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DESIGN OPTIMISATION OF A COMPOSITE CYLINDRICAL PRESSURE VESSEL USING FEA

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Abstract- Interest in studying of the shell arises from the fifties of twentieth century. The assemblies, containing thin shells, find wide use in the modern engineering, especially in ships, aircraft and spacecraft industry. The shell vibrations and buckling modes are analyzed by means of numerical methods, to clarify qualitatively the critical loads and different buckling modes. In today's aerospace and aircraft industries, structural efficiency is the main concern. Due to their high specific strength and light weight, fiber reinforced composites find a wide range of applications. Light weight compression load carrying structures form part of all aircraft, and space vehicle fuel tanks, air cylinders are some of the many applications. In the present work, design analysis of fiber reinforced multi layered composite shell, with optimum fiber orientations; minimum mass under strength constraints for a cylinder under axial loading for static and buckling analysis on the pressure vessel has been studied. The modeling is carried out in Catia V5 R20 and the analysis is carried out in Ansys 15.0 solver.

Index Terms- *lightweight compression, reinforced multi-layered, thin shells.*

I. INTRODUCTION

Pressure vessels are important because many liquids and gases must be stored under high pressure. Special emphasis is placed upon the strength of the vessel to prevent explosions as a result of rupture. Codes for the safety of such vessels have been developed that specify the design of the container for specified conditions. Most pressure vessels are required to carry only low pressures and thus are constructed of tubes and sheets rolled to form cylinders. Some pressure vessels must carry high pressures, however, and the thickness of the vessel walls must increase in order to provide adequate strength.

Cylindrical shells (see Fig.1) such as thin-walled laminated composite unstiffened vessels like deep submarine exploration housings and autonomous underwater vehicles are subjected to any combination of in plane, Out of plane and shear loads due to the high external hydrostatic pressure during their application. Due to the geometry of these structures, buckling is one of the most important failure criteria. Buckling failure mode of a stiffened cylindrical shell can further be subdivided into global buckling, local skin buckling and stiffener crippling. Global buckling is collapse of the whole structure, i.e. collapse of the stiffeners and the shell as one unit. Local skin buckling and the stiffeners crippling on the other hand are localized failure modes involving local failure of only the skin in the first case and the stiffeners in the second case.

Fig.1. Cylindrical Shells

II. PROBLEM IDENTIFICATION

In today's aerospace and aircraft industries, structural efficiency is the main concern. Due to their high specific strength and light weight, fiber reinforced composites find a wide range of applications. Light weight compression load carrying structures form part of all aircraft, and space vehicle fuel tanks, air cylinders are some of the many applications. An analytical procedure is developed to design and predict the behaviour of fiber reinforced composite pressure vessels. The classical lamination theory and generalized plane strain model is used in the formulation of the elasticity problem.

Internal pressure axial force and body force due to rotation in addition to temperature and moisture variation throughout the body are considered. Some 3D failure theories are applied to obtain the optimum values for the winding angle, burst pressure, maximum axial force and the maximum angular speed of the pressure vessel

In the present work, design analysis of fiber reinforced multi layered composite shell, with optimum fiber orientations; minimum mass under strength constraints for a cylinder with or without stiffeners under axial loading for static and buckling analysis on the pressure vessel has been studied.

III. MODELING OF CYLINDRICAL PRESSURE VESSEL

The modeling of the Cylindrical Pressure Vessel is done in Catia V5 R20.

Introduction to Catia V5 R20:

CATIA-V5 is the industry's de facto standard 3D mechanical design suit. It is the world's leading CAD/CAM /CAE software, gives a broad range of integrated solutions to cover all aspects of product design and manufacturing. Much of its success can be attributed to its technology which spurs its customer's to more quickly and consistently innovate a new robust, parametric, feature based model. Because that CATIA-V5 is unmatched in this field, in all processes, in all countries, in all kind of companies along the supply chains.

