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Weight Optimization of LPG Cylinder through Finite Element Analysis

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Abstract:-It is desired to have a light weight, high strength and easy handling of LPG cylinder which economically satisfies the customer requirements. The study aims at reduction of weight of LPG cylinder. The commonly used material for the manufacturing of LPG cylinder is steel, but it is heavier and have safety issues. To find latest technologies, materials and techniques used in design and fabrication of LPG cylinder in industry for improving the existing LPG cylinder. To design and develop a light weight, high strength LPG Cylinder which is cheaper in cost as compared to the existing one. The finite element analysis of LPG cylinder using various materials viz. Steel, Aluminium alloy, Mg alloy has been carried out. At first the modelling is done in CATIA V5 R20 and then imported to ANSYS 16.0. The analysis has been done in ANSYS 16.0 and compared to classical mathematical formulations. Calculations are performed to determine the weight of the cylinder and the least weight material is chosen for the new LPG cylinder. Finally comparison between these materials is carried out stresses and deformations level maximum and minimum then we have find out, Aluminium is the best material than other materials because of its light weight.

Keywords: Aluminium Alloy, Magnesium Alloy, Finite Element Analysis, Stress, Cylinder, Deformation.

I. INTRODUCTION

1.1 Introduction of LPG Cylinder :- Liquefied petroleum gas or liquid petroleum gas, also referred to as simply propane or butane, are flammable mixtures of hydrocarbon gases used as fuel in heating appliances, cooking equipment and vehicles.LPG is mixture of hydrocarbon gases, the most common being butane and propane. At room temperature, LPG is colorless and odourless non poisonous gas. For safety reasons, only 80% liquid is filled in LPG remaining 20% contains gaseous LPG. Anormal LPG cooking system is made of a steel cylinder filled with LPG, a pressure controller, a tube connecting the cylinder to the pressure controller and the burner and finally the burner itself. LPG is heavier than air, e.g. propane is one and a half times heavier than air and can therefore accumulate above the ground.

1.2 LPG Market Production, Supply and Consumption: - LPG is separated from raw oil and gas during extraction or refining. In order to stabilize the raw oil or gas, the accompanying products are extracted during a cleaning process. The accompanying gases are then either processed or burnt on the spot. The latter process is also known as flaring and approximately 140 billion m³ of potential LPG are burnt every year. Through further processing of the accompanying gasses, propane and butane are gained, which are used as LPG.A sophisticated infrastructure for the distribution of LPG is shown in figure 1.1. It can then be sold to distributors in its pressurized form. 1.3 LPG as a by-product of the oil and gas industry is directly dependent on the extraction of fossil fuels. While larger production capacities may open up from the development of new fossil fuel sources, it has to be highlighted that most conventional fossil fuel fields are already being exploited.

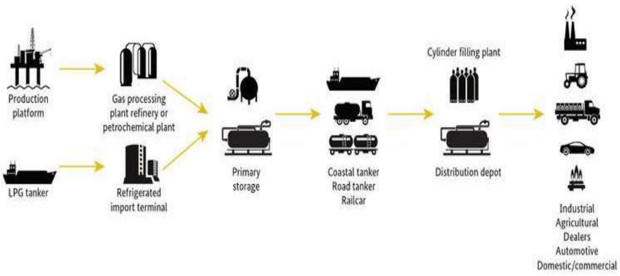


Figure 1.1

1.3 Features of LPG :- LPG is a low carbon fuel, it is used in thousands of industrial and commercial applications. LPG is cleaner than any other fossil fuel, highly energy-efficient and safe to use. In addition to these factors, LPG available and supports the use of renewable technologies. The Advantages of using LPG as an energy source are

1. Increased fuel savings.

2. High rate of heating – as high as 400 °C per hour

3. Better heat transfer with LPG firing.

4. No wastage of fuel due to spillage.

5. Uniformity and increased end-product quality

1.4 Applications of LPG cylinder

1.4.1 Cooking :- A mixture of air and LPG can be ignited if the amount of LPG in air is between 2%-10%. The ignition temperature is above 380°C. The maximum flame temperature for LPG is around 2,000°C. The affordability of LPG is still a substantial barrier for many households that want to use LPG. Evidence shows that subsidies have benefitted wealthier urban users more than low-income users as the former are in a better position to afford the high initial costs, e.g. to purchase the cylinder and the LPG burner. In most countries, access to LPG is limited to urban areas and LPG supply shortages are a frequent occurrence in rural areas.

1.4.2 Rural Heating :- LPG used as a power source for combined heat and power technologies (CHP). CHP is the process of generating electrical power and useful heat from a single fuel source.

