International Journal of Applied Research 2015; 1(12): 1042-1045

International Journal of Applied Research

ISSN Print: 2394-7500
ISSN Online: 2394-5869
Impact Factor: 5.2
IJAR 2015; 1(12): 1042-1045
www.allresearchjournal.com
Received: 24-09-2015
Accepted: 27-10-2015

M Dhanunjayaraju
M.Tech Student, Department of Mechanical Engineering
Chirala Engineering College, Chirala.

TL Rakesh Babu
Associate professor
Department of Mechanical Engineering
Chirala Engineering College, Chirala.

Correspondence
M Dhanunjayaraju
M.Tech Student, Department of Mechanical Engineering
Chirala Engineering College, Chirala.

Stress analysis of LPG cylinder with composites

M Dhanunjayaraju, TL Rakesh Babu

Abstract
In this paper weight of Liquid petroleum gas (LPG) cylinder is reduced by replacing the alternative materials. So, the finite element analysis of Liquefied Petroleum Gas (LPG) cylinders made of Steel and Fiber Reinforced Plastic (FRP) composites has been carried out. Finite element analysis of composite cylinder subjected to internal pressure is performed. Layered shell element of a versatile FE analysis package ANSYS has been used to model the shell with FRP composites.
Number of cases are considered to study the stresses and deformations due to pressure loading inside the cylinder. First, the results of stresses and deformation for steel cylinders are compared with the analytical solution available in literature in order to validate the model and the software. The weight savings are also presented for steel, Glass Fiber Reinforced Plastic (GFRP) composites and Carbon Fiber Reinforced Plastic (CFRP) composite LPG cylinders. Variations of stresses and deformations throughout the cylinder made of steel, GFRP and CFRP are studied.
By Comparing the Maximum Vanishes Stress is high for CFRP; The Maximum Longitudinal Stress is high for CFRP, Maximum longitudinal deformation is for CFRP. The maximum weight was saved in CFRP.
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 its use in household applications.

Keywords: Stress Analysis, LPG Cylinder, Composites

1. Introduction

1.1 Liquefied Petroleum Gas (LPG)

LPG (propane or butane) is a colorless liquid which readily evaporates into a gas. It has no smell, although it will normally have an odor added to help detect leaks. When mixed with air, the gas can burn or explode when it meets a source of ignition. It is heavier than air, so it tends to sink towards the ground. Liquefied Petroleum (LP) Gas is composed predominantly a mixture of the following hydrocarbons: propane, propylene, butane or butylenes. 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 expansion ratio of gas from liquid is 270:1 at atmospheric pressure. It is this expansion factor which makes LP-Gas more economical to transport and store large quantities of gaseous fuel in a small container in liquid state.

LP-gas inside a container is in two states of matter, liquid and vapour. The liquid portion of container is in the bottom and the vapour is in the uppermost part of the vessel, i.e. the space above the liquid level. Containers are normally filled 80-85% liquid, leaving a 15-20% vapour space for expansion due to temperature increase.

The vapour pressure of propane increases as the liquid temperature increases. Propane at -42^0C inside a container would register zero pressure. At 0^0C, propane vapour pressure will increase to 380 k Pa. At 38^0C, the vapour pressure of propane would be 1200 k Pa. LP-gas is odorless and non-toxic. A distinct smelling odourant such as ethyl mercaptan is added as a detection agent for all domestic, and for most commercial and industrial LP-gas. The purpose is to introduce sufficient odourant so that the presence of unburnt gas can be readily detected before it reaches a mixture that is flammable and comes in contact with a source of ignition.

1.2 Liquefied Petroleum Gas (LPG) Cylinders
LPG is supplied in pressurized cylinders to keep it liquefied. The LPG (Liquefied Petroleum Gas) Cylinders (fig.1.1) 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 lightweight 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 FRP (Fiber Reinforced Plastic) Composites, we can think of producing LPG cylinders with FRP to reduce its weight.

Unlike aerospace applications, where weight reduction of a component is of prime requirement, in commercial household applications, reliability/safety as well as weight of the component is given more importance. Keeping the issue of reliability and weight in view, the high-end composite material technology can very well be implemented in design of household LPG cylinders.