Catia-v5 is also the perfect solution for the manufacturing enterprise, with associative applications, robust responsiveness and web connectivity that make it the ideal flexible engineering solution to accelerate innovations. Catia-v5 provides easy to use solution tailored to the needs of small medium sized enterprises as well as large industrial corporations in all industries, consumer goods, fabrications and assembly. Electrical and electronics goods, automotive, aerospace, shipbuilding and plant design. It is user friendly solid and surface modeling can be done easily.
The model is as shown in the figure 2 as shown below:

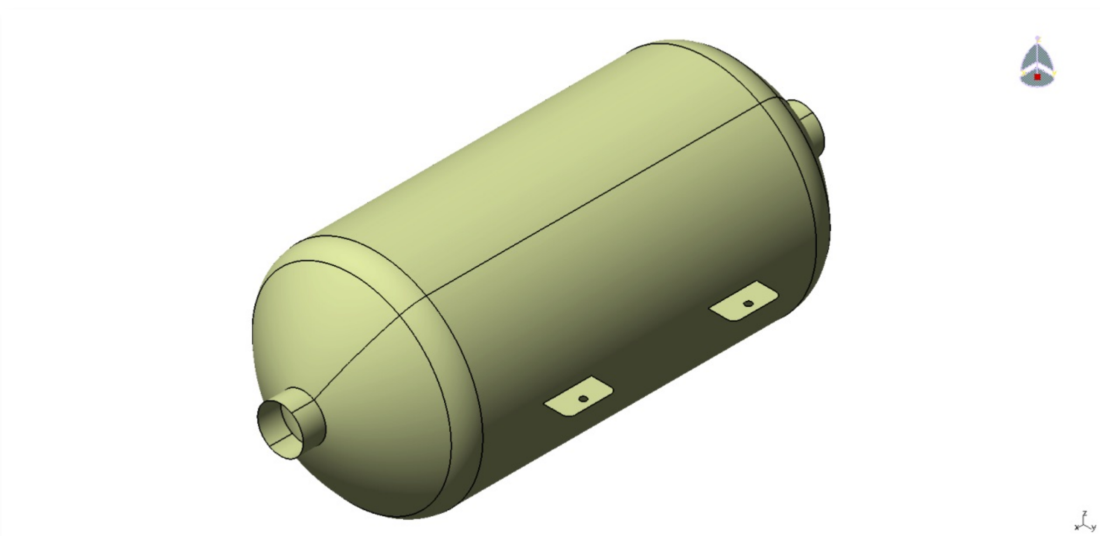

Fig 2. Cylindrical pressure vessel Model

The drawing Specifications taken are as shown in the Figure 2 below:

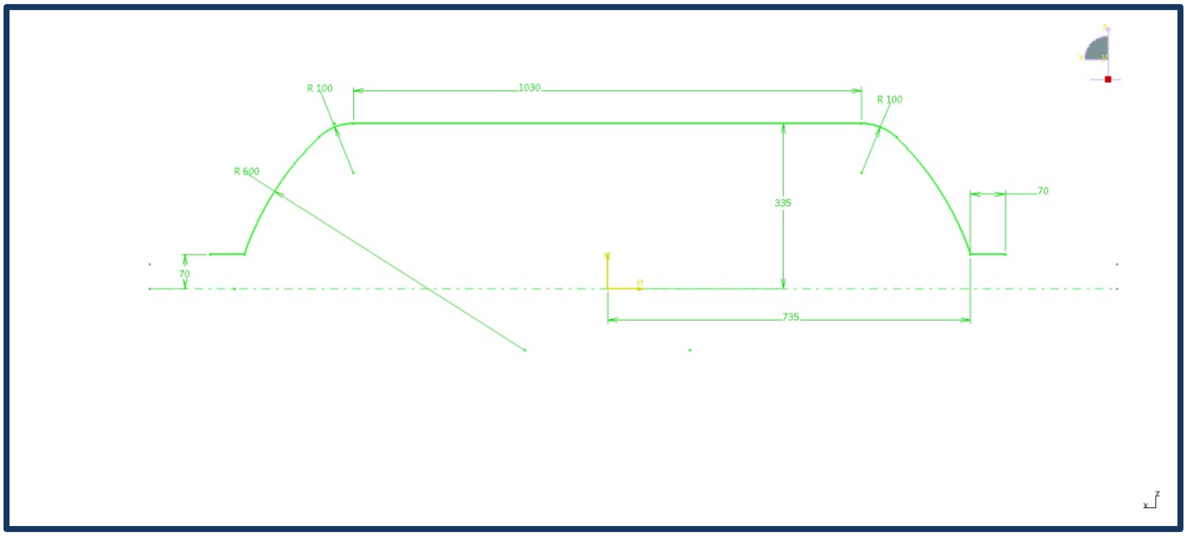

Fig. 3 Drawing Specifications for the Cylindrical Pressure Vessel.

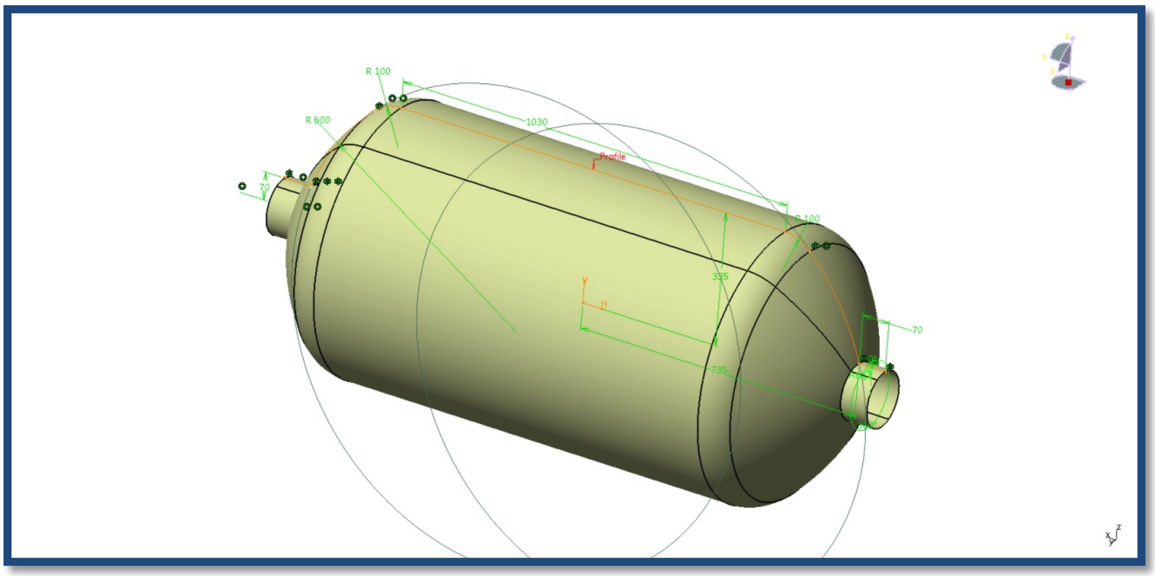

Fig. 4 Drawing Specifications for the Cylindrical pressure vessel.

IV. ANALYSIS OF CYLINDRICAL PRESSURE VESSEL

The analysis of the cylindrical pressure vessel is done in Ansys 15.0 and the analysis reports are as shown below. The geometry and the mesh model in Ansys are as shown in the Fig.3 and Fig. 4 below respectively.