1.4.3 **Motor Fuel :-** LPG is used to fuel internal combustion engines, it is often referred to as autogas or autopropane. It has been used since 1940s as a petrol alternative for spark ignition engines.Autogas is the common name for liquefied petroleum gas (LPG) when it is used asa fuel in internal combustion engines in vehicles as well as in stationery applications.

1.4.4 Refrigerator :- LPG is instrumental in providing off-the-grid refrigeration, usually by means of a gasabsorption refrigerator. Blended of pure, dry propane (refrigerant designator **R-290**)and isobutane (R-600a) the blend "R-290a" has negligible ozone depletion potential and verylow global warming potential and can serve as a functional replacement for R-12, R-22, R-134 and other chlorofluorocarbon or hydro fluorocarbon refrigerants in conventional stationeryrefrigeration and air conditioning systems [9].

II. LITERATURE REVIEW

2.1 Somaiah et al. [2016] - The study of this paper is to elaborate on the design procedure of alternative materials for the manufacturing of liquid petroleum gas (LPG) cylinder. LPG is a colorless liquid that readily evaporates into a gas. A mixer of air, the gas can burn or explode when it meets a source of ignition. Composite materials are macroscopic combinations of two or more distinct materials having a discrete and recognizable interface separating them. Composites are heterogeneous materials. The weight savings are also presented for steel, Glass Fiber Reinforced Plastic (GFRP) composites LPG. LPG cylinder is reduced by cylinders replacing conventional metal by GFRP material [1].

2.2Amruta Muralidhar Kulkarni et al. [2015] - Finite Element Analysis is carried out using ANSYS commercial code. Burst Pressure (B.P.) is determined by applying Twice Elastic Slope Criteria (TESCA) of plastic collapse. Then the Mean Error (ME) is calculated between the experimental results and the results obtained by Finite Element Analysis (FEA). The FEA results showed a good agreement with experimental results [2].

2.3 Remya Gopi et al. [2015] – Liquefied Petroleum Gas (LPG) is increasingly becoming the preferred choice of fuel in the world. The increase in patronage could be attributed to its affordability, efficiency and environmental friendliness. It has become necessary to design and execute the best customer oriented practices and to internalize them for providing enhanced satisfaction to the customer through the employees. LP-gas inside a container is in two states of matter, liquid and vapor. The liquid portion of container is in the bottom and the vapour is in the uppermost part of the vessel. Liquefied Petroleum (LP) Gas is stored and handled as a liquid when under pressure inside a LP-Gas container.

2.4 Alok Tom et al. [2014] - Finite element analysis of cylinder subjected to internal pressure is performed. The analysis done in ANSYS is compared with classical mathematical formulations.

Calculations are performed to determine the weight of the cylinders and the least weighed material is chosen for the new LPG cylinder. The cost estimation is also performed to check the economic viability of the new LPG cylinder [4].

2.5 **T.Ashok et al. [2013]** - The study of this paper weight of LPG cylinder can be saved enormously by using FRP composites and the stress values are also well within the limit of capability of materials. This gives a clear justification for its use in household applications. Weight of the steel cylinder = 13.31 kg (without end frames) Weight of the GFRP cylinder = 3.02 kg (without end frames) and Weight saving = 10.29 kg [5].

III. METHODOLOGY

3.1 Research Methodology :- The following are the steps followed as the methodology adopted for the present work.

(a) Study of different parameters of a gas cylinder.

(b) Modeling of the gas cylinder.

(c) Analysis

3.2 Modeling of LPG Cylinder

Various 3D models of LPG cylinder have been made with different height. CATIA is used for creating the model of LPG cylinder, which was thus imported to ANSYS software.

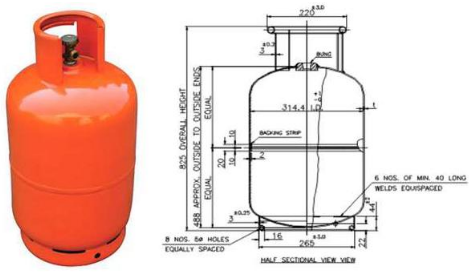


Figure 3.1 LPG Cylinder

We have to consider 15.9 kg of LPG gas cylinder

Table 3.1

Empty gas cylinder weight	
with frame holder	15.9 Kg
without frame holder	13 Kg
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

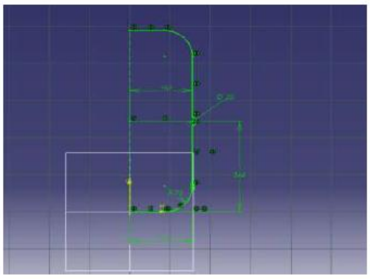
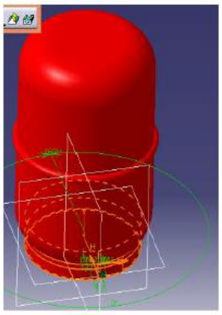


