ANALYSIS OF COMPOSITE LAMINATED TUBE USING FEA

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ABSTRACT –Filament Winding is a one of the composite manufacturing process for controlling amount of resin and leaning fiber should be wrapped over a rotating mandrel. Previously these techniques were used to produce chemical and water tankers. In the existing work a study on behavior of composite laminated tube with different fiber angles using FEA toot ANSYS. The filament wound composite tubes are replicated as three layered orthotropic tubes. Under dissimilar loading conditions like (displacement and pressure) by using different helix angles / fiber angle. FEM analysis is conferred for all loading condition. Finally, the optimum fiber is recommended for manufacturing the composite.

Keywords: Filament wound, Finite Element Analysis, Composite Materials, Helix angle / Fiber angle, orthotropic cylinder.

1. INTRODUCTION

A. Filament Winding

Filament winding is one of the important composite manufacturing process methods, where resin and fiber orientations are controlled and oriented suitable fibers are wound about a mandrel which rotate along the axis of rotation and is cured. Initially this technique is used to produce water tanks, chemical tanks and pressure vessels. The development this technique is also used in several applications likes helicopter rotor shaft, high pressure pipelines and many automobile sectors.

B. Filament Winding Machines

Filament winding technique, fiber strands (Any Fiber) are passed across the resin tank. Fibers are impregnated wholly with resin. These impetrated resin fibers are passed over rotating mandrel. These strands while wounding over the mandrel is controlled by a definite fiber orientation. The representation of filament winding machine is shown in fig.1. Fiber tension must be in an optimal level so as to prevent the breaks in the fiber or begin fiber rupture on the surface. Curing is done by heating in oven and final product i.e. composites are taken out from the mandrel. For removing metallic mandrel, hydraulic rams are used. An elevated fiber volume fraction is achieved by the composite by using FWT (Filament Winding Techniques). CNC FWT is used now a day, which may independently monitor each and every movement of the complete process [10].

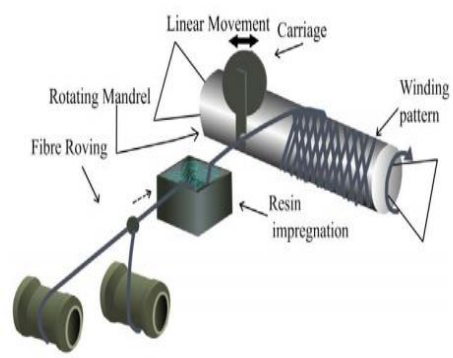

Figure 1: Schematic layout Filament Winding Machine (FWM) **(Courtesy [10])**

2. MATERIAL SELECTION

Composite materials are composed of two components and shapes into a new material with properties diverge from the individual components. Mainly composites are poised of a mass materials and a strengthening material, normally fibers. The composite material properties are determined by volume fractions of matrix and fiber, volumetric ratio and orientation. The volumetric ratio of fibers is largely gritty by the method of manufacturing.

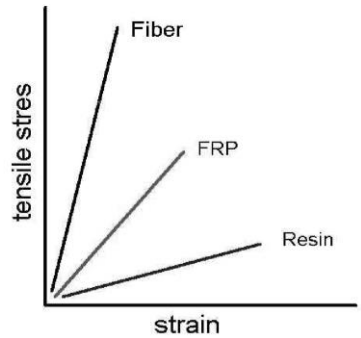

Figure 2: Comparison of Fiber, FRP and Resin Mechanical Properties (Courtesy Nptel)

3. MODELLING AND ANALYSIS OF TUBE

In the FEA model of the filament wound tubes, the tubes are assumed to be made of orthotropic adjacent layers. Therefore, crossing of fibers and changes in the fiber orientation are neglected. All layers are assumed equal in thickness and the thicknesses of each layer are calculated by dividing the thickness of the tube by the number of layers. In 'Internal Pressure Loading Analysis', the tube is fixed from a node at one end and internal pressure is applied to inner layer of the tube. There are no other constraint or loading in this analysis.

In 'Combined Loading Analysis', the tube is fixed from one

end, by applying 'all DOF constraint' on end lines of the tube surface. Then, an axial load, a transverse load and a torque are applied to the other end, namely on nodes within the fixing length. This fixing length is specified during entering user-defined inputs. Tube dimensions can be found in Table 3.1.