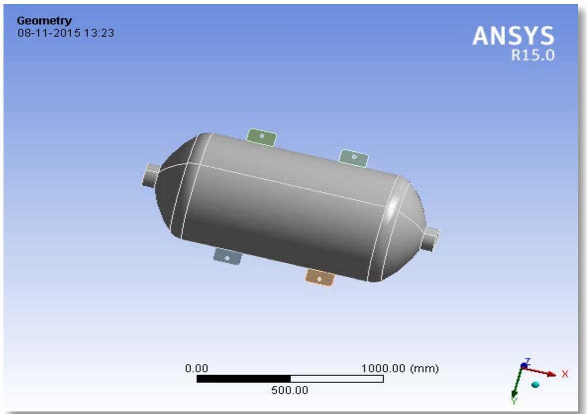

Fig. 5 Geometry of the cylindrical pressure vessel

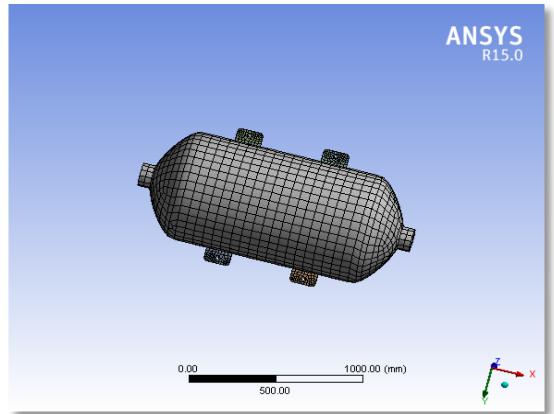

Fig. 6 Mesh of the cylindrical pressure vessel

The analysis is carried out for the Steel material and the composite material for the cylindrical pressure vessel.

Analysis of Steel cylindrical pressure vessel:

The Boundary Conditions are given as the pressure of 3MPa and fixed at the stiffeners of the pressure vessel. The deformation and Equivalent Stress reports for the steel cylindrical pressure vessels are are as shown in the Fig. 5 and Fig. 6 respectively.