Fig.3.2 Sketch of cylinder base feature

3.2.1.2 Extruding the sketch



(a)

(b)

Fig.3.3 (a) Extruding Using shaft Tool (b) LPG Cylinder Model Using CATIA V5R20

Figure 3.1 LPG Cylinder ANSYS View

IV. SIMULATION AND RESULTS

Simulation of improved LPG cylinder is done using ANSYS software. ANSYS 16.0 software has an easy-to-use set of tools for 3-D mechanical design, documentation, and product simulation.

Static analysis of LPG Cylinder using ANSYS

Static structural analysis is done on LPG cylinder by using ANSYS 16.0. Static Analysis is

done on the cylinder, as it is a member with is simply supported and other end is hinged. Static

Structural analysis considers strain, stress, deflection and force caused due to external load acting on it and these loads do not induce significant damping effects.

Assumptions

For the study of cylinder in response to the load acting on it, some Assumptions have been

made. In this analysis it is based on the assumption the point loads are acting over the

Cylinder surface. Steady load and steady response. That is, the loads and the jaw plate response

are assumed to be very slow with respect to time.

Creating a New project in ANSYS software

Firstly, we have to add the static structural template into the project, this is done by double

Clicking on the toolbox

Project > Static Structural > Engineering Data > Define Material Properties > Project

Defining of Material Properties

Add New Material in B4: Engineering Data, and name it **Aluminum**, now we are required

To input actual Manganese Steel properties. For this, different properties value are Input in

Properties of Outline row 3:

Physical Properties

Go to Physical Properties in Toolbox, then in dropdown menu, choose density, by right

Clicking > include property.

Linear Elastic Properties

Isotropic elastic limit > include property

Strength

Include property > tensile yield > compression yield > tensile ultimate strength

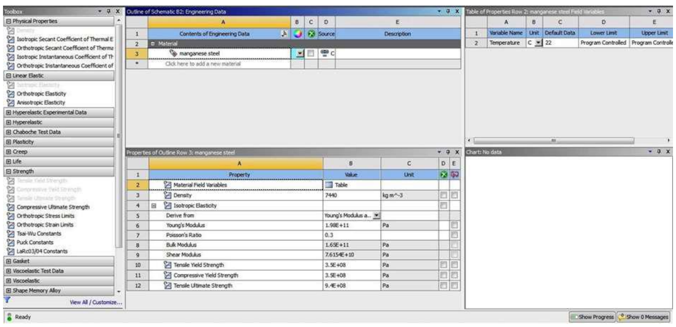


Fig.4.1 Adding the material properties

Fig.4.2 Importing the CATIA model in .iges format to ANSYS

Importing model and Material assigning

Geometry > import geometry > model

Geometry > part-1> Material > Assignment > Aluminum

Meshing

Insert method > select the model to be meshed > Apply in Scope dropdown menu.

Details of mesh:

Size- Adaptive

Relevant center –medium

Element size –Default

Mesh > Generate mesh

FEA model is generated

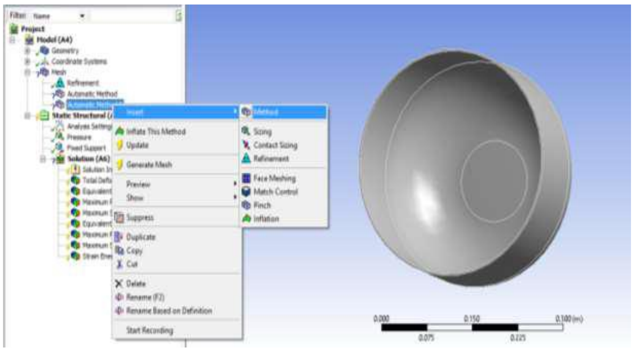


Fig.4.3 Inserting the method of meshing

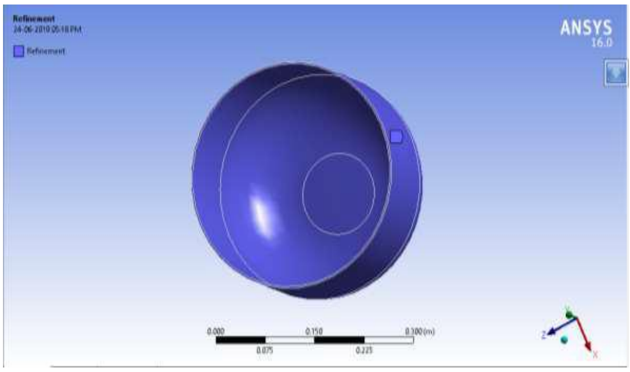


Fig.4.4 Selected body for meshing

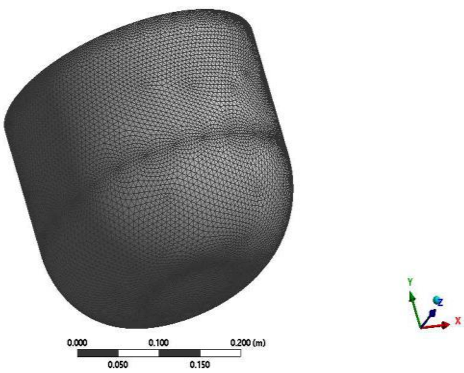


Fig.4.5 Mesh Model of LPG cylinder

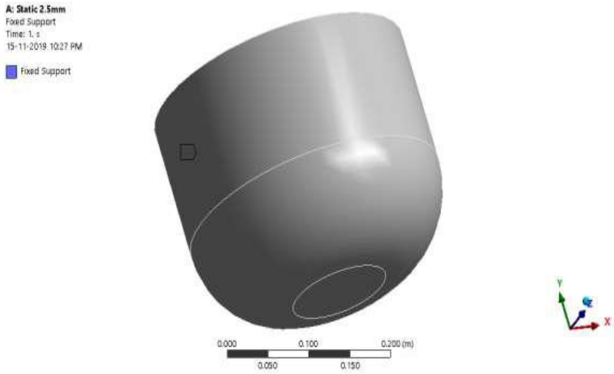


Fig.4.6 Fixed Support

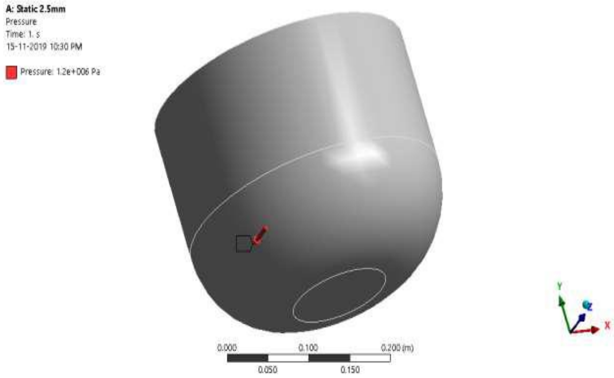


Fig.4.7 Pressure

4.2.1 Cylinder thickness 2.5 mm

4.2.1.1 von-Mises stress in LPG cylinder with thickness 2.5 mm

The figure 4.8 shows the range of the von Mises stress. The von Mises stress may be maximum

up to 651.21MPa and minimum up to 0.67 MPa

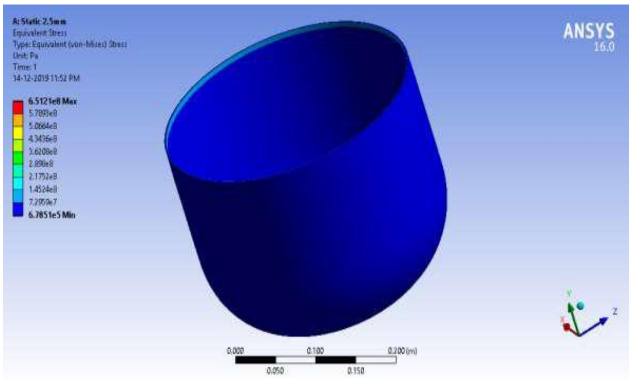


Fig.4.8 von Mises stress of Steel LPG cylinder (2.5mm)

The figure 4.9 shows the range of the von Mises stress. The von Mises stress may be maximum

up to 664.7 MPa and minimum up to 0.74 MPa

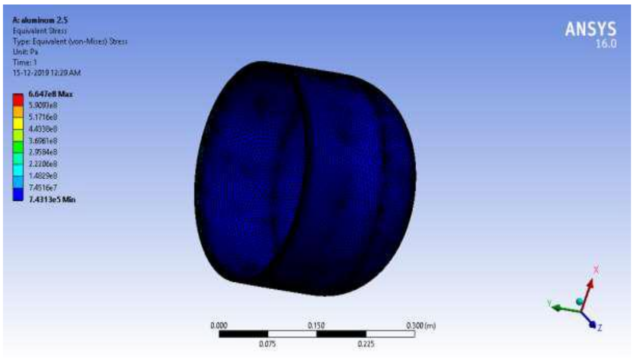


Fig.4.9 von Mises stress of Aluminum LPG cylinder (2.5mm)