Any pressure vessel made of metallic materials has a major drawback of severe bursts in worst cases. For example, when gas cylinders catch fire, it explodes heavily creating danger for its users. Whereas, FRP gas cylinders doesn't explode (Leak before fail approach) due to porosity formation of materials. Due to formation of leakage through the thickness, the flames simply start coming out slowly, which is a fail-safe design approach.

Western countries like USA, Germany, UK, and Russia have already started using FRP composites for LPG cylinders. They are producing it on large scale and in another 15-20 years, they are going to replace all existing steel cylinders by FRP composites. This gives a clear picture of the world market scenario of FRP composite gas cylinders. Being a developing country, we should also go neck-to-neck with them and start thinking towards making gas cylinders with FRP composites.

1.3 Composite Materials
A composite material is formed by combining two or more materials to achieve some superior properties. In other words, composite materials are macroscopic combinations of two or more distinct materials having a discrete and recognizable interface separating them. Thus composites are heterogeneous materials. By combining two or more materials together, we can tailor make composite materials, which are lighter and stiffer, stronger that any other materials man have ever used. A variety of materials, which we see around us, are composites e.g. wood, bones etc.

1.4 Fiber Reinforced composite
Fiber Reinforced composite materials consist of fibers of high strength and modulus embedded in or bonded to matrix with distinct interfaces between them. In this form, both fibers and matrix retain their physical and chemical identities, yet they produce a combination of properties that cannot be achieved with either of the constituents acting alone. In general, fibers are the principal load carrying members, while the surrounding matrix keeps them in the desired location and orientation, acts as a load transfer medium between them, and protects them from environment damages due to elevated temperatures and humidity for example. Thus, even though the fibers provide reinforcement for the matrix, the latter also serves number of useful functions in a fiber reinforced composite material.

1.5 Enrico Papa and Alberto Corigliano
Results of an experimental investigation into the mechanical behavior of a composite sandwich conceived as a lightweight material for naval engineering applications. The sandwich structure is formed by a three-dimensional glass fiber/polymer matrix fabric with transverse piles interconnecting the skins; the core is filled with polymer matrix/glass microspheres syntactic foam; additional Glass Fiber Reinforced Plastics extra-skins are laminated on the external facings of the filled fabric. The main features of the experimental tests on syntactic foam, skins and sandwich panels are presented and discussed, with focus on both in-plane and out-of-plane responses. This work is part of a broader research investigation aimed at a complete characterization, both experimental and numerical, of the complex mechanical behavior of this composite sandwich.

1.6 Alberto Corigliano*, Egidio Rizzi, Enrico Papa 2000.
Results of an experimental and numerical investigation on the mechanical behavior of a composite sandwich primarily designed for naval engineering applications. The skins of the sandwich are made of glass- fiber/polymer-matrix composites; their interior layers are connected with interwoven threads called piles which cross the sandwich core. Such core consists of syntactic foam made by hollow glass microspheres embedded in an epoxy matrix. Experimental tests and numerical finite element (FE) simulations on both the sandwich composite and its separate components have been performed in order to characterize fully the complex mechanical behavior of such a highly heterogeneous material.

1.7 Nikhil Gupta and Eyassu Woldesenbet 2005. Micro balloons (hollow particles) of the same outer radius but with five different inner radius values are used to fabricate five types of syntactic foam slabs. These five types of slabs are used as core material to fabricate sandwich composites. Three and four point bending and short beam shear strength tests are carried out to characterize the flexural behavior of syntactic foam core sandwich composites. The effect of change in micro balloon Radius Ratio (ratio of the inner to the outer radius) on the flexural properties of the sandwich composites is also studied. The results show that in three and four-point bending tests the failure is governed by tensile properties of the foam core and the strength is not affected by the micro balloon radius ratio. Shear failure takes place in short beam shear tests, which makes the micro balloon radius ratio an important factor in determining the strength of the sandwich composite.

2. Geometric Model
The geometry of the gas cylinder is shown in fig.1. 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.