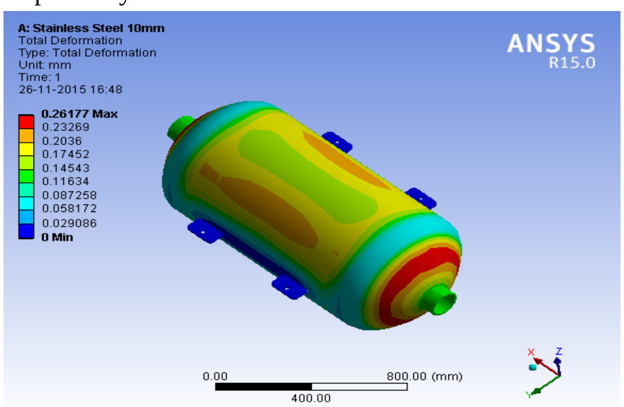

Fig. 7 Deformation of the Steel pressure vessel

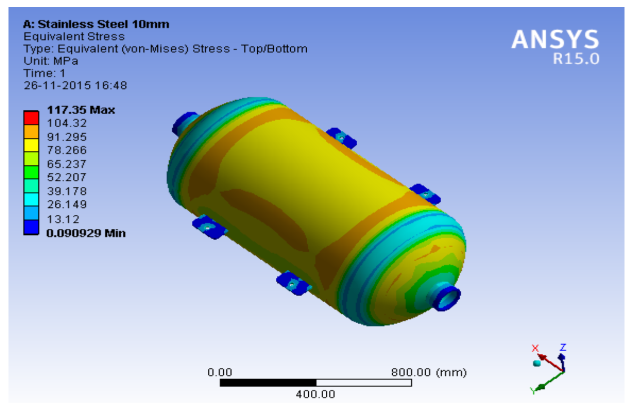

Fig.8 Equivalent Stress of the Steel pressure vessel

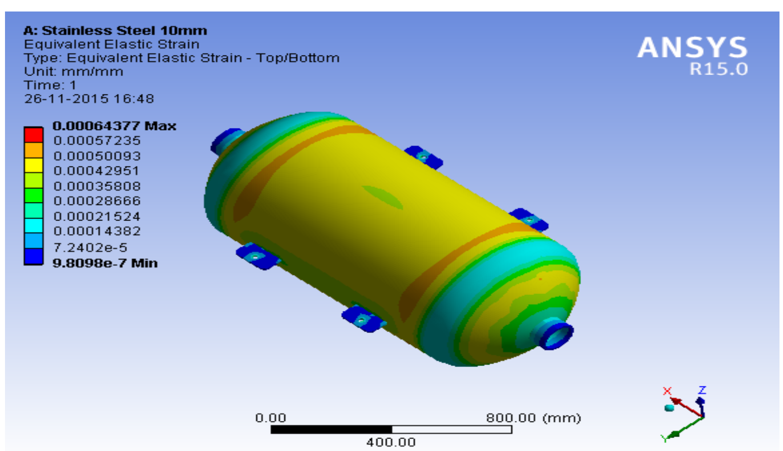

Fig.9 Equivalent Strain of the Steel pressure vessel

The deformation and Equivalent Stress reports for the composite cylindrical pressure vessels are are as shown in the Fig. 10 to Fig. 12 respectively.

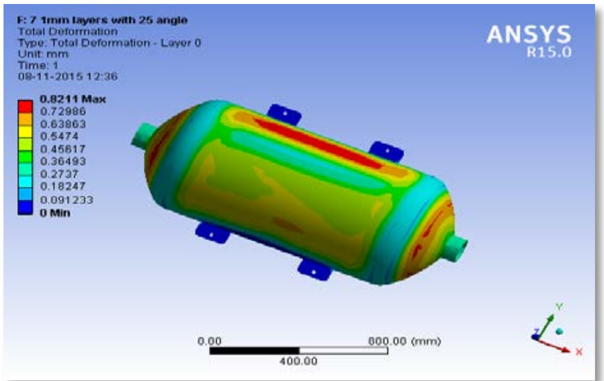

Fig. 10 Deformation of the Composite pressure vessel-25^0

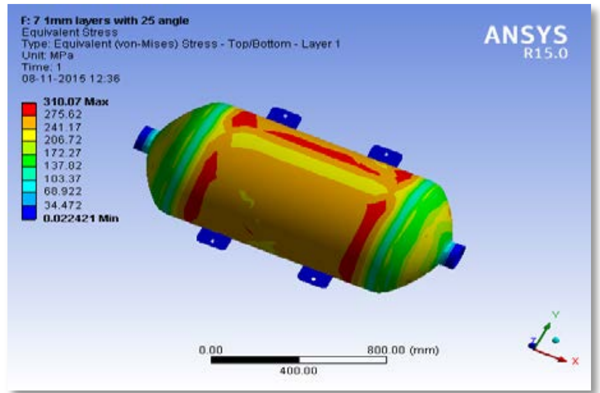

Fig.11 Equivalent Stress of Composite pressure vessel-25^0

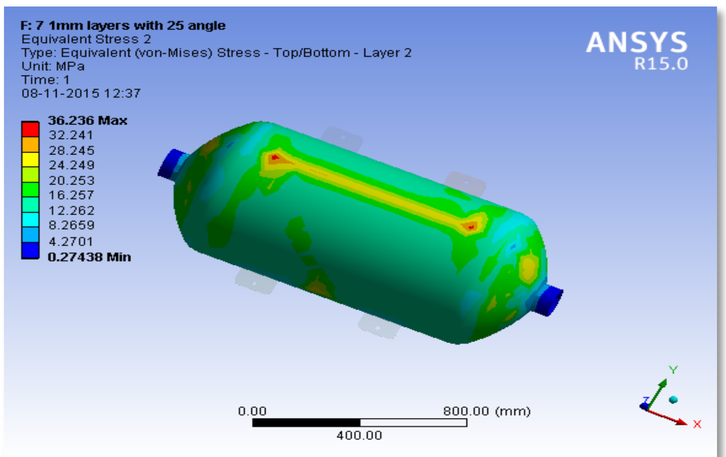

Fig.12 Equivalent Stress of the composite pressure vessel-25^0

Also the analysis is carried out for the leaf spring which consists of composite material 8 layers, 9 layers and 10layers. The deformation of and the Equivalent Stress reports for the composite cylindrical pressure vessel are shown in the Fig. 13 to Fig. 18 respectively.

