyst (Hardener) and resin with Al ready in the proper proportions. The general ratio of mixing the hardener and the resin is 10:1. The hardener or the catalyst provides a boost to the polymerization of the resin with that of the glass fiber or the used reinforcement. Thus, it is mandatory in order to maintain the adequate ratio of mixing with the matrix in order to avoid excess polymerization leading to improper adhesion with the reinforcement. The hardener used is HY556 hardener with the epoxy resin, LY950. Once the mixture is ready a coat of this is applied over the mould followed by a coat of GFRP matrix. This sequence is repeated until a thickness obtained from ANSYS calculations is reached. Once the necessary thickness is obtained, the composite material is allowed a time of 24 to 36 hours for it to dry up completely.

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**Figure 1.1 GFRP-Al cylinder**

**Figure1. 2 GFRP Matrix**

### 2.2 COMPONENT

Once the composite has completely dried up, the mould is removed to yield the composite cylinder. The cylinder is then subjected to Leak Test and Hydro-static Test before it is distributed in the market. This is to ensure whether the cylinder is able to withstand the pressure which it was designed to withstand. Also any leaks or cracks or holes in the product can be found by the leak test.

## III. THEORETICAL CALCULATIONS

Extensive calculations are made with standard formulas to find out the values of thickness required to sustain the pressure involved and the weight of the resulting cylinder [3]. These values are then compared with the values obtained from software analysis.

### 3.1THICKNESS CALCULATION

The general equation for the thickness of the cylinder is calculated by the formula for low carbon steel cylinder and with the values given in table 1, including a tolerance to thickness, the thickness of the commonly used steel cylinder is about 2.5 mm

**Table3.1**

| Pr (KgF/ mm$^2$ ) | $D_O$ (mm) | Re (KgF/ mm$^2$) | t (mm) |
|---|---|---|---|
| 25 | 320 | 20.41 | 2.44 |

The general equation for the thickness of the cylinder is calculated by the formula for GFRP- Al cylinder and with the values given in table 2, including a tolerance to thickness. , the thickness of the GFRP-Al composite cylinder is found to be about 5 mm.

**Table 3.2**

| Pr (KgF/ mm$^2$ ) | $D_O$ (mm) | Re (KgF/ mm$^2$) | t (mm) |
|---|---|---|---|
| 25 | 320 | 12.75 | 4.87 |

In order to calculate the weight of the cylinder, the volume of the cylinder is calculated with the following data given in table 3, and then mass of the cylinder is calculated theoretically, the mass of the cylinder (excluding the handle and base) is found to be 5.4Kg. The overall mass of the empty GFRP-Al composite cylinder will be close to 5.7

Kg with including the weight of handle and base.

**Table 3.3**

| $D_O$ (cm) | $D_i$ (cm) | Ro (cm) | Ri (cm) | l (cm) | t (cm) | ρ (g/cc) |
|---|---|---|---|---|---|---|
| 32 | 31 | 16 | 15.5 | 36 | 0.5 | 1.8 |

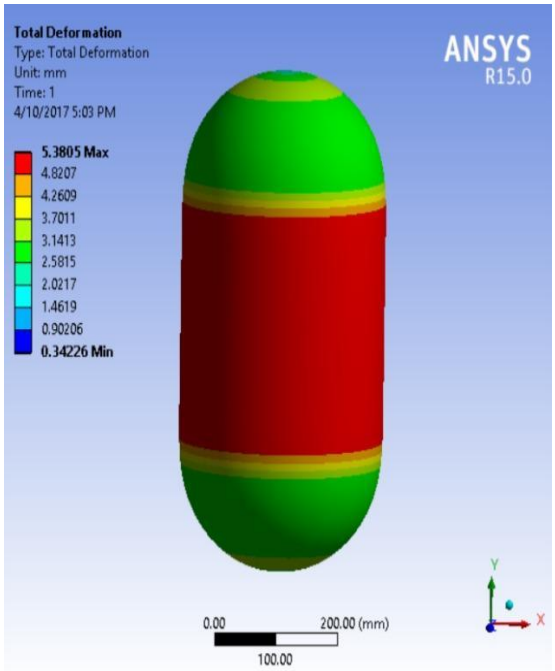



**Fig. 1.3 ANSYS report for steel**

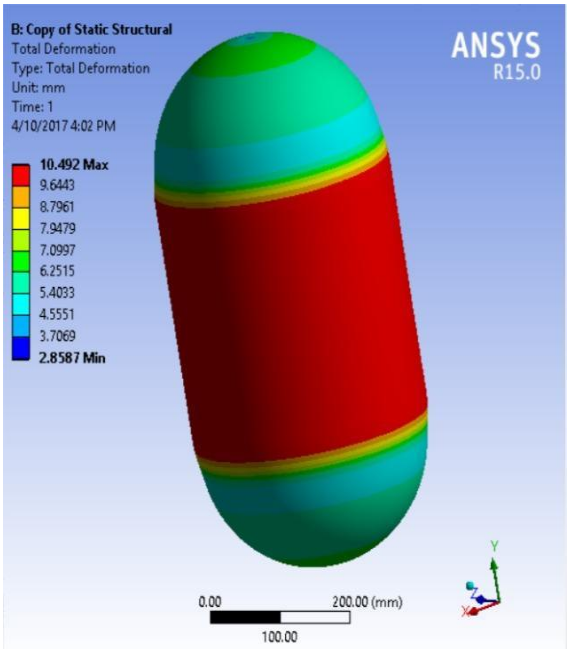



**Fig. 1.4 ANSYS report for GFRP-AlCylinder of 2.5mm thickness**

Cylinder of 2.5mm thickness

### 3.2 PERCENTAGE REDUCTION IN WEIGHT

In calculation of percentage reduction in weight is revealed that, the weight reduction percentage is found to be 60 %( % reduction is 0.598 X 100). (i.e.) the weight of GFRP-Al composite cylinder is just 40% of the actual weight of the traditional steel cylinder. Whereas the Actual weight of an empty cylinder is 14.2 Kg and weight of GFRP-Al cylinder is 5.7 Kg