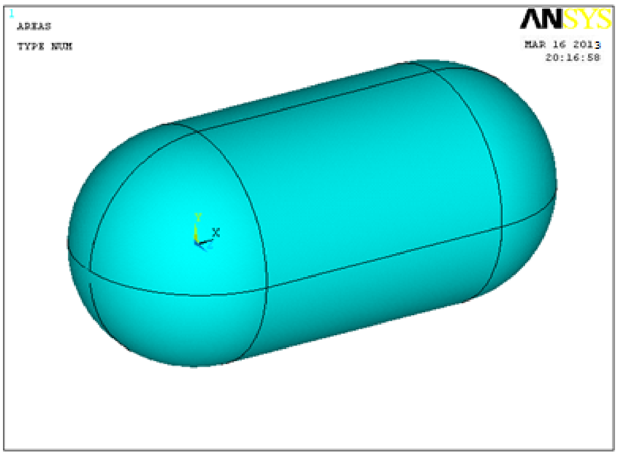

Fig 1: 3-D View of the geometric model

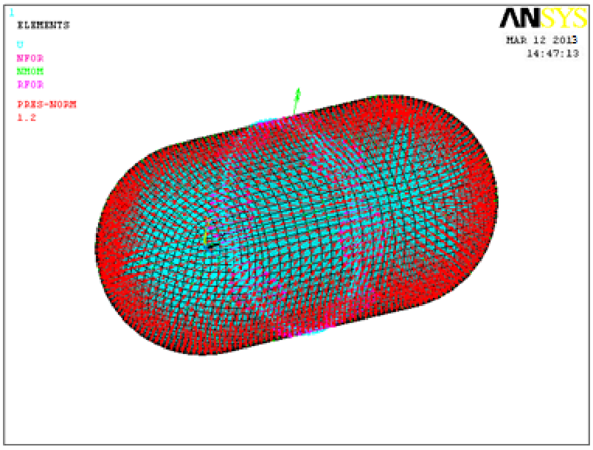

Fig 2: Internal pressure applied on Steel cylinder

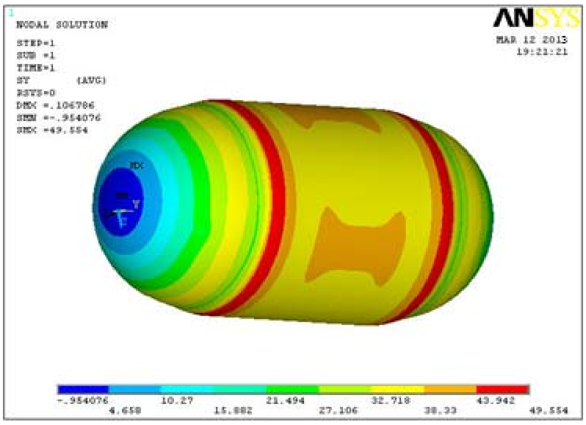

Fig 3: Longitudinal stress (in M Pa) contour plot for steel cylinder

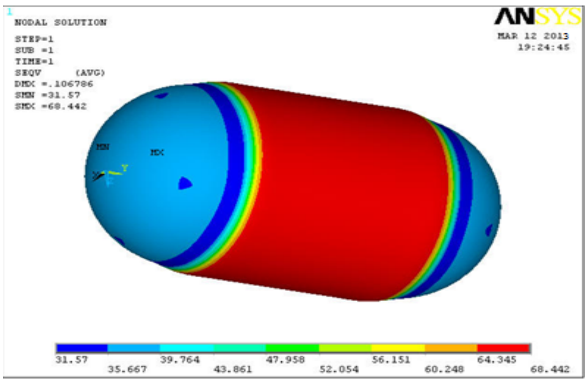

Fig 4: Von-misses stress contour plot for steel cylinder
Maximum Vonmises stress =68.81 M Pa