The figure 4.10 shows the range of the von Mises stress. The von Mises stress may be maximum up to 673.11 MPa and minimum up to 0.49 MPa

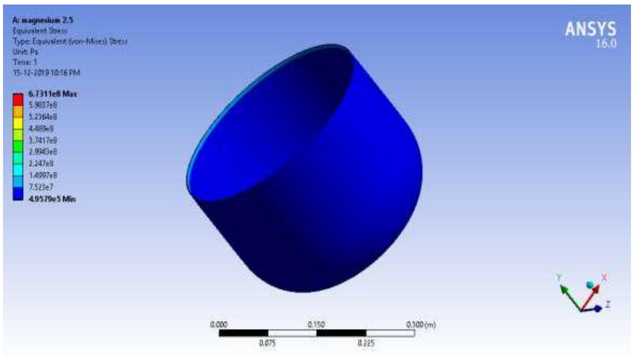


Fig.4.10 von Mises stress of Magnesium LPG cylinder (2.5mm)

4.2.1.2 Total Deformation in LPG cylinder with thickness 2.5 mm

The figure 4.11 shows the range of the Total Deformation. The Total Deformation may be

maximum up to 0.0024 m.

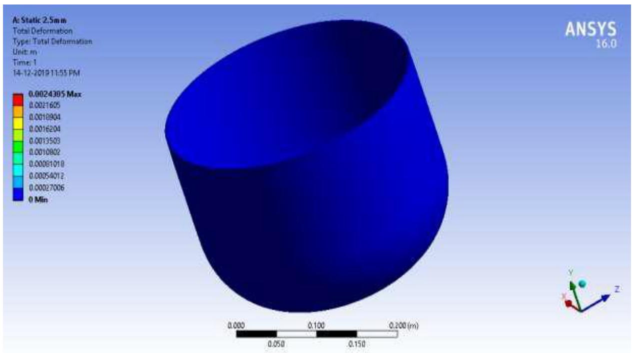


Fig.4.11 Total Deformation of Steel LPG cylinder (2.5mm)

The figure 4.12 shows the range of the Total Deformation. The Total Deformation may be

maximum up to 0.0067 m.

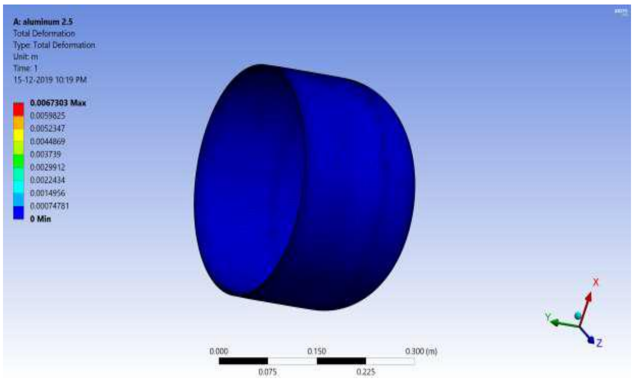


Fig.4.12 Total Deformation of Aluminum LPG cylinder (2.5mm)

The figure 4.13 shows the range of the Total Deformation. The Total Deformation may be

maximum up to 0.0104 m.

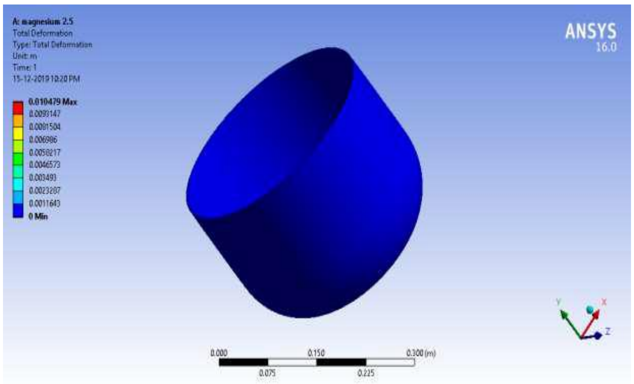


Fig.4.13 Total Deformation of Magnesium LPG cylinder (2.5mm)

4.2.1.3 Mass in LPG cylinder with thickness 2.5 mm

The figure 4.14 shows mass in cylinder. Total mass is 6.0164 kg and weight is 117.92 N