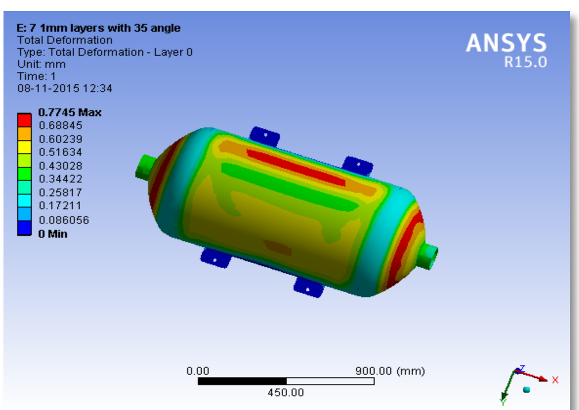

Fig.13 Deformation of the composite pressure vessel-35^0

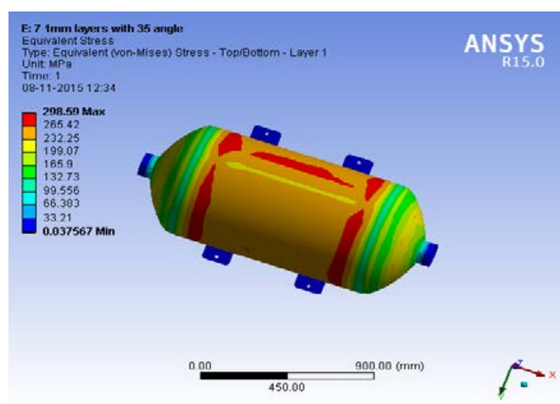

Fig.14 Equivalent Stress of the composite pressure vessel-35^0

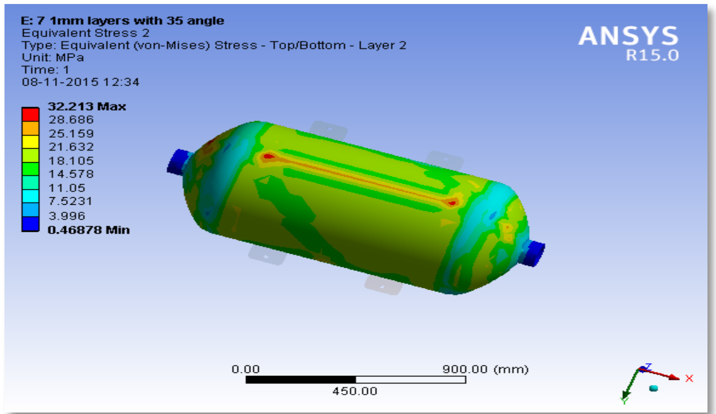

Fig.15 Equivalent Stress of the hybrid cylindrical pressure vessel-Layer 2 for 35^0

