Determination of Stresses of Vehicle LPG Cylinder and Its Optimization using FE Approach

Madhuri P[1] Mr. Lohiteshjaga Kumar[2] Dr. T. P. Bharathesh[3] Mr. Praveen Kumar[4]
[1]PG Scholar [2,3]Assistant Professor [4]Professor
[1,2,3,4]Department of Mechanical Engineering
[1,2,3,4]Akshaya Institute of Technology, Tumakuru, Karnataka, India

Abstract— LPG is the most generally utilized elective fuel in the car IC Engines. Current days the greater part of the flame mishaps are accounted for in view of disappointment of the chambers. Stuffing of the chambers and temperature are the central point for the disappointment. Increment in the weight of LPG in the barrel may prompts blasting of the chamber. A large number of the pioneers has been completed test work to improve the plan of the LPG chambers. Likewise because of increment in the weight in the chamber builds the interior anxieties which prompts disappointment of the barrel. In the present work gauge plan of the LPG chamber has been concentrated to comprehend the worries in the barrel. Consequently in the present work spiral and circumferential stiffeners has been given in the chamber to improve the plan and quality of the barrel which decreases the burdens. Business FEA device Ansys Workbench is utilized to do the examination. A chamber with 12 outspread stiffeners got better outcomes contrasted with gauge plan and circumferential stiffeners. FEA results has been contrasted and the Theoretical outcomes and it is approved.

Keywords: LPG Cylinder, Stress, FEM, Ansys

I. Introduction

LPG is gotten from hydrocarbons delivered all through refining of unrefined petroleum and from heavier parts of common gas. It is oil inferred vapid fuel LPG comprises of propane or butane or mixes of each. Little amounts of ethane or pentane will likewise be blessing. LPG has over the top octane rating of 112 RON which empowers higher pressure proportion to be procured and consequently gives higher warm effectiveness. Because of low assurance expense, fiscal commercial center cost and surroundings charming attributes LPG is getting to be well known. It is increasingly more utilized as an aviation charge and a refrigerant changing chlorofluorocarbons in an endeavor to decrease harm to the layer. At the point when broadly utilized as a vehicle fuel it is regularly alluded as a vehicle gas.

II. Objectives and Methodology

Following are the major Objectives:

- The primary objective of the current work is to estimate the stresses of baseline design of vehicle LPG cylinders
- Determination of Hoop Stress, Longitudinal Stress and Von-Mises Stress
- Design and optimization of vehicle LPG cylinder to avoid the hazardous situation.

A. Methodology

1) Review the design of LPG cylinders based on ASME code.
2) Generating the model of cylinder in Catia V5 R20.
3) Import the geometry into ANSYS Workbench.
4) Mesh the model and preparation of boundary conditions.
5) Estimate the stresses using FE Approach.
6) Compare the results with literature.
7) Validate ANSYS results with Theoretical Results.
8) Design modifications for increasing the efficiency.

III. Design and Analysis of Vehicle LPG Cylinder

Theoretical Calculations for the LPG Cylinder for Steel

A. Data for the Calculations:

P: Internal Pressure in the Cylinder =1.2 mm
D: Diameter of the Cylinder= 320 mm
t: Thickness of the Cylinder= 2.5 mm
σH: Hoop Stress
σL: Longitudinal Stress
σV: Von-Mises Stress