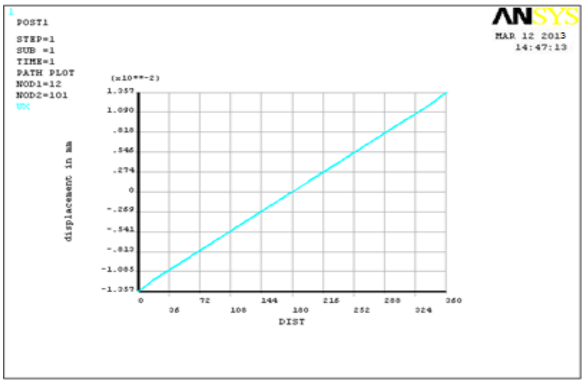

Fig 5: Graph for the Longitudinal Displacement

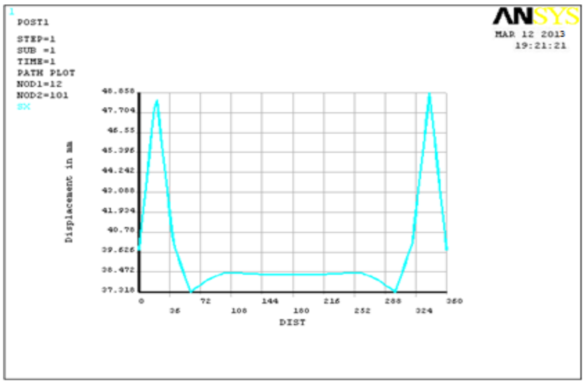

Fig 6: Longitudinal Stress variations Graph for Steel Cylinder

3. Analytical Calculation for LPG Steel cylinder

a. Cylindrical portion

Hoop stress, $\sigma_H = \frac{PD}{2t} = \frac{1.2*320}{2*2.5}$ = 76.8 M Pa

Longitudinal stress, $\sigma_L = \frac{PD}{4t} = \frac{1.2*320}{4*2.5}$ = 38.4 M Pa

Longitudinal strain, $\varepsilon = \frac{\sigma_L}{E} = \frac{38.4}{207*E3}$ = 0.000185

Longitudinal Deformation, δ = $\frac{\Pr^2(1-\nu)}{2Et}$ = 0.050mm.

b. Hemispherical End dome portion

Hoop stress, $\sigma_L = \frac{PD}{4t} = \frac{1.2*320}{4*2.5}$ **= 38.4 M Pa**

The detailed results of FE analysis as well as classical method for the cylinder are listed below.

Table 1: Comparison of results for steel

Sl. No.	RESULTS	FE METHOD	ANALYTICAL METHOD
1	Longitudinal stress, M Pa	43.48	38.4
2	Hoop stress, M Pa	79.30	76.8
3	Von-misses stress, M Pa	68.81	66.5
4	Longitudinal Deformation, mm	0.033	0.050