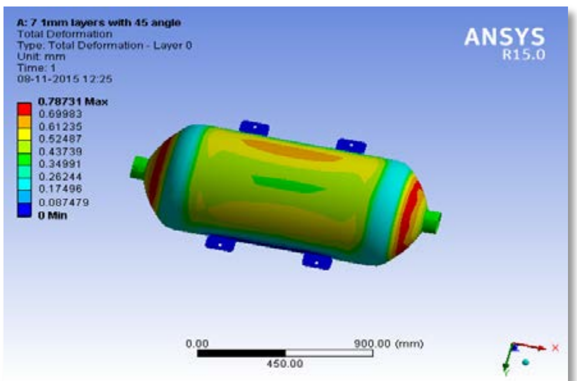

Fig.16 Deformation of the composite pressure vessel-45^0

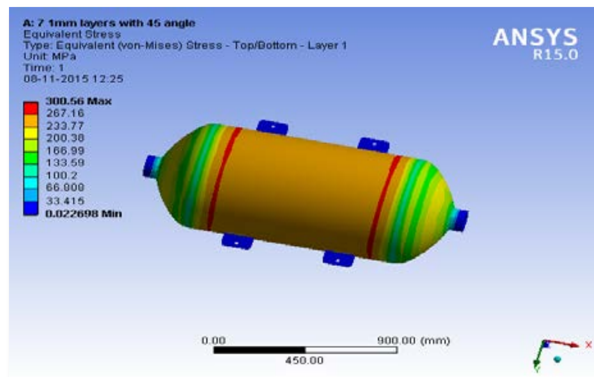

Fig.17 Equivalent Stress of the composite pressure vessel-45^0

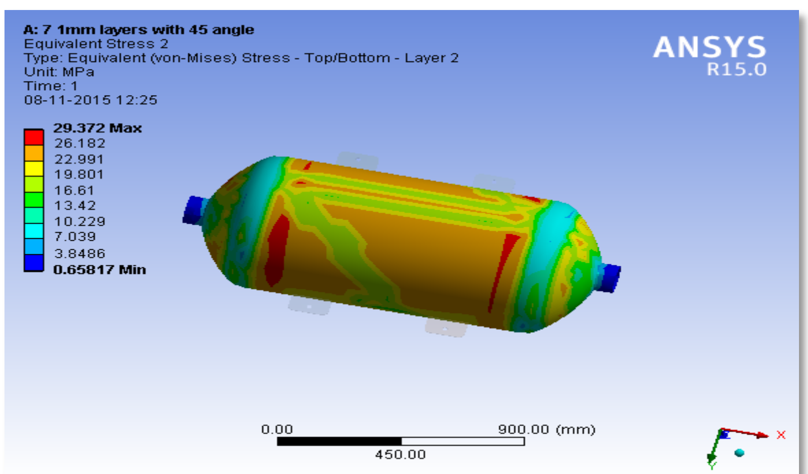

Fig.18 Equivalent Stress of the composite pressure vessel-Layer 2 for 45^0

The weight factor is taken into consideration. The stainless steel constitutes to 254.34kg whereas the composite cylindrical pressure vessel constitutes to around 134.12kg to 159.36kg depending upon the number of composite layers.

V. RESULTS AND DISCUSSION

The analysis of Steel Cylindrical pressure vessel with the composite cylindrical pressure vessel is done. In addition we would like to change the orientation of composite cylindrical pressure vessel in such a way that the thickness is 1mm with variants of 7 layers, 8 layers, 9 layers and 10layers of composite allowed with an angle of 25^0, 35^0, 45^0,55^0,65^0,75^0 and 90^0.

The results for the composite pressure vessel of 1mm with 7 layers and different angles of orientation are as shown below:

Table 1: Composite pressure vessel of 1mm with 7 layers and different angles of orientation

	Total Deformation (mm)	Equivalent Stress-Layer 1 (Mpa)	Equivalent Stress-Layer 2 (Mpa)
7 1mm layers with 25 degree angle orientation	0.8211	310.07	36.236
7 1mm layers with 35 degree angle orientation	0.7745	298.59	32.213
7 1mm layers with 45 degree angle orientation	**0.7873**	**300.56**	**29.372**
7 1mm layers with 55 degree angle orientation	0.8601	316.7	33.56
7 1mm layers with 65 degree angle orientation	1.0889	326.02	37.128
7 1mm layers with 75 degree angle orientation	1.2292	328.3	39.001
7 1mm layers with 90 degree angle orientation	1.2948	327.2	39.819