1) *Hoop Stress in the Cylinder*

$$\sigma H = \frac{PD}{2t}$$

$$\sigma H = \frac{1.2 * 320}{2 * 2.5}$$

$$\sigma H = 76.8 \text{ MPa}$$

2) *Longitudinal Stress in the Cylinder*

$$\sigma L = \frac{PD}{4t}$$

$$\sigma L = \frac{1.2 * 320}{4 * 2.5}$$

$$\sigma L = 38.4 \text{ MPa}$$

3) *Von-Mises Stress in the Cylinder*

$$\sigma V = \sqrt{\sigma H^2} + \sigma L^2 - (\sigma H * \sigma L)$$

$$\sigma V = 66.5 \text{ MPa}$$

IV. Static Structural Analysis of Base Model of Vehicle LPG Cylinder (Without Stiffener)

A. Vehicle LPG Cylinder and its Design Parameters:

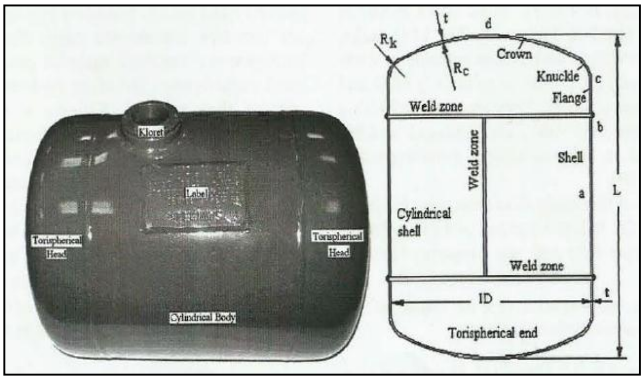


Fig. 1: Vehicle LPG Cylinder and Its Design Parameters

Design Parameters

- ID = Inner Diameter
- T = minimum wall thickness

- Rk = knuckle radius
- Rc =crown radius
- L =length of cylindrical shell

Material Specifications of Cylinder and Stiffeners (For 35 Liters)

Specification of the cylinder

- Young's modulus=104Gpa
- Material of the cylinder=Erdemir-6842 steel
- Inner diameter=320 mm
- Wall thickness=2.5mm
- Capacity=35 liters

Specification of the Stiffeners

- Material of the stiffener=Erdemir-6842 steel
- Length of the radial stiffener=468mm
- Length of the circumferential stiffener=974mm

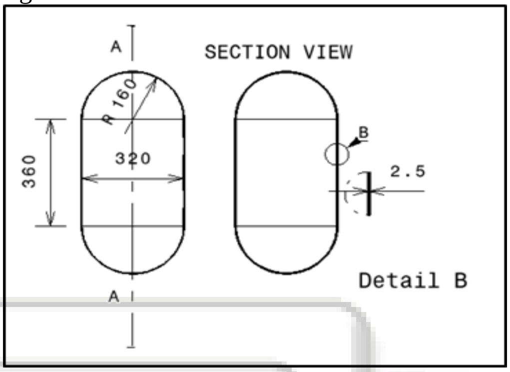


Fig. 2: 2D Drawing of Vehicle LPG Cylinder

B. *3D Model of Vehicle LPG Cylinder*

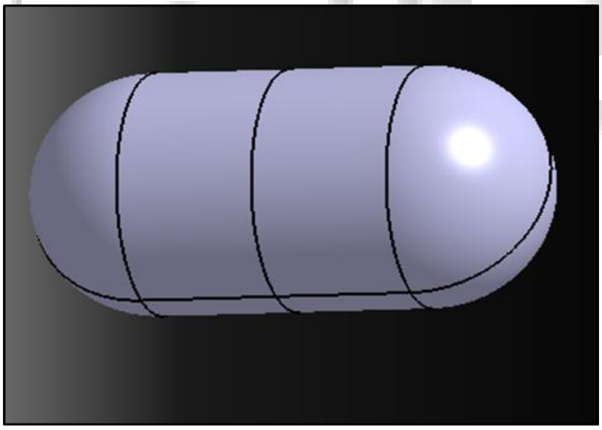


Fig. 3: 2D Drawing of Vehicle LPG Cylinder

C. *Symmetrical Model of Vehicle LPG Cylinder*

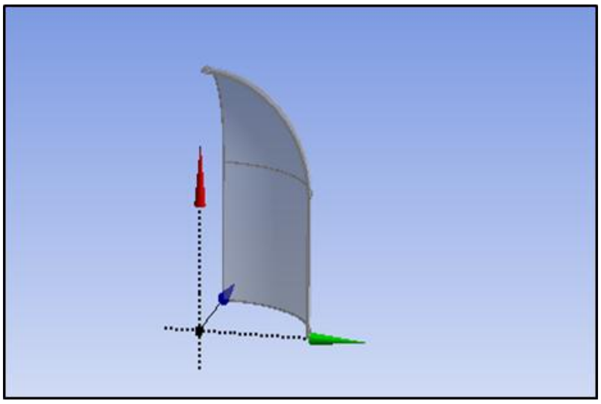


Fig. 4: Symmetrical Model of Vehicle LPG Cylinder

D. *FE Model of Vehicle LPG Cylinder*

- Below fig shows the Finite Element Model of Vehicle LPG Cylinder
- Total 9372 Elements has been generated