TABLE 2: Dimensions of the tube

Tube Length (mm)	400
Fixing length (mm)	20
Average radius (mm)	60.565
Tube thickness (mm)	1.13

Input parameters of the APDL analyses, which are entered by using GUI , are as follows:

- Geometry of the Tube (diameter, length and thickness)
- Number of Layers
- Angle Orientations for each Layer
- Fixing length, where end loads will be applied (for combined loading model)
- 9 Elastic Constants
- 9 Strain Strength Constants
- 9 Stress Strength Constants
- 3 Coupling Coefficients
- Loading (Inner and outer pressure, Transverse Load, Axial Load and Torque).

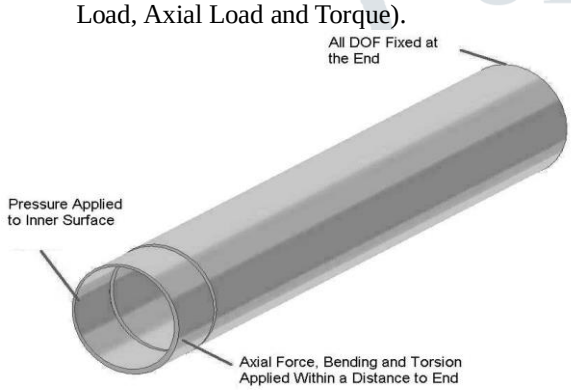

Figure 3: Boundary Conditions of Laminated Tube.

Analyses are done with the following order of operations:

1. Geometrical Properties are entered
2. Elastic Constants are entered
3. Strength Constants are entered
4. Loading Conditions are entered
5. Layer Orientation and mesh density are entered
6. Analysis is defined as a structural analysis
7. Element type is specified
8. Layer orientation and thickness are specified
9. Geometry is constructed with specified properties
10. Fixing areas are specified
11. Meshing is constructed
12. Boundary conditions are applied
13. Solution is done
14. Post processing is done