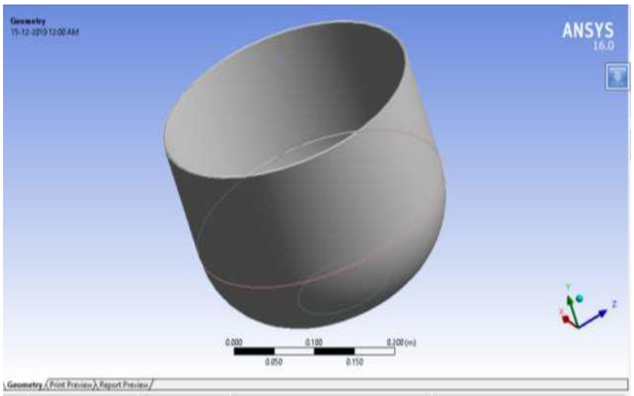


Fig.4.14 Mass of Steel LPG cylinder (2.5mm)

The figure 4.15 shows mass in cylinder. Total mass is 2.123 kg and weight is 41.61 N.

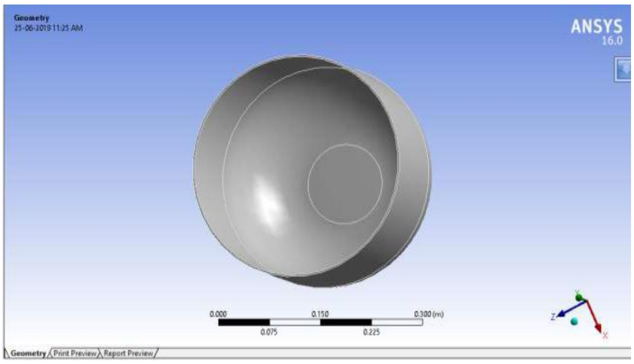


Fig.4.15 Mass of Aluminum LPG cylinder (2.5mm)

The figure 4.16 shows mass in cylinder. Total mass is 1.379 kg and weight is 27.038 N

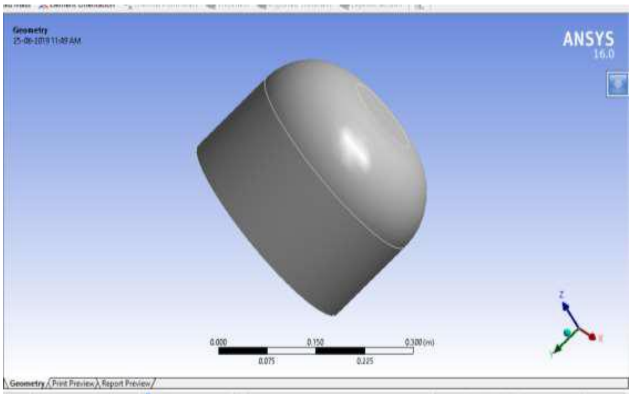


Fig.4.16 Mass of Magnesium LPGcylinder(2.5mm)

4.2.1.4 Maximum principal stress in LPG cylinder with thickness 2.5 mm

The figure 4.17 shows the range of the Maximum Principle stress. The Maximum Principle

stress may be maximum up to 651.1 MPa and minimum up to -35.11 MPa

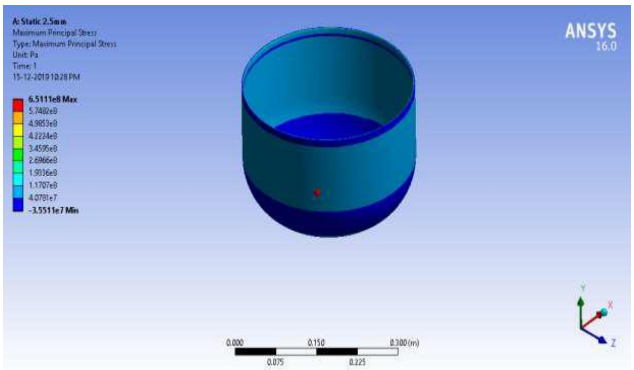


Fig.4.17 Maximum Principal Stress of Steel LPG cylinder (2.5mm)

The figure 4.18 shows the range of the Maximum Principle stress. The Maximum Principle

stress may be maximum up to 651.1 MPa and minimum up to -35.11 MPa

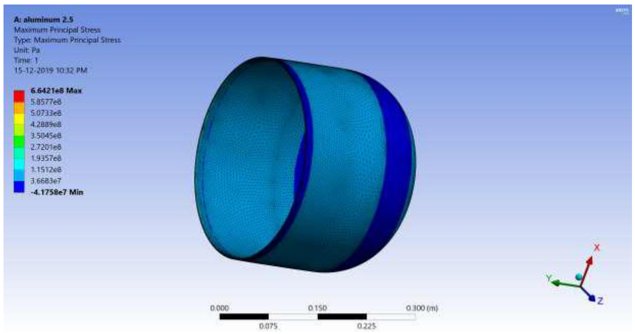


Fig.4.18 Maximum principal stress of Aluminum LPG cylinder (2.5mm)