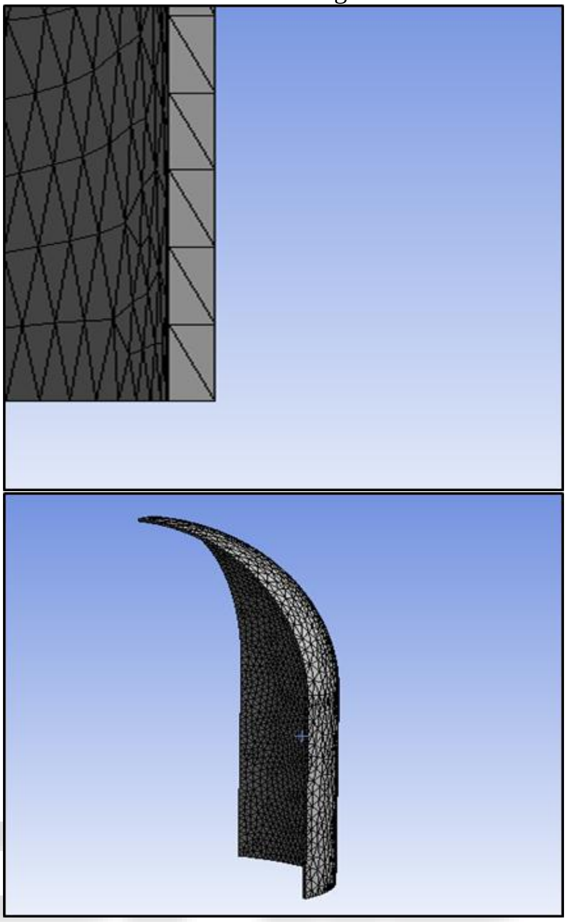
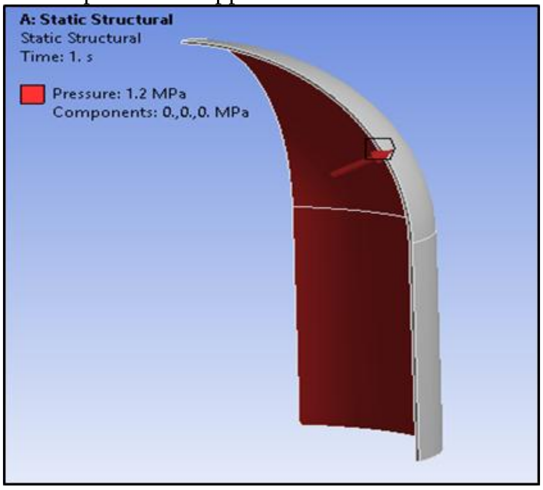


Fig. 5: FE Model of Vehicle LPG Cylinder

E. *Boundary Conditions*

- The boundary conditions used for the analysis is shown in Figure below
- By applying symmetry Boundary Conditions on both sides, models are self-constrained and no need to apply any more constraints.
- Internal pressure is applied of 1.2 MP



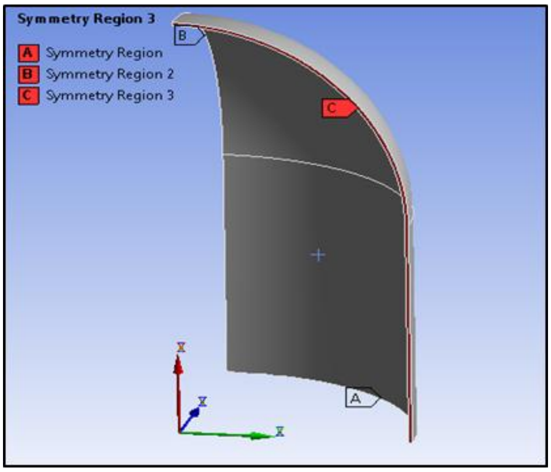


Fig. 6: Boundary Conditions

F. Results of Static Structural Analysis of Vehicle LPG Cylinder

1) Von-Mises Stress Plot

- Below fig shows the Von-Mises0Stress Plot
- Maximum Von-Mises Stress of 68.20 MPa has been achieved