The results for the composite pressure vessel of 1mm with 8 layers and different angles of orientation are as shown below:

Table 2: Composite pressure vessel of 1mm with 8 layers and different angles of orientation

	Total Deformation (mm)	Equivalent Stress-Layer 1 (Mpa)	Equivalent Stress-Layer 2 (Mpa)
8 1mm layers with 25 degree angle orientation	0.7818	303.03	35.555
8 1mm layers with 35 degree angle orientation	0.7325	291.67	32.275
8 1mm layers with 45 degree angle orientation	**0.7466**	**282.87**	**31.605**
8 1mm layers with 55 degree angle orientation	0.8381	299.4	33.234
8 1mm layers with 65 degree angle orientation	1.0543	309.12	36.113

8 1mm layers with 75 degree angle orientation	1.1853	311.39	37.568
8 1mm layers with 90 degree angle orientation	1.246	314.98	38.219

The results for the composite pressure vessel of 1mm with 9 layers and different angles of orientation are as shown below:

Table 3: Composite pressure vessel of 1mm with 9 layers and different angles of orientation

	Total Deformation (mm)	**Equivalent Stress-Layer 1 (Mpa)**	**Equivalent Stress-Layer 2 (Mpa)**
9 1mm layers with 25 degree angle orientation	0.7464	295.17	34.551
9 1mm layers with 35 degree angle orientation	0.6939	284.68	31.005
9 1mm layers with 45 degree angle orientation	**0.711**	**269.44**	**28.31**
9 1mm layers with 55 degree angle orientation	0.8171	282.87	31.338
9 1mm layers with 65 degree angle orientation	1.018	292.93	34.358
9 1mm layers with 75 degree angle orientation	1.138	302.39	35.87
9 1mm layers with 90 degree angle orientation	1.1923	306.86	36.671

The results for the composite pressure vessel of 1mm with 10 layers and different angles of orientation are as shown below:

Table 4: Composite pressure vessel of 1mm with 10 layers and different angles of orientation

	Total Deformation (mm)	**Equivalent Stress-Layer 1 (Mpa)**	**Equivalent Stress-Layer 2 (Mpa)**
10 1mm layers with 25 degree angle orientation	0.7102	288.34	33.753
10 1mm layers with 35 degree angle orientation	0.655	277.54	30.724
10 1mm layers with 45degree angle orientation	**0.673**	**261.66**	**30.052**
10 1mm layers with 55 degree angle orientation	0.7915	269.15	31.051

10 1mm layers with 65 degree angle orientation	0.9778	284.21	33.584
10 1mm layers with 75 degree angle orientation	1.0888	294.59	34.954
10 1mm layers with 90 degree angle orientation	1.1396	299.91	35.269

VI. CONCLUSION

This project work involves the comparison of conventional steel and Composite material cylindrical pressure vessel under static loading conditions the model is preferred of in Catia V5 R20 and then analysis is perform through ANSYS 15.0 from the result obtained it will be concluded that the development of a composite cylindrical pressure vessel having constant cross sectional area, where the stress level at any station in the Composite pressure vessel is considered drop and rise due to the orientation of composite, has proved to be very effective. Taking weight into consideration, we can conclude that 7layers gives lesser weight. But, taking stress and weight into consideration, 10layers is giving the desired result. The results are found to be effective for the composite lamia for 45^0 orientations. The deformation is tending to reduce for the 10layers composite orientation so as the Equivalent Stress. The Lamina stacking sequence is appropriate which is free from extension – bending, coupling which reduces the effective stiffness of the lamina, since the laminates are symmetric. Appropriate number of plies needed in each orientation and thickness of the shell is safe from static and buckling analysis is concerned. The comparison plots obtain desired results for stresses and deformations with lamina orientations for the chosen composite materials.

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