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Finite Element Analysis of Automobile LPG Cylinder Using Composite Material

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Abstract: *As the usages of fossil fuels are increasing day by day as the numbers of automobiles on roads are increasing, this is contributing to the increasing levels of pollution in the atmosphere. Now the automotive industry is looking forward to promote the alternative fuels usage for automotive propulsion. In this sinerio LPG, CNG fuels are the immediate solutions to reduce the pollutants concentration in the atmosphere even though they are coming from fossil fuels. Composite materials can be utilized to design better storage systems at lower rates when compared to conventional metallic materials. FEA is implemented to the present problem to arrive it better solutions pertained to various geometries of pressure vessel made of E-GLASS/EPOXY composite. Providing solutions for the design of pressure vessel made of filament wound technology with Cylinder with spherical ends.*
Keywords**:** *composite material, stress analysis, finite element method.*

I. Introduction

Vessels, tanks, and pipelines that carry, store, or receive fluids are called pressure vessels. A pressure vessel is defined as a container with a pressure differential between inside and outside. The inside pressure is usually higher than the outside, except for some isolated situations. Pressure vessels are usually spherical or cylindrical, with domed ends [1]. The cylindrical vessels are generally preferred, since they present simpler manufacturing problems and make better use of the available space. Boiler drums, heat exchangers, chemical reactors, and so on, are generally cylindrical. Spherical vessels have the advantage of requiring thinner walls for a given pressure and diameter than the equivalent cylinder. Composites consist of two or more materials or material phases that are combined to produce a material that has superior properties to those of its individual constituents [2]. The constituents are combined at a macroscopic level and are not soluble in each other. The main difference between a composite and an alloy is that constituent materials are insoluble in each other and the individual constituents retain those properties, where as in alloys, constituent materials are soluble in each other and form a new material which has different properties from its constituents [3] . One constituent is called reinforcing phase and the one in which the reinforcing phase is embedded is called matrix [4]. Historical or natural examples of composites are abundant: brick made of clay reinforced with straw, mud wall with bamboo shoots, concrete, granite consisting of quartz, mica and feldspar, wood (cellulose fibers in lignin matrix), etc.

1.1 Fibers of FRC

The primary function of the fibers is to carry the loads along their longitudinal directions. Common fiber reinforcing agents include [5]

Aluminum, Aluminum oxide, Aluminum silica

- Asbestos
- Beryllium, Beryllium carbide, Beryllium oxide
- Carbon (Graphite)
- Glass (E-glass, S-glass, D-glass)
- Molybdenum
- Polyamide (Aromatic polyamide, Aramid), e.g.,Kevlar 29 and Kevlar 49.
- Polyester
- Quartz (Fused silica).
- Steel
- Tantalum
- Titanium.

- Tungsten
- Tungsten monocarbide

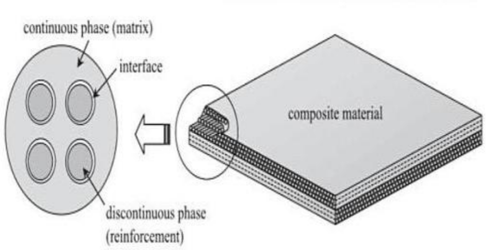

Fig.1. Composite material

Table.1.Properties of composite reinforcing fibers

Material	E, Gpa	σ_b,GPa	ρ, kg/m^3	E/ρ, MJ/kg	σ_b/ρ, MJ/kg	cost, $/kg
E Glass	72.4	2.4	2540	28.5	0.95	1.1
S Glass	85.5	4.5	2490	34.3	1.8	22-33
Aramid	124	3.6	1440	86	2.5	22-33
Boron	400	3.5	2450	163	1.43	330-440
HS Graphite	253	4.5	1800	140	2.5	66-110
HM Graphite	520	2.4	1850	281	1.3	220-660

II. METHODOLOGY ADOPTED FOR DESIGN OPTIMIZATION

2.1 Design Approach

The design of the FRP components requires a definite approach with consensus of discussion depending on the functional requirements. The complex nature of failure behavior of fiber reinforced composites makes the design approach complex [6] . In view of developing user friendly approaches for design of commercial FRP products the preset work provides a path way towards establishing simple methods for required class of products [7]. The laminate design software is a basic tool utilized to estimate the elastic properties of the laminate [8]. Popular FEA soft ware is utilized to analyze few components with critical operating conditions to identify the critical parameters influencing the design objective [9]. The design of the pressure vessel comprises of hemispherical dishes with cylindrical shell. The geometrical model of the L.P.G storage tank is shown in the figure 2. The working pressure of domestic L.P.G cylinder is of the order of 1.0132 N/mm^2 to 1.7 N/mm^2 [10]. In the present work the design pressure of FRP L.P.G cylinder is considered with the same internal pressure as that of steel domestic L.P.G cylinder, the material considered for the designing of the cylinder is glass/epoxy and the manufacturing process considered is helical filament winding technique [11]. The conventional L.P.G cylinder is made of low carbon steel, 3mm thick. The elastic properties of the lamina with reference to the helix angle are estimated before proceeding towards the FE analysis [12]. In the present work the thickness of FRP pressure vessel is considered as 12mm. In order to select the better orientation sequence FE analysis is performed [13]. The filament winding process provides a reinforcement volume fractions ranging from 0.6 to 0.75, in the present work the volume fraction considered for FE analysis is considered as 0.6 for keeping the design in safe limits.

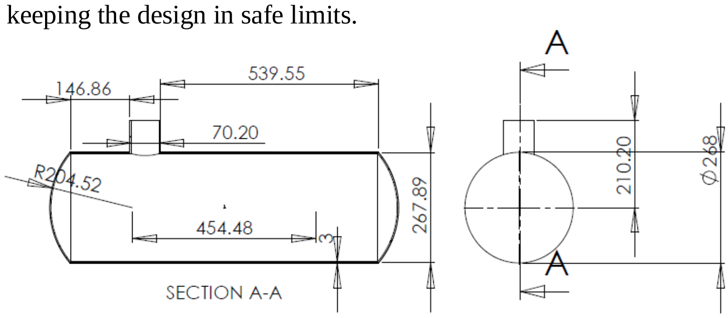

Fig 2: LPG FRP pressure vessel geometric details

The ± symbol represents the cross ply orientation and numerical value represents the angle measured with reference to the X- axis and the prefix number after square brackets shows the number of layers in the laminate. The mechanical properties of reinforcement (E-glass) and Epoxy resin (k-6 hardener) are shown in table. The properties of cross ply orientation with the above mentioned orientation sequences are also estimated by laminate design software as shown in the table 2. These properties are used when FE analysis is implemented to the problem.

Table.2: e-glass fibers and epoxy resin (k-6 hardener) mechanical properties

S.No	E-glass fibers		Epoxy resin with k-6 hardener	
	Mechanical properties	values	values	units
1.	Young's modulus	74500	3500	MPa
2.	Tensile strength	1900 -2600	60	MPa
3.	Elongation	0 - 3.2	------	%

Table 3: material properties for glass/epoxy laminate

	Young's modulus in x-direction E_{11} (N/mm^2)	Young's modulus in y-direction E_{22} (N/mm^2)	Major poison's ratio ν_{12}	Minor poison's ratio ν_{21}	Shear Modulus G_{12} (N/mm^2)
Material properties of the laminate about 12-axis	56.75	12.2706	0.225	0.0486	5.2041

III. FINITE ELEMENT ANALYSIS

Finite element Analysis is a powerful numerical technique for analysis. FEA is used for stress analysis in that area of solid mechanics. The basic concept of finite element method is that a body / structure may be divided in two smaller elements called finite elements. The properties of the element are formulated and combined to obtain the solution for the entire body or structure. For a given practical design problem the engineer has to idealize the physical system into a FE model with proper boundary conditions and loads that are acting on the system. Then the discretization of a given body or structure into cells of finite elements is performed and the mathematical model is analyzed for every element and then for complete structure. The various unknown parameters are computed by using known parameters.

3.1 Steps Involve In Ansys:

3.1.1Preprocessor:

All inputs like element selection, real constrain, material properties (young's modulus, poisons ratio, shear modulus) and meshing of the design is given here. And FE analysis is carried out in the solution.

3.1.2. Solution:

The boundary conditions like displacement and pressures are given here. And the results are obtained in general post processor.

3.1.3. Post Processor:

In post processors the results obtain are

- Deformation Mechanical
- Strain (both Longitudinal and hoops strain)
- Inter laminate shear stress and Shear stress

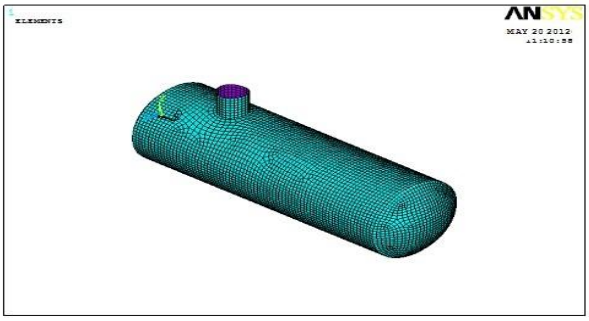

Fig.3. Geometric and meshed model of steel pressure vessel with 3mm thickness

3.2. Stress Analysis of Steel Cylinder Using FEA

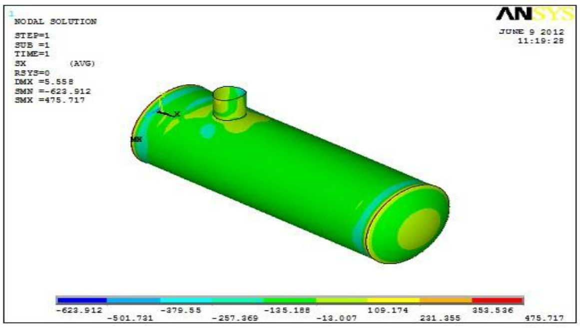

Fig 4. stress of steel cylinder at 30atm in x-direction

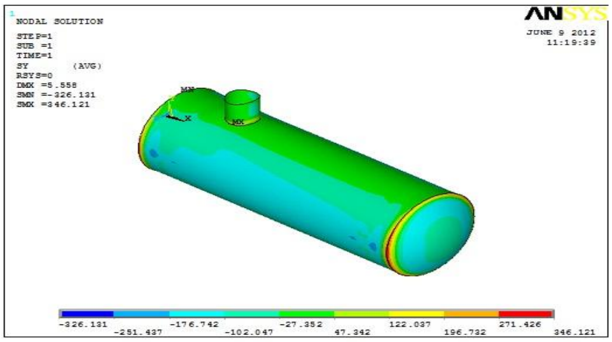

Fig.5. Stress of steel cylinder at 30atm in y-direction

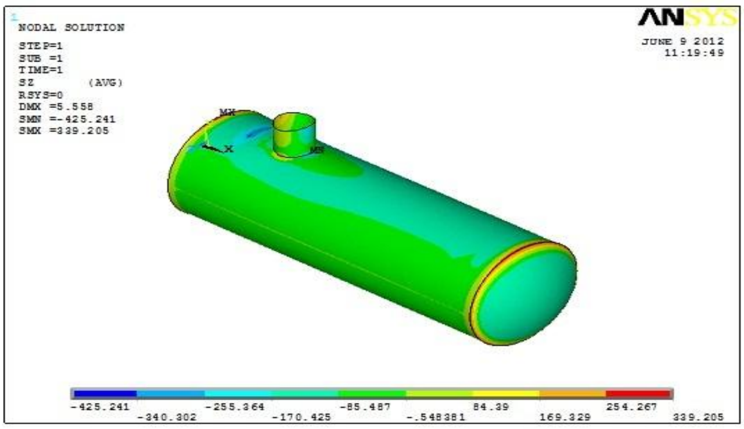

Fig.6. Stress of steel cylinder at 30atm in z-direction

Table.4. stress values for steel cylinder at10, 17,30atm pressure.

Atmospheric pressure	Stress value In x-direction	Stress value In y-direction	Stress value In z-direction
10atm	158.572	115.374	113.068
17atm	269.573	196.135	192.216
30atm	475.717	346.121	339.205

3.3. Strain Analysis of Steel Cylinder Using FEA

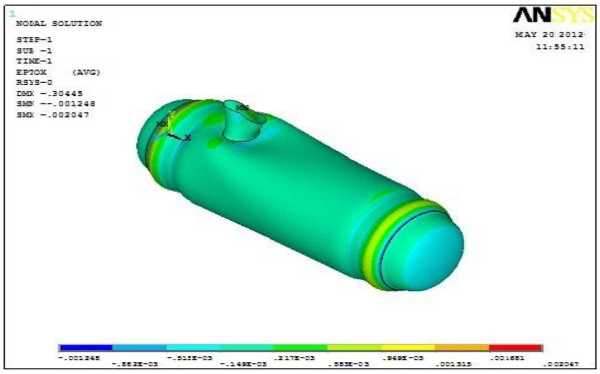

Fig.7. Deformation and longitudinal strain for steel pressure vessel at 3.5N/mm^2

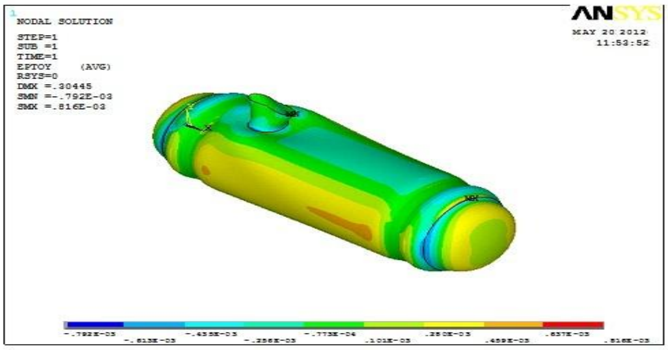

Fig.8. Deformation and hoop strain for steel pressure vessel at 3.5n/mm^2

IV. RESULTS & DISCUSSION

The result of steel pressure vessel at different helix angles to find deformation, longitudinal strain and hoop Strain.

S.No	Helix Angle (deg)	Deformation (mm)	Longitudinal strain	Hoop strain
1	$[\pm10]_{12}$	0.31794	0.002049	0.001673
2	$[\pm20]_{12}$	0.319222	0.002027	0.00144
3	$[\pm30]_{12}$	0.320946	0.001962	0.001153
4	$[\pm45]_{12}$	0.309525	0.001738	0.001057
5	$[\pm58]_{12}$	0.286926	0.001945	0.001323
6	$[\pm65]_{12}$	0.277432	0.002045	0.001422
7	$[\pm75]_{12}$	0.272913	0.002121	0.001511
8	$[\pm80]_{12}$	0.273289	0.00214	0.001562

V. CONCLUSION

As the automotives are vulnerable to crashing, the passengers' safety is to be enhanced by the failure characteristics of F.R.P component. The objective of this project work is establishing theoretical procedure for design of pressure vessels of this kind is successful, but the facts could be established only by adopting suitable testing procedures. Failure strain in composite material is 4% more than the failure strain of steel. In the present project design for given pressures, the strains are well below 0.4%.So we can say that the design is safe even with this level of designing. Even with this level of designing the weight reduction is 30%, which is very important factor to be considered while using the polymer composites as a structural material. Excellent corrosion resistance improved passenger's safety life span of F.R.P tank is improved to an extent of 100%. Fragmentation during fracture is completely eliminated, as the failure behavior of polymer components is different from isotropic material. The confidence level of using this product in commercial scale could be improved by subjecting this product to suitable tests based on automotive safety norms.

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