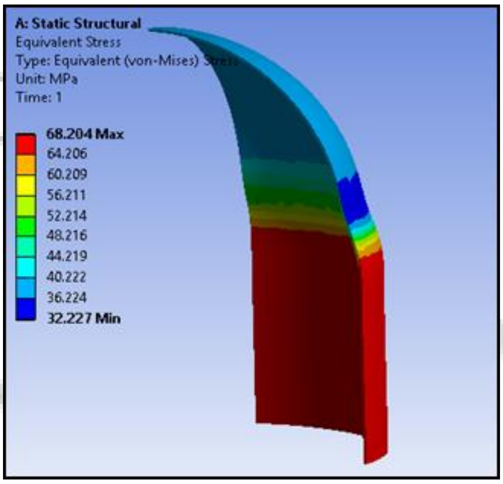


Fig. 7: Von-Mises Stress Plot

2) Displacement Plot

- Above fig shows the Displacement Plot
- Maximum Displacement of 0.000103mm has been achieved

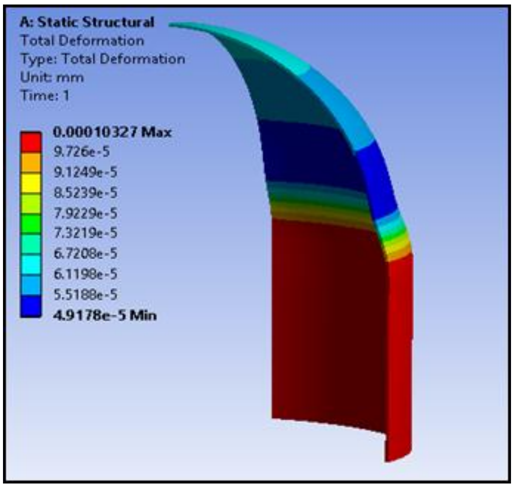


Fig. 8: Displacement Plot

3) Hoop Stress Plot

- Maximum Hoop Stress has been plotted in the below fig
- Maximum Stresses has been appeared in the middle of the cylinder
- Maximum Hoop Stress is of 77.47 MPa has achieved

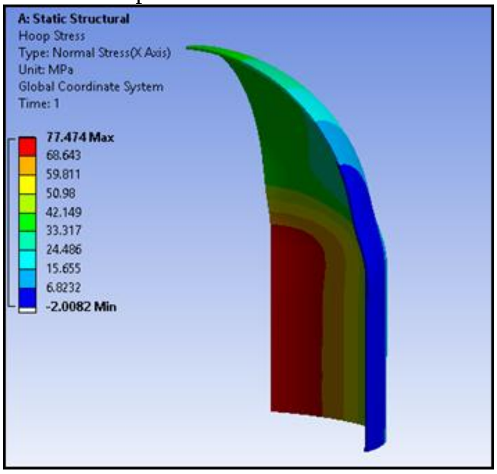


Fig. 9: Hoop Stress Plot

4) Longitudinal Stress Plot

- Maximum Longitudinal Stress has been plotted in thebelow fig
- Maximum Stresses has been appeared in the flanged area of the cylinder
- Longitudinal Stress of 49.06 MPa has achieved

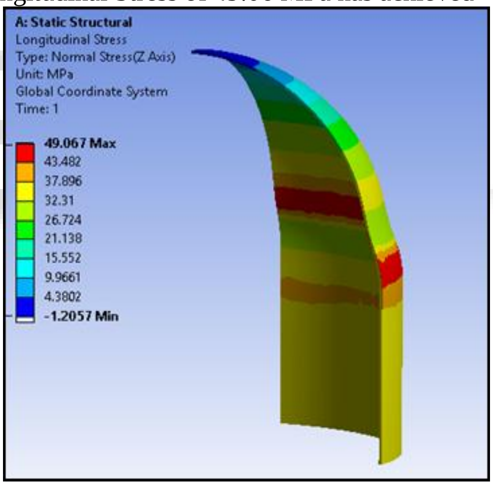


Fig. 10: Longitudinal Stress Plot

V. STATIC STRUCTURAL ANALYSIS OF VEHICLE LPG CYLINDER WITH RADIAL STIFFENERS (WITH 6 STIFFENERS)

A. Geometry of Cylinder with 6 Radial Stiffeners

- Six radial stiffeners of 2.5mm thick are created on the outer surface of cylinder.
- This strengthens the cylinder and reduces stress