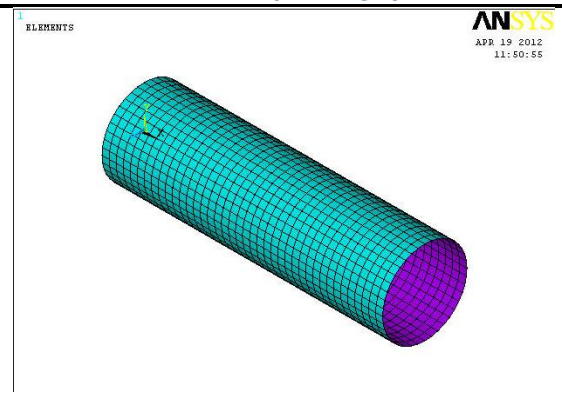

Figure 4: Meshed Model of Orthotropic Cylindrical Shell

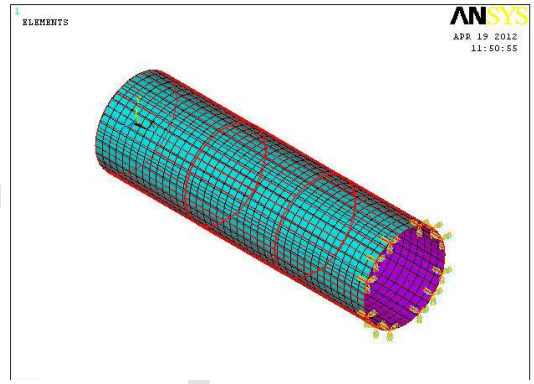

Figure 5: Application of Internal Pressure And Load

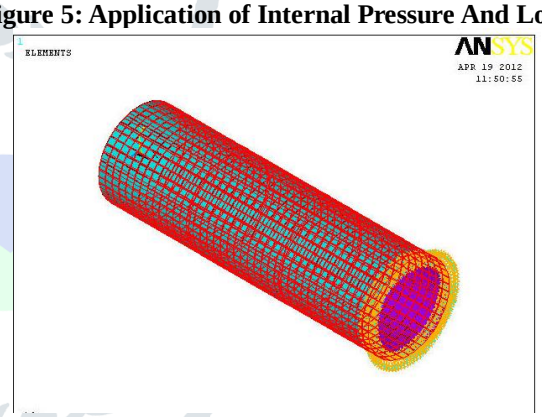

Figure 6: Solved Cylinder

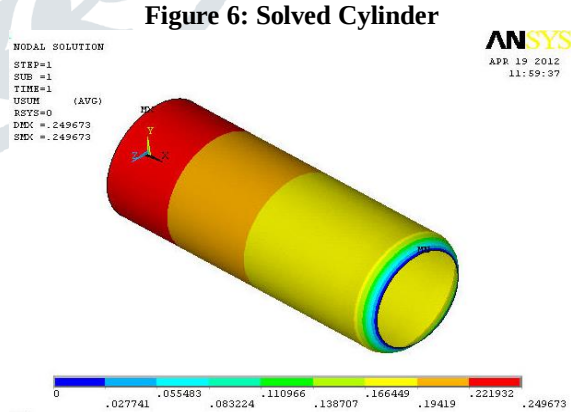

Figure 7: Deformation of Cylinder

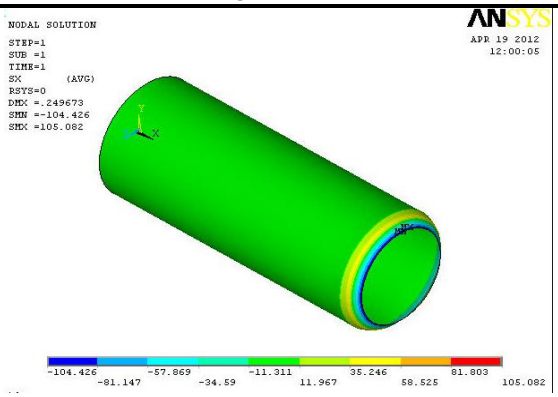

Figure 8: Stresses along X-direction in Cylinder

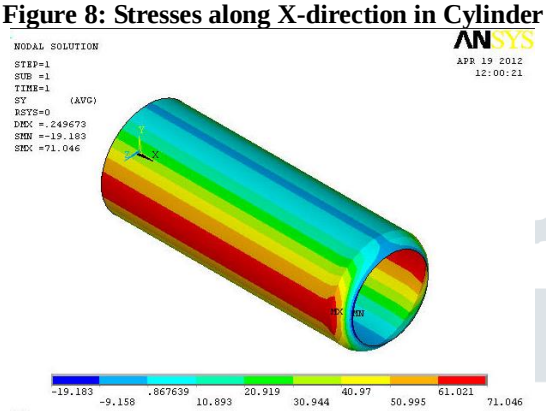

Figure 9: Stresses along Y-direction in Cylinder

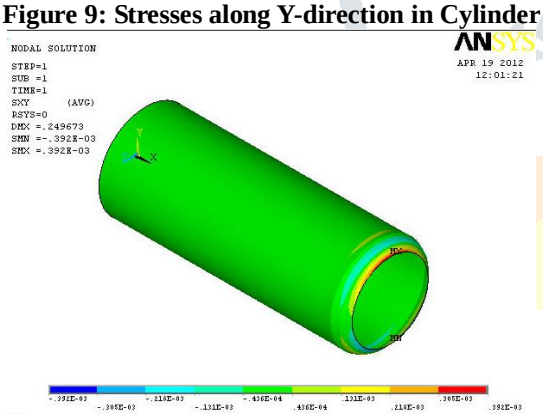

Figure 10: Stresses along XY-direction in Cylinder

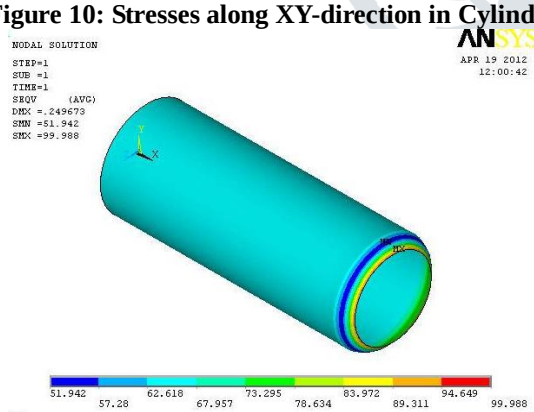

Figure 11: Von Mises Stresses in Cylinder

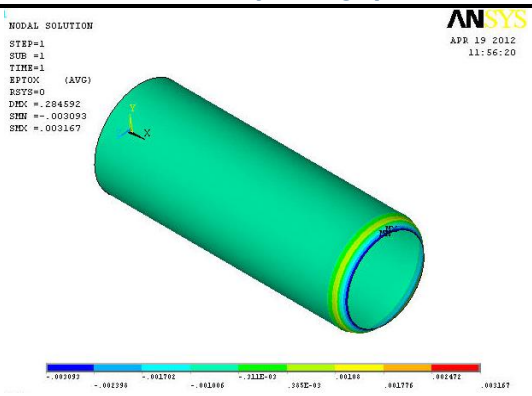

Figure 12: Strains along X-direction