4. LPG Cylinder Made Of Gfrp

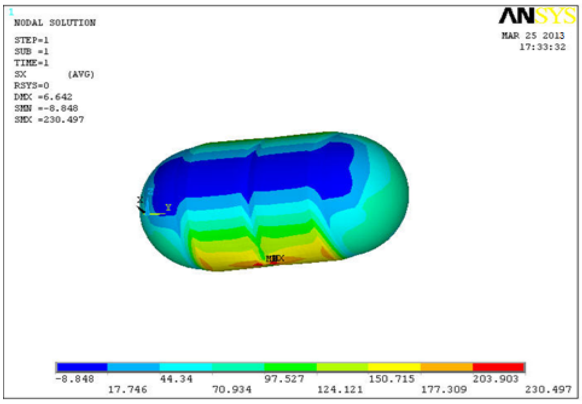

Fig 7: Longitudinal stress (M Pa) contour plot for GFRP cylinder

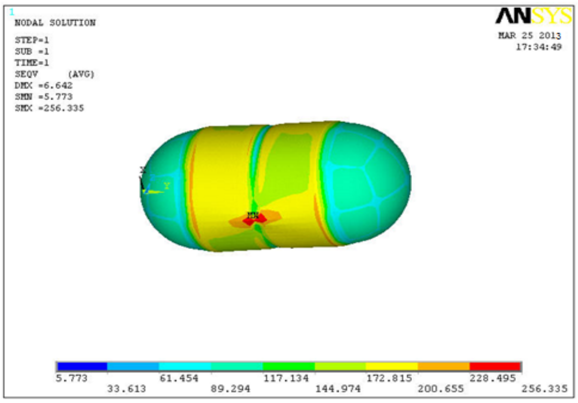

Fig 8: Von-misses stress (M Pa) contour plot for GFRP cylinder

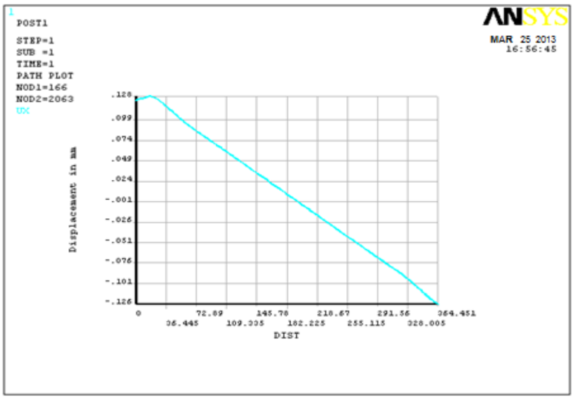

Fig 9: Graph showing the variation of Displacement

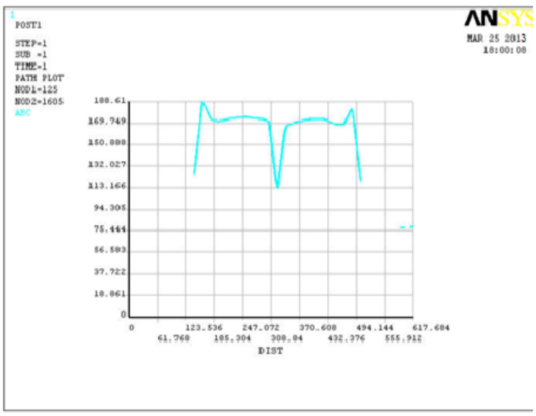

Fig 10: Graph showing the variations of Vonmises Stress

Table 2: Comparisons of GFRP and CFRP

CRITERIA	GFRP	CFRP
Maximum Vanishes Stress in M Pa	65	109.97
Maximum Longitudinal Stress in M Pa	44.36	54.36
Maximum longitudinal deformation in mm	0.161	0.135

5. Conclusions

Based on the analysis of LPG cylinders made of different materials like steel, GFRP and CFRP, following salient conclusions have emerged out from the present investigations:

1. 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 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)
Weight saving = 10.29 kg
Weight of the CFRP cylinder = 2.62 kg (without end frames)
Weight saving = 10.69 kg

2. Apart from the weight savings, FRP composite LPG cylinders offer 'Leak before fail approach of design' which may be a design advantage in terms of safety and reliability.

6. References

1. Jones RM. Mechanics of Composite Materials Mc Graw Hill Book Co, 1975.
2. Mallick PK. Fiber Reinforced Composites, 1997
3. Agarwal BD, Brootman LJ. Analysis and performance of Fiber Reinforced Composites Wiley publishers 2nd Edition, 1990.
4. Peters ST. Handbook of Composites Chapman and Hall London 2nd Edition, 1998.
5. Geoff Eckold. Design and Manufacture of Composite Structures Jaico publishing House, 1995.
6. Vasiliev VV, Morozov EV. Mechanics and Analysis of Composite Materials Elsevier Science, 2001.
7. Kumar S, Pradhan B. Finite Element Analysis of Low-Velocity Impact Damage in Composite Laminates, Journal of Reinforced Plastics and Composites. 2000; 19(04).
8. Jha SK, Kumar S. Finite Element Analysis of Deformations, Stresses and Damages in FRP Composite Laminates Subjected to Uniformly Distributed Loadings; National Conference on Light Metals and Composites for Strategic and Social needs; RRL Trivandrum, October 2002.
9. Jha SK. M. Tech. Thesis on 3-D FE Analysis of FRP Composite Beams and Plates; Mechanical Engineering Department, NIT Jamshedpur, April 2002.