

Finite Element Analysis OF GFRP LPG Cylinder

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Abstract - 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. When compressed moderately at normal temperature, it becomes liquid. When gas is withdrawn, the pressure drops and the liquid reverts to gas. This means that it can be transported and stored as liquid and burnt as gas. The LPG cylinders can be used for carrying the gas. The conventional cylinders are made of steel. The conventional cylinders have some disadvantages such as not having accurate way of showing the rate of fuel consumption and level of fullness or emptiness of the fuel, easily been rusted, hard to move because of the weight. By making the conventional cylinder with FRP it helps to over-come the problems. This paper is innovation of an alternative material GFRP of Liquid petroleum gas cylinder. So, the finite element analysis of Liquefied Petroleum Gas (LPG) cylinders made of Steel and Glass Fiber Reinforced Plastic (GFRP) composites were carried out. Finite element analysis of composite cylinder subjected to internal pressure were performed. FE analysis package ANSYS is used to model the shell composites.

Keywords - LPG, Steel cylinders , GFRP cylinder ,Allowable pressure ,Optimum thickness

1. INTRODUCTION

Liquefied petroleum gas (LPG) is a mixture of butane and propane gases stored under pressure, usually in steel cylinders. LPG is heavier than air, non-toxic and odourless. A smelling agent is added to aid users to detect leaks. LPG is a safe, economical and convenient fuel as it has high calorific value (13.8 kWh/kg, which is equivalent to 13.8 units of electricity), provides instantaneous heat, is easy to ignite and clean-burning and is very portable. It is the most environment friendly of the commonly used fossil fuels because it emits low levels of harmful combustion products. Typical uses of LPG include: cooking, space and water heating, refrigeration, lighting, brazing, soldering, welding, in school/technical laboratories, domestic households, restaurants, hospitals, small businesses, and recreation/leisure.

LPG appliances include: stoves/ovens, grills/ braais, heaters (portable and fixed), instantaneous water heaters, lamps (portable and fixed), refrigeration and welding plant, and Bunsen burners. Appliances are designed to operate both at an unregulated high pressure (e.g. CADAC (or similar) type of camping appliances) and at a lower pressure controlled by a regulator mounted on the gas storage cylinder. High pressure and low-pressure appliances are not interchangeable. Most households use gas appliances with a small dedicated gas cylinder, rather than a reticulated system of gas piping and fixed storage cylinders. LPG storage cylinders are supplied in a range of standard sizes in two categories: camping/hobby type and household/industrial type.

this work is about lpg cylinder that is made up of glass fibre reinforced polymers(gfrp).fibres are usually glass, carbon, basalt, etc .for present case the lpg cylinder is indented to be made of with glass fibre. this method had number of advantages with it. the conventional cylinders had some disadvantages such as not having accurate way of showing the rate of fuel consumption and level of fullness or emptiness of the fuel, hard to move . because of the weight. By making the conventional cylinder with FRP it will help to over-come the problems. This FRP LPG cylinder is analyzed using finite element analysis method. FE analysis package ANSYS has been used to model the shell with FRP composites .The properties used for FE analysis are taken from available literatures. FEA used to the study the stresses and deformations due to pressure inside cylinder.

The main objectives of the project are understand the concept of FRP incorporated LPG cylinder ,Simulate FEA to evaluate the stress in the cylinder ,Simulate FEA to evaluate the deformation in the cylinder, Study optimum design of the FRP LPG cylinder ,Study ultimate load capacity under applied load. The Scope of Work are Problem study & input data finalization ,Concept study of FRP incorporated LPG cylinder,3d model generation of the sample model using ANSYS,FEM Analysis: Static Structural Analysis ,model / drawing generation in ANSYS ,Project documentation with plots/sketches & result study observation

Scope

LPG is supplied in pressurised cylinders to keep it liquefied. The LPG (Liquefied Petroleum Gas) cylinders , from past many years, are being manufactured in our country from the very conventional metallic material such as steel. The weight of the cylinder becomes more as density of steel is higher compared to other light weight materials. In household applications, thrust should be given towards use of low density materials so that the weight will come down. With the advancement of low-density materials like GFRP (Glass Fibre Reinforced Polymer) Composites, we can think of producing LPG cylinders with GFRP to reduce its weight in future ,to increase safety, for measuring the amount of liquid consumption etc .