The figure 4.19 shows the range of the Maximum Principle stress. The Maximum Principle

stress may be maximum up to 672.2 MPa and minimum up to -46.66 MPa

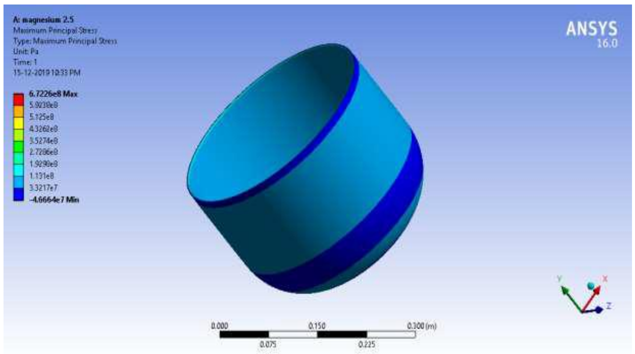


Fig.4.19 Maximum principal stress of Magnesium LPG cylinder (2.5mm)

4.2.2 Cylinder thickness 3.1 mm

4.2.2.1 von-Mises stress in LPG cylinder with thickness 3.1 mm

The figure 4.20 shows the range of the von Mises stress. The von Mises stress may be

maximum up to 441.7 MPa and minimum up to 0.34 MPa

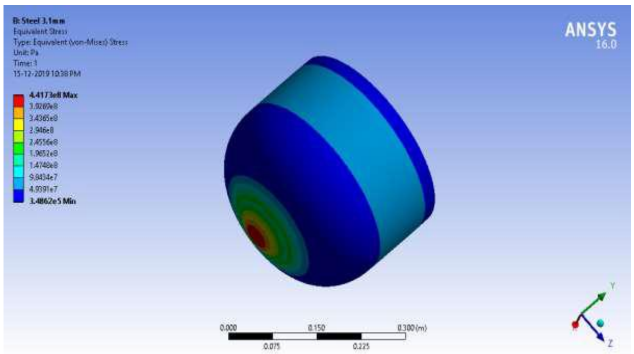


Fig.4.20 von Mises stress of Steel LPG cylinder (3.1mm)

The figure 4.21 shows the range of the von Mises stress. The von Mises stress may be

maximum up to 450.9 MPa and minimum up to 0.38 MPa

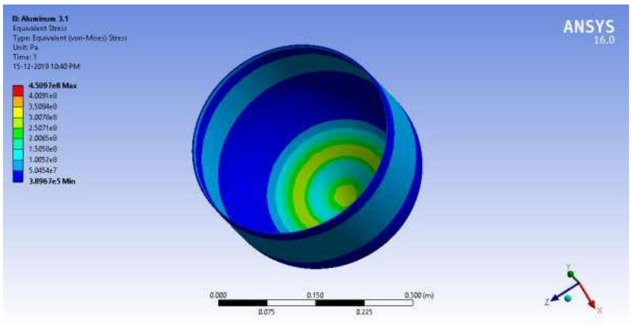


Fig.4.21 von Mises stress of Aluminum LPG cylinder (3.1mm)

The figure 4.22 shows the range of the von Mises stress. The von Mises stress may be

maximum up to 459.52 MPa and minimum up to 0.59 MPa

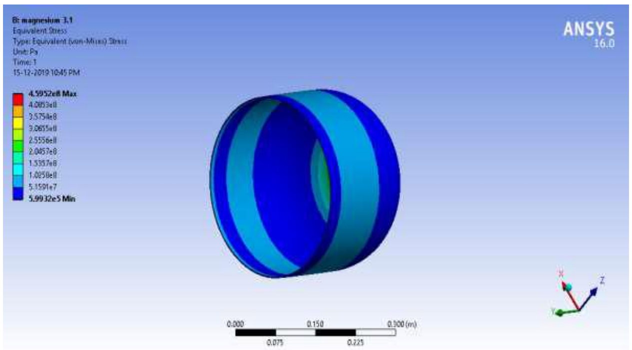


Fig.4.22 von Mises stress of Magnesium LPG cylinder (3.1mm)

4.2.2.2 Total deformation in LPG cylinder with thickness 3.1 mm

The figure 4.23 shows the range of the Total Deformation. The Total Deformation may be

maximum up to 0.0014 m.