## IV. EXPERIMENTATION AND ANALYSIS

### 4.1 ANALYSIS FOR STEEL CYLINDER- 2.5MM AND GFRP-Al CYLINDER- 2.5mm THICK

Upon the application of a test pressure of 25 Kg F/ $mm^2$ for a steel cylinder with a thickness of 2.5mm, a maximum deformation of 5.3805mm was observed. For 2.5 mm thickness of GFRP cylinder, the deformation is found to be ranging from 2.8587 mm to 10.492 mm which is very high and the difference between this and benchmark steel cylinder is greater than anticipated

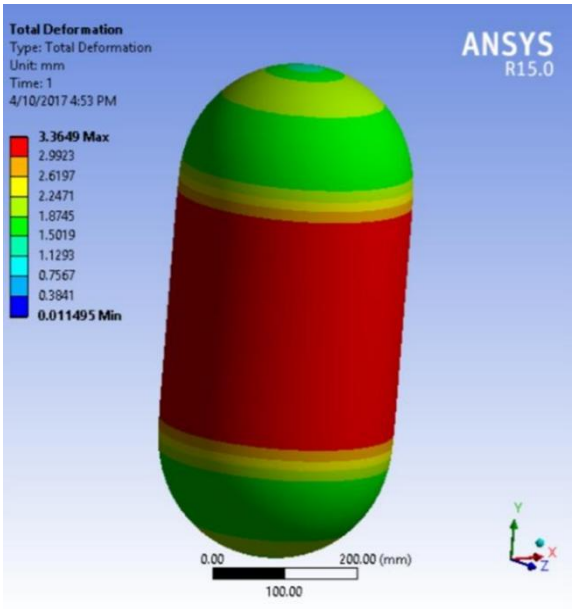



**Fig. 1.5 ANSYS report of GFRP-Al cylinder**

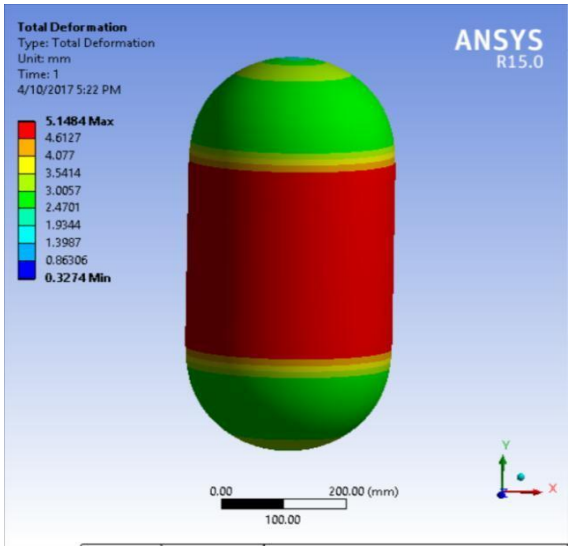


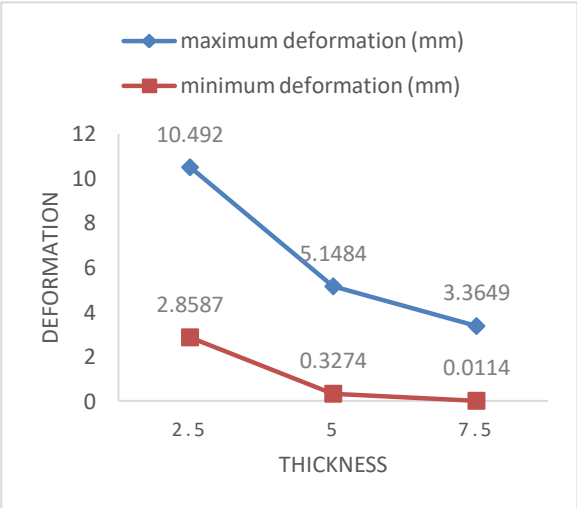

**Fig.1.6 ANSYS report of GFRP-Al cylinder of 5 mm thickness of 7.5 mm thicknes**

4.2Analysis for GFRP-Al cylinder 5mm and 7.5 mm thick

For a thickness of 5mm of GFRP-Al composite cylinder the deformation values ranges from 0.3274mm to 5.1484mm which is very close to the value obtained from that of the steel cylinder. For 7.5 mm thickness of GFRP cylinder, the maximum deformation value is found to be 3.3649 mm which is good technically but the weight of the cylinder is not promising

## V. RESULTS AND DISCUSSION

The various deformation values are compared to for the selection of appropriate thickness. From the graph 5.1 it is clearly evident that GFRP-Al composite with thickness of 7.5mm having minimum deformation, besides the material with 5 mm having moderate deformation . Upon the preparation of the GFRP-Al composite cylinder with the thickness of 5mm, it yields a gross weight of 5.7 kg.




Through theoretical calculations derived that a thickness of 5mm is required to withstand the same forces withstood by a steel cylinder of thickness Graph 5.1 Deformation of GFRP-Al composite material 2.5mm, undergoing the same deformations

## VI. CONCLUSION

In this paper the material GFRP-Al composite is used, which has enough strength and mechanical properties to withstand the high pressure at which the gases are stored. The analysis done actually validates this calculation which supports our argument. This also bolsters our findings. Hence from all the above derived results a weight reduction of nearly 60% is achieved when compared to both the cylinders.

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