B. Results of Static Structural Analysis of Vehicle LPG Cylinder

1) Von-MisesStress Plot

- Below fig shows the Von-MisesStress Plot
- Maximum Von-MisesStress of 62.71 MPa has been achieved

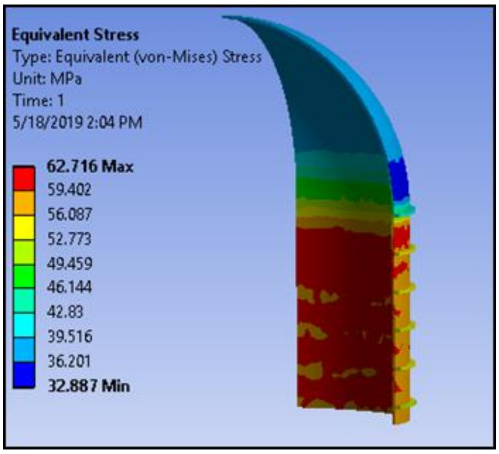


Fig. 11: Von-Mises Stress Plot

2) *Displacement Plot*

- Above fig shows the Displacement Plot
- Maximum Displacement of 9.11e-5 mm has been achieved

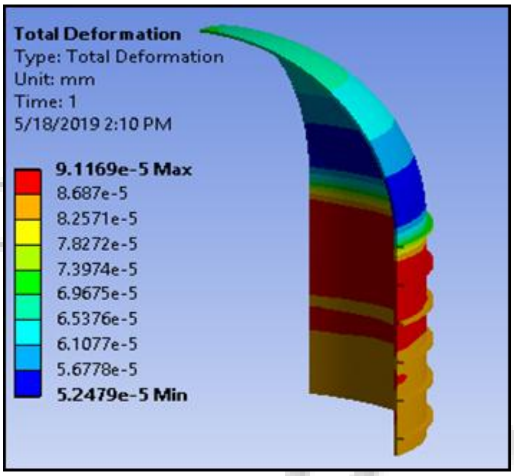


Fig. 12: Displacement Plot

3) *Hoop Stress Plot*

- Maximum Hoop Stress has been plotted in the below fig
- Maximum Stresses has been appeared in the middle of the cylinder
- Maximum Hoop Stress is of 70.28 MPa has achieved

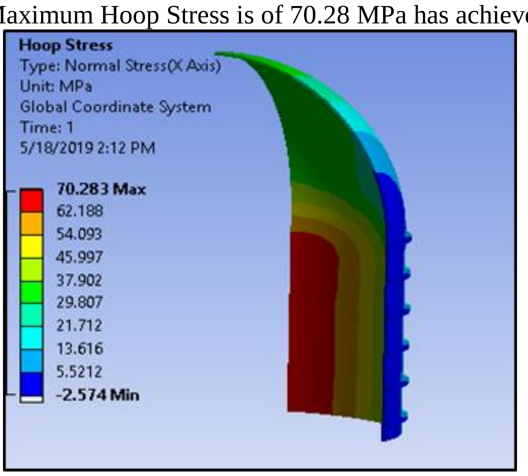


Fig. 13: Hoop Stress Plot

4) *Longitudinal Stress Plot*

- Maximum Longitudinal Stress has been plotted in the below fig
- Maximum Stresses has been appeared in the flanged area of the cylinder
- Longitudinal Stress of 49.97 MPa has achieved

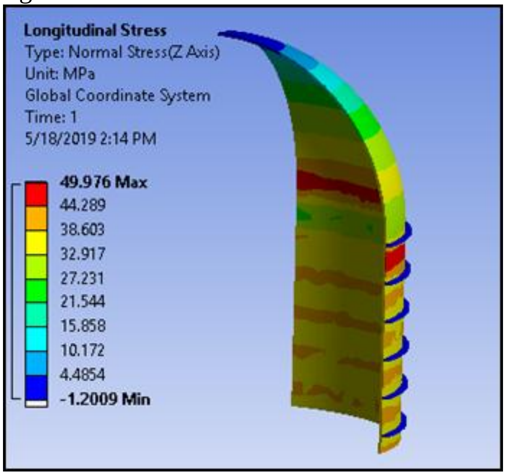


Fig. 14: Longitudinal Stress Plot

VI. Static Structural Analysis of Vehicle LPG Cylinder with Radial Stiffeners (with 12 Stiffener)

A. Geometry of Cylinder with 12 Radial Stiffeners

- Six radial stiffeners of 2.5mm thick are created on the outer surface of cylinder.
- This strengthens the cylinder and reduces stresses.