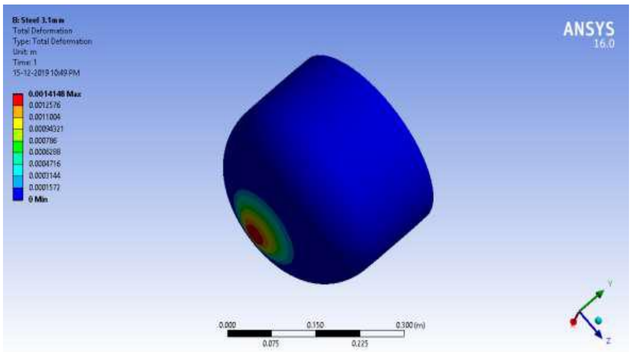


Fig.4.23 Total Deformation of Steel LPG cylinder (3.1mm)

The figure 4.24 shows the range of the Total Deformation. The Total Deformation may be

maximum up to 0.0039 m.

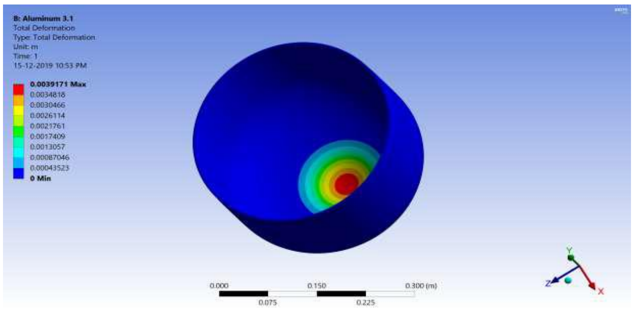


Fig.4.24 Total Deformation of Aluminum LPG cylinder (3.1mm)

The figure 4.25 shows the range of the Total Deformation. The Total Deformation may be

maximum up to 0.0061 m.

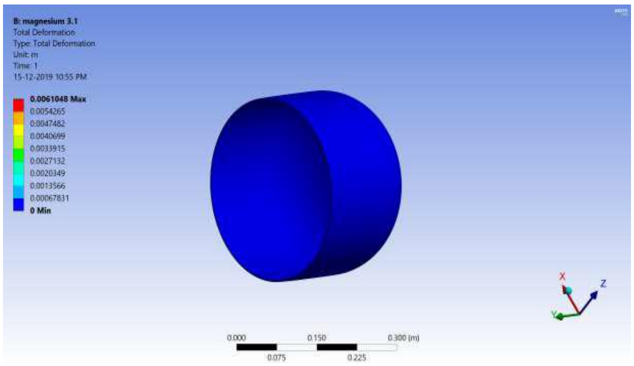


Fig.4.25 Total Deformation of Magnesium LPG cylinder (3.1mm)

Table 4.1
Simulation result

Steel			
S No	Thickness	Stress (Von Mises MPa)	
		Max.	Min.
1	2.5mm	651.21	0.67
2	3.1mm	441.7	0.34
3	3.4mm	382.8	0.59
Steel			
S No	Thickness	Stress (Principal MPa)	
		Max.	Min.
1	2.5mm	651.1	-35.11
2	3.1mm	550.5	-28.44
3	3.4mm	382.8	-25.37
Steel			
S No	Thickness	Total Deformation (m)	
1	2.5mm	0.0024	
2	3.1mm	0.0014	
3	3.4mm	0.00112	
Aluminum Alloy			
S No	Thickness	Stress (Von Mises MPa)	
		Max.	Min.
1	2.5mm	664.7	0.74
2	3.1mm	450.9	0.38
3	3.4mm	390.1	0.43
4	4mm	296.4	0.44
5	4.5mm	241.96	0.59
Aluminum Alloy			
S No	Thickness	Stress (Principal MPa)	
		Max.	Min.
1	2.5mm	664.2	-41.7
2	3.1mm	451.2	-32.8
3	3.4mm	389.9	-29.8
4	4mm	296.61	-25.2
5	4.5mm	241.9	-22.4

V. CONCLUSION AND FUTURE SCOPE

5.1 Conclusion

Based on the analysis of a LPG cylinder made of different materials following conclusions were drawn The new design model of a gas cylinder made of composite material viz. Aluminum Alloy of composition 5052H38 and thickness 4.5mm (slightly greater than existing one) exhibited greater strength (pressure induced by gas on cylinder walls) among all the chosen materials in the analysis .

The new designed model is easy in transportation from Industry to homes. The new design help household wives to move the cylinders easily hence reducing human efforts.

5.2 Future scope

At present, the field of material science has excelled to provide the technology of high strength and low cost material to the manufacture. Thus design and optimization of these parameters for a gas cylinder may be done in future using variety of composite materials.

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