2. ANALYTICAL VALIDATION

In order to validate the model and software. The results for stresses for steel cylinders in the ANSYS were compared with the analytical solution available in literature.

2.1 Material Properties

The properties of steel cylinder are, Density, $\rho = 7.8 \text{ gm/cc}$, Young's modulus, $E=207\text{Gpa}$ Poisson ratio, $\nu = 0.3$ Yield strength = 480 MPa

1.1 Analytical Calculation For LPG Steel Cylinder.

Cylindrical portion Hoop stress :

$$\sigma_H = \frac{PD}{2t} = \frac{1.2 \times 320}{2 \times 2.5} = 76.8 \text{ MPa.} \quad (1)$$

$$\text{Longitudinal stress : } \sigma_L = \frac{PD}{4t} \quad (2)$$

$$= \frac{1.2 \times 320}{4 \times 2.5} = 38.4 \text{ MPa}$$

$$\text{Von-mises stress: } \sigma_v = \sqrt{\sigma_H^2 + \sigma_L^2 - (\sigma_H \times \sigma_L)} \quad (3)$$

$$= \sqrt{(76.8^2 + 38.4^2 - (76.8 \times 38.4))}$$

$$= 66.5 \text{ MPa}$$

2.3 Geometric Model

The geometry of the gas cylinder is shown in fig. It has been approximated by hemispherical ends of 160mm radius. Length of the cylindrical portion is 360mm. The total length of the cylinder is 680mm.

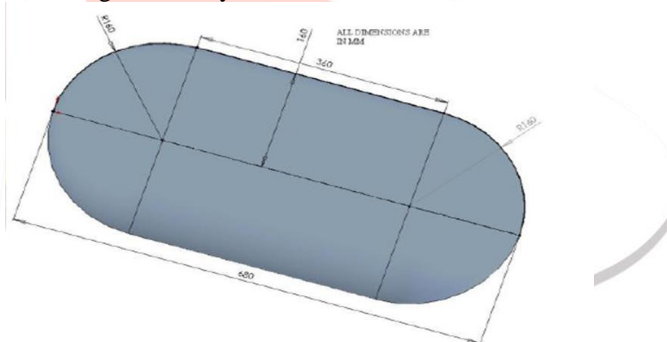


Fig.2.1 Geometric model of LPG cylinder.

2.4 Shell Element 181 Model.

Shell 181 is geometrically 2D but spatially 3D element. It has six degrees of freedom at each node, Translation in the nodal x, y and z directions about the nodal x, y and z axes. The element can be used for modelling 3D thin to moderately-thick shell structures.

2.5 Loads And Boundary Conditions.

An internal pressure load of 1.2 MPa has been applied. To simulate a proper boundary condition, the extreme end nodes of the cylinder are fixed in X-degree of freedom ($U_x = 0$). Here it has been assumed that the mid plane deformation along x-direction is zero.

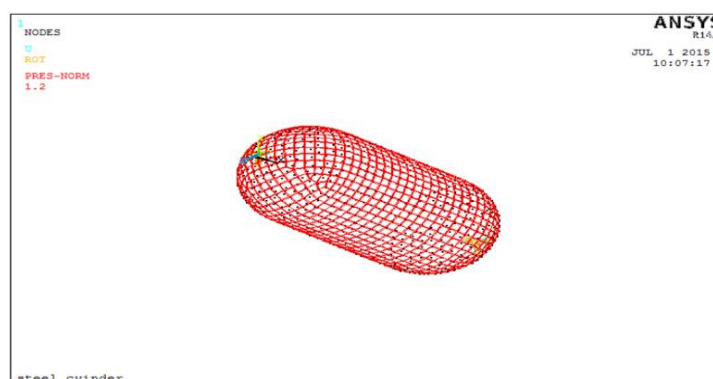


Fig 2.2 3D model after loading.

2.6 Results And Discussions.

The longitudinal (X-component) Stress contour plot is shown in fig.4.3. For which the maximum stress is occurring at the mid plane at which the cylinder is constrained along the longitudinal direction (x-direction). Maximum Longitudinal stress = 40.0447 MPa.

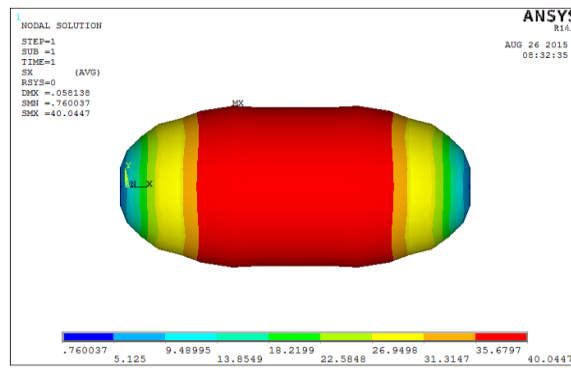


Fig.2.3 Longitudinal stress contour plot for steel cylinder.

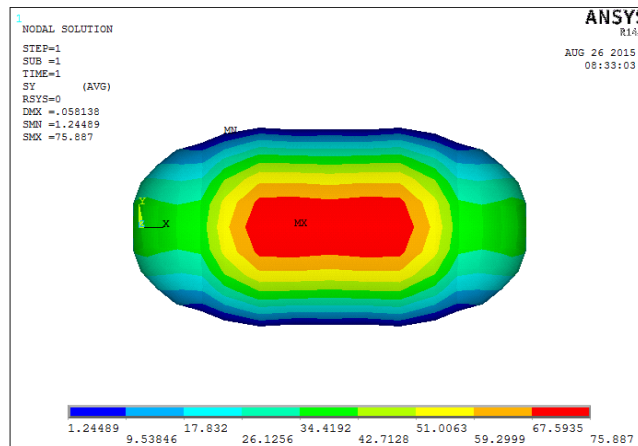


Fig 2.4 Hoop stress contour plot for steel cylinder.

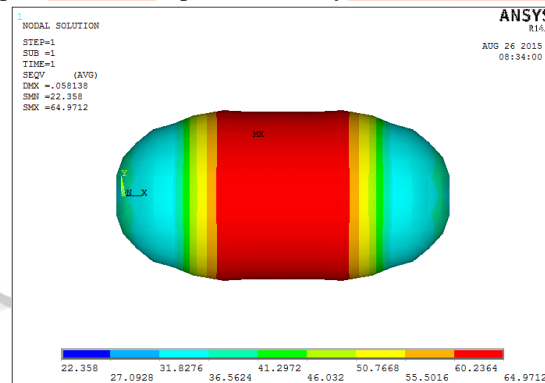


Fig 2.5 Vonmises stress for steel cylinder.

Table 1.Comparison between LPG and steel cylinder

RESULT	FE METHOD	ANALYTICAL METHOD	% ERROR
Longitudinal stress	40.0447	38.4	4.2
Hoops stress	75.887	76.8	1.18
Von-mises Stress, MPa	64.9712	66.5	2.29

3.ANALYSIS OF GFRP LPG CYLINDER.

The performance of the steel cylinders has also been compared with FRP cylinders. This may be a technical proposal for the use of FRP composites in gas cylinders in our Country. Glass fibers are the most common of all reinforcing fibers for polymeric matrix composites. The principal advantages of glass fibers are low cost, high tensile strength, high chemical resistance and excellent insulating properties and is transparent.

3.1 LPG Cylinder Made Of GFRP.

The GFRP cylinder has been modeled in ANSYS . The eight-noded linear layered shell element (SHELL91) with six degrees of freedom (ux, uy, uz,rotx, roty, rotz) has been used to discretize the cylinder.

3.2 Material Properties

The material used is Glass Fiber Reinforced Plastic (GFRP) composites for which material properties are listed below

- Elastic Modulus, E = 26 GPa
- Poisson's Ratio, = 0.28
- Density, ρ = 1.8 Kg/mm³
- Yield strength = 125 MPa
- Ultimate tensile strength = 530 MPa.

3.3 Loads And Boundary Conditions

An internal pressure load of 1.2 MPa has been applied . To simulate a proper boundary condition, the extreme end nodes of the cylinder are fixed in X-degree of freedom ($U_x = 0$) . Here it has been assumed that the mid plane deformation along x-direction is zero.

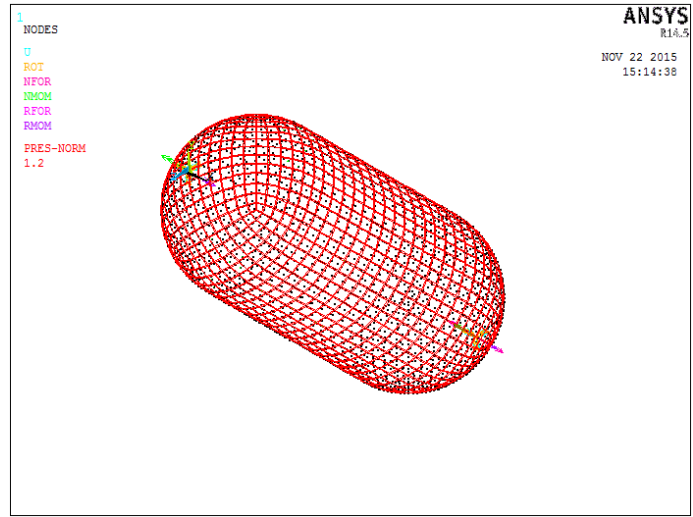


Fig.3.1 GFRP Cylinder after loading.

3.4 Results And Discussions.

The longitudinal (X-component) Stress contour plot is shown in fig.5.2. For which the maximum stress is occurring at the mid plane at which the cylinder is constrained along the longitudinal direction . (x-direction). Maximum Longitudinal stress = 39.9938 MPa.

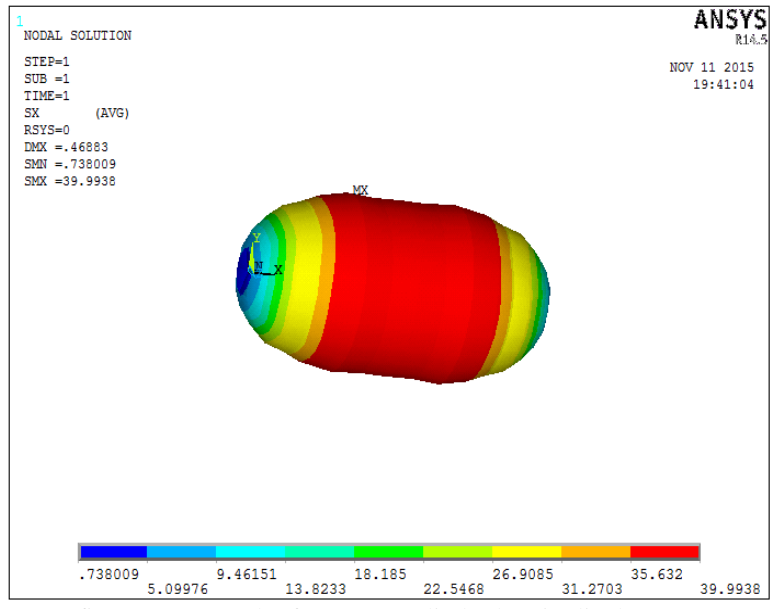


fig 3.2 contour plot for GFRP cylinder longitudinal stress.

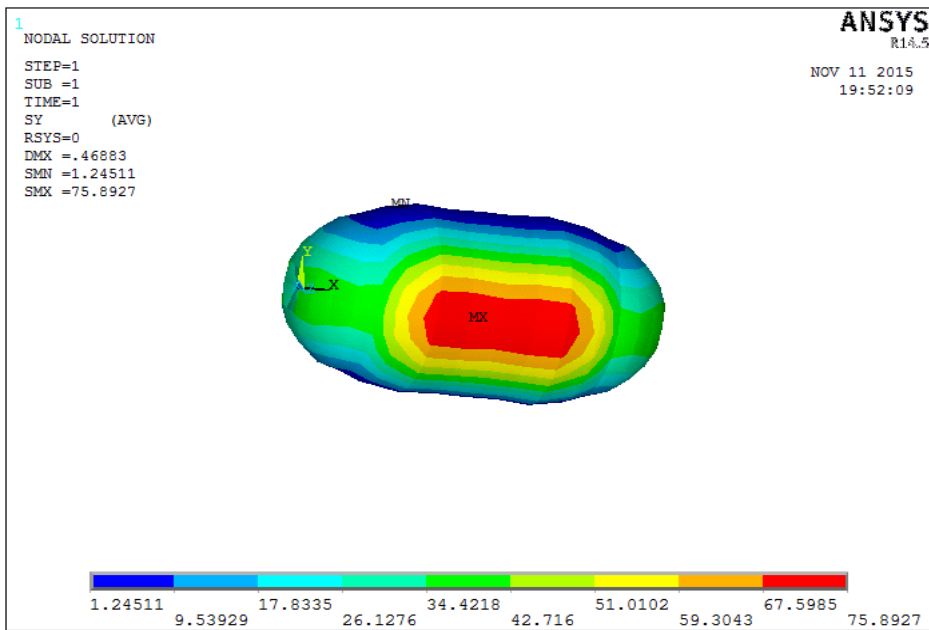


Fig 3.3 contour plot for GFRP LPG cylinder hoops stress.

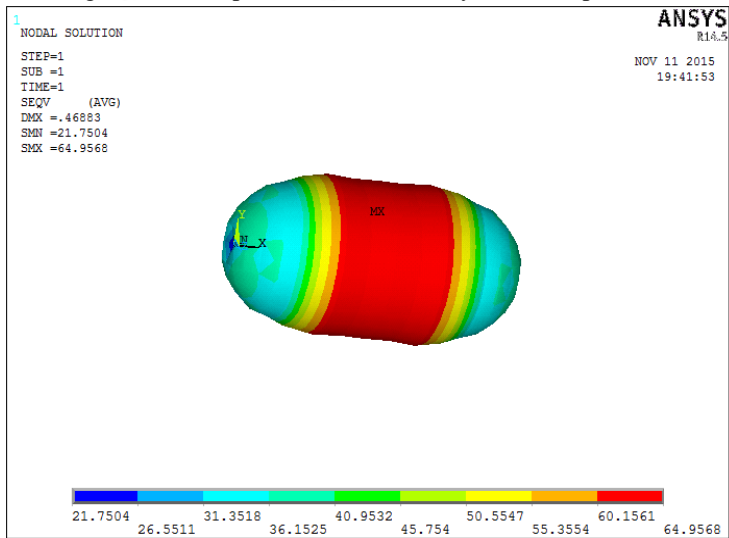


Fig 3.4 contour plot for GFRP LPG cylinder vonmises stress.

The figure is the figure showing the Vonmises stress plot for GFRP cylinder .For which the Maximum Vonmises stress =64.9568 MPa.

Table.2 Comparison Of GFRP And Steel Cylinder.

CRITERIA	GFRP	STEEL
Maximum Vonmises Stress in MPa	64.9568	64.9712
Maximum Hoop Stress in MPa	75.8	75.0887
Maximum Longitudinal Stress in MPa	39.9938	40.0447

Based on the analysis of LPG cylinder made of different materials like Steel and GFRP following conclusion have emerged out from the present investigations:

- The 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 it’s use in household applications.

4 ALLOWABLE LOAD FOR GFRP LPG CYLINDER.

4.1 Allowable Load .

From the references the factor of safety and the tensile strength of the GFRP cylinder is known. The allowable stress can be calculated by using the relation.

Allowable or permissible or working stress=Ultimate strength/factor of safety.

Knowing the allowable stress the allowable load for GFRP can be calculated by time history analysis.

Ultimate Tensile strength GFRP =530Mpa

Factor of safety GFRP cylinder =5

Allowable stress = Tensile strength GFRP/ Factor of safety GFRP cylinder

$$=530/5=106\text{Mpa}$$

The maximum allowable pressure of the GFRP cylinder can be find. From time history analysis the maximum allowable pressure up to allowable stress =1.94Mpa.

5 OPTIMUM THICKNESS.

Knowing the allowable stress optimum thickness can be calculated. From the references the factor of safety and the tensile strength of the GFRP cylinder is known. The allowable stress can be calculated by using the relation.

Allowable or permissible or working stress=Ultimate strength/factor of safety.

Tensile strength GFRP =530Mpa

Factor of safety GFRP cylinder =Allowable stress
 =Tensile strength GFRP/Factor of safety GFRP cylinder
 =530/5=106Mpa.

Time history analysis of the GFRP LPG cylinder for an approximate pressure range. Here we uses pressure 1.2 to 2.Total 5 subsets were selected for each main step.

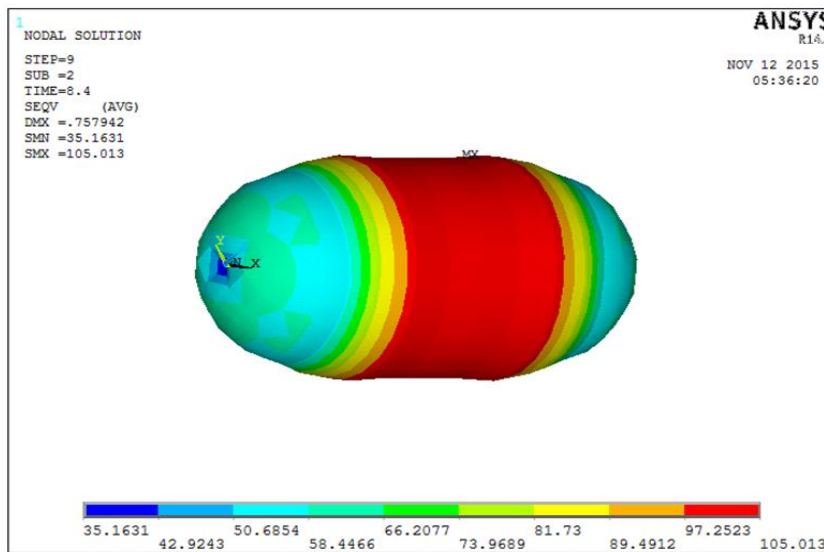


Fig 5.1 contour plot for GFRP cylinder (maximum allowable pressure.)

The analysis of GFRP cylinder for different thickness gets done by using ANSYS software .By using the stress results for different thickness we can check the stress with the allowable stress. The optimum thickness is the one for which the vonmises stress is maximum and less than 106Mpa.

The vomises stress for different thicknesses are as below.

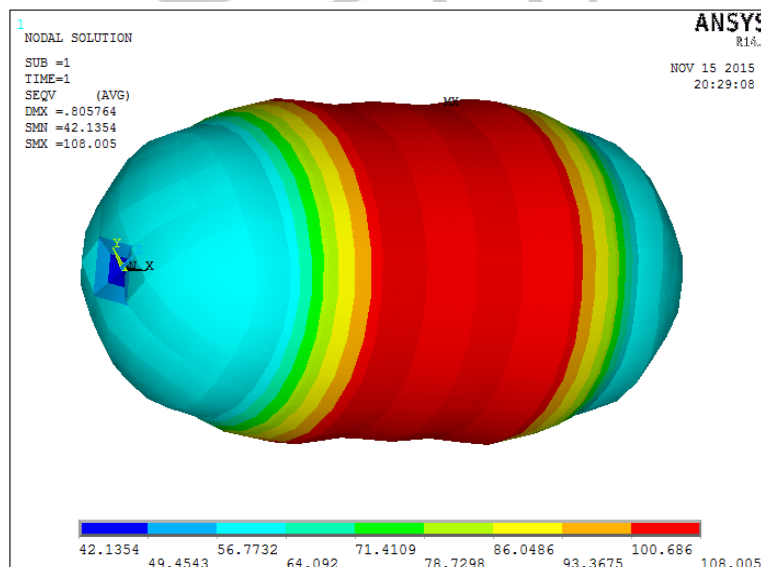


Fig5.2 contour plot for GFRP cylinder vonmises stress(1.5mm thickness).

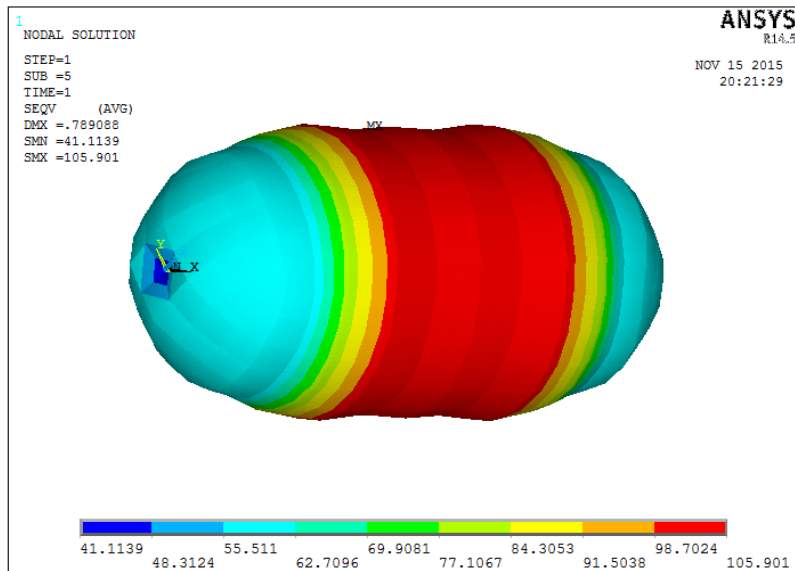


Fig5.3 contour plot for GFRP cylinder vonmises stress(1.53mm thickness).

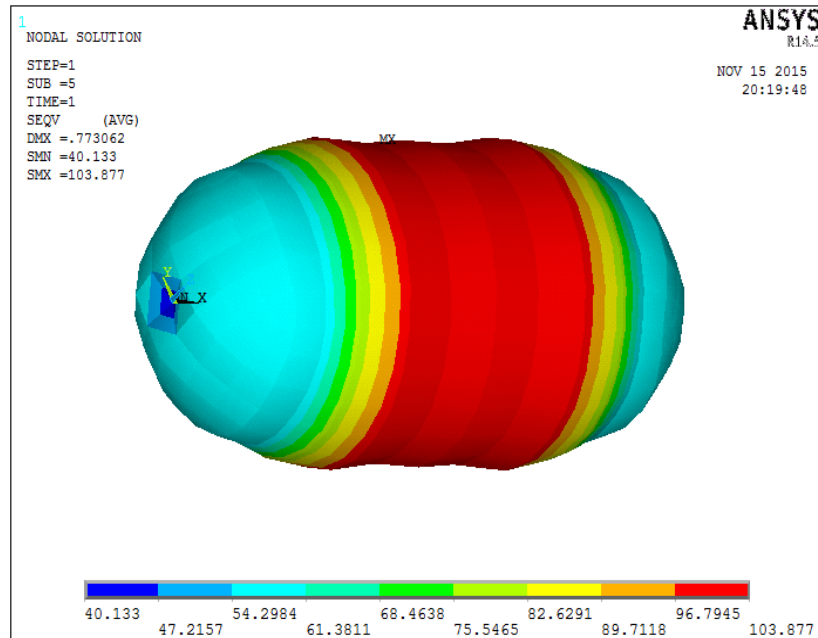


Fig 5.3 contour plot for GFRP cylinder vonmises stress(1.54mm thickness).

Table.3 Stress for different thickness.

Thickness	Vonmises stress
1.5	108.005Mpa
1.53	105.901Mpa
1.54	103.877Mpa

The optimum thickness = 1.53mm.

6.CONCLUSION

The literature review and introduction focused on contributions related to finite element modelling and finite element analysis of GFRP LPG cylinder, materials used and past efforts most closely related to the needs of present work. The GFRP cylinders are more preferable compared to steel cylinder.

Maximum pressure load that can be applied for GFRP cylinder is 1.94Mpa. The optimum thickness for GFRP cylinder is 1.53mm.The GFRP cylinder is more preferable than steel cylinders.

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