B. Results of Static Structural Analysis of Vehicle LPG Cylinder

1) *Von-Mises Stress Plot*

- Below fig shows the Von-Mises0Stress Plot
- Maximum Von-Mises0Stress of 55.38 MPa hasbeen achieved

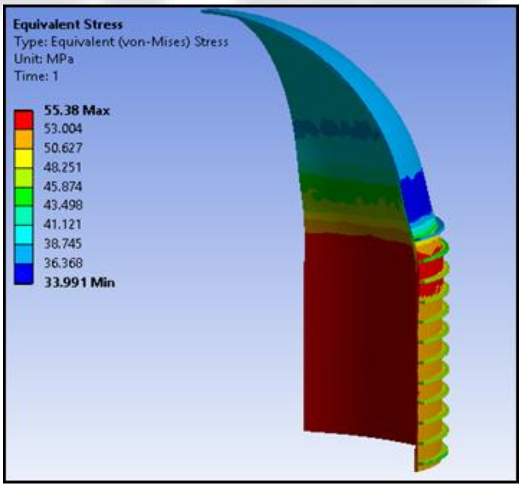


Fig. 15: Von-Mises Stress Plot

2) *Displacement Plot*

- Above fig shows the Displacement Plot
- Maximum Displacement of 8.16 e-5 mm has been achieved

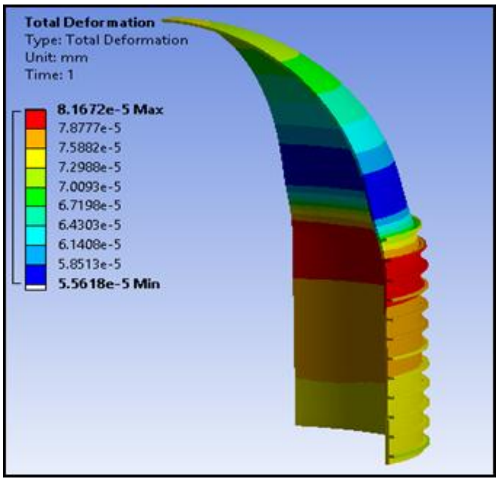


Fig. 16: Displacement Plot

3) Hoop Stress Plot

– Maximum Hoop0Stress has been plotted in the below fig
– Maximum Stresses has been appeared in the middle of the cylinder
– Maximum Hoop Stress is of 61.69 MPa has achieved

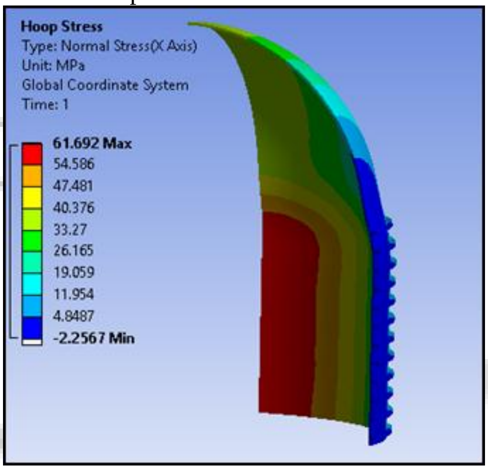


Fig. 17: Hoop Stress Plot

4) Longitudinal Stress Plot

– Maximum Longitudinal Stress has been plotted in the fig
– Maximum Stresses has been appeared in the flanged area of the cylinder
– Longitudinal Stress of 49.29 MPa has achieved

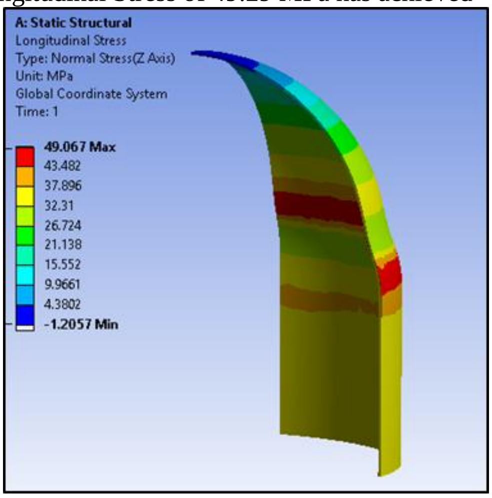


Fig. 18: Longitudinal Stress Plot

VII. STATIC STRUCTURAL ANALYSIS OF VEHICLE LPG CYLINDER WITH CIRCUMFERENTIAL STIFFENER

A. Geometry of Cylinder with Circumferential Stiffeners

– Six radial stiffeners of 2.5mm thick are created on the outer surface of cylinder.
– This strengthens the cylinder and reduces stresses.

B. Results of Static Structural Analysis of Vehicle LPG Cylinder

1) Von-Mises0Stress Plot

– Below fig shows the Von-Mises0Stress Plot
– Maximum0Von-Mises Stress of 84.38 MPa has been achieved.

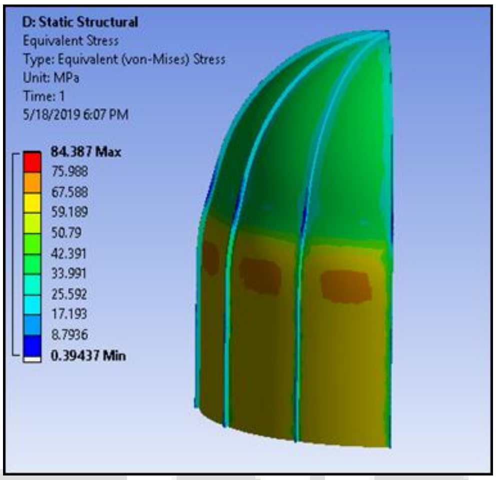


Fig. 19: Von-Mises Stress Plot

2) Displacement Plot

– Above fig shows the Displacement Plot
– Maximum Displacement of 1.0 e-4 mm has been achieved

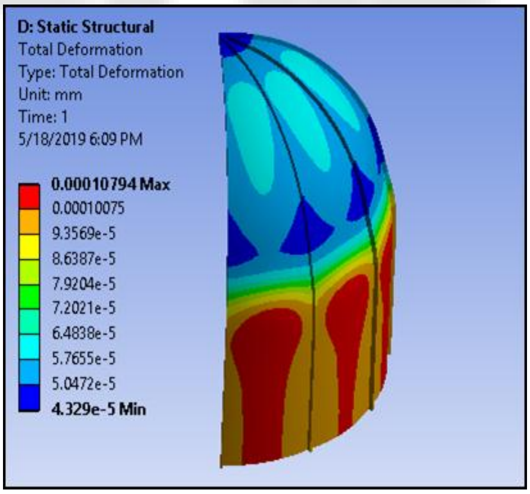


Fig. 20: Displacement Plot

3) Hoop Stress Plot

– Maximum Hoop Stress has been plotted in the below fig
– Maximum Stresses has been appeared in the middle of the cylinder
– Maximum Hoop Stress is of 92.45 MPa has achieved

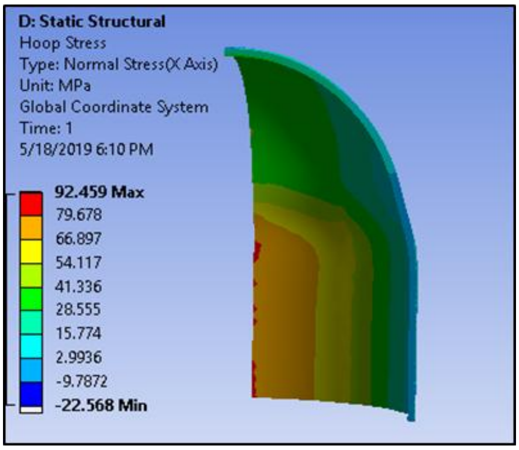


Fig. 21: Hoop Stress Plot

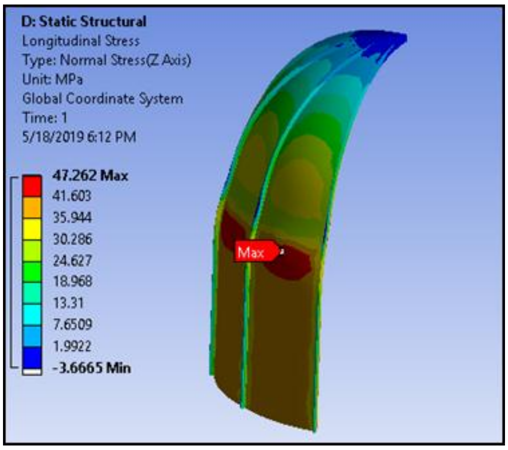


Fig. 22: Longitudinal Stress Plot

4) *Longitudinal Stress Plot*

- Maximum Longitudinal Stress has been plotted in the fig
- Maximum Stresses has been appeared in the flanged area of the cylinder
- Longitudinal Stress of 47.26 MPa has achieved

VIII. RESULTS AND DISCUSSION

The theoretical result for the thickness 2.5mm cylinder showing similar results compared to simulation results. Hence the simulation result is matching with experimental result with 2.4 % error.

Stresses & Displacement	Theoretical Results	FEA Results	% Error
Von-Mises Stress (MPa)	66.5	68.20	2.4
Hoop Stress (MPa)	76.8	77.47	0.86
Longitudinal Stress (MPa)	38.4	49.06	21
Displacement (mm)	1.1e^{-4} mm	1.03e^{-4}	6.3

Table 1: Simulation Result with Experimental Result (without stiffeners)

In this project we have designed the vehicle LPG cylinder using stiffeners which are shown0in below table.

Iteration	Von-Mises Stress (MPa)	Hoop Stress (MPa)	Longitudinal Stress (MPa)	Displacement (mm)
6 radial stiffeners	62.71	70.28	49.9	9.1 e^{-5}
12 radial stiffeners	55.38	61.69	49.9	8.16 e^{-5}
6 circumferential stiffeners	84.38	92.45	47.26	1.0 e^{-4}

Table 2: Obtained Results0for New Design of LPG Cylinder (with stiffeners)

For cylinder of same capacity and wall thickness, providing 12 radial stiffeners shows a better result, when compared to cylinder designed to have 6 radial stiffeners. The design optimization has been done by providing 12 radial stiffeners. From the above results it can be concluded that cylinder with 12 radial stiffeners generating lesser stresses compared to baseline design.

IX. CONCLUSION

From the above results it can be clear that the theoretical results are matching with the FEA results. Hence the method adopted in the FE Analysis is correct.

From the above FEA results the following conclusions can be made:

- Theoretical results are matching FEA Analysis results for the baseline design
- It can be observed that providing the circumferential stiffeners in the cylinder will not affect much in the design hence radial stiffeners are adopted
- Providing the 6 radial stiffeners in the cylinder will reduce the stresses
- Providing the 12 radial stiffeners in the cylinder will further reduces the stresses with the same thickness of the cylinder

Hence it can be concluded that Vehicle LPG Cylinder with the 12 radial stiffeners can be used for the better safety.

REFERENCES

[1] LohiteshJaga Kumar et al., "Study of the static structural analysis of the mono crankshaft for bending and torsional load", Volume 4, Issue 6, June 2018.

[2] Ahmed Ibrahim,et.al., "Stress Analysis of Thin-Walled Pressure Vessels", 3 February 2015.

[3] Dhanaraj,et.al, "Design & Stress Analysis of a Cylinder with Closed ends using ANSYS",ISSN : 2248-9622, Vol. 5, Issue 4, (Part -6) April 2015.

[4] Siva SankaraRaju R, "Deformation of stress and deformation analysis on LPG steel cylinder, IJERA,ISSN : 2248-9622, Vol. 3, Issue 1, Jan-Feb 2013.

[5] T. Subramani,et.al, "Finite Element Analysis of Thin Walled-Shell Structures by ANSYS and LS-DYNA",IJMER Vol.2, Issue.4, ISSN: 2249-6645 July-Aug 2012 .

[6] Laxmikant D. Rangari, "Stress analysis of LPG cylinder using ANSYS software" IJERA Vol.2, Issue.4, ISSN: 2248-9622 July-Aug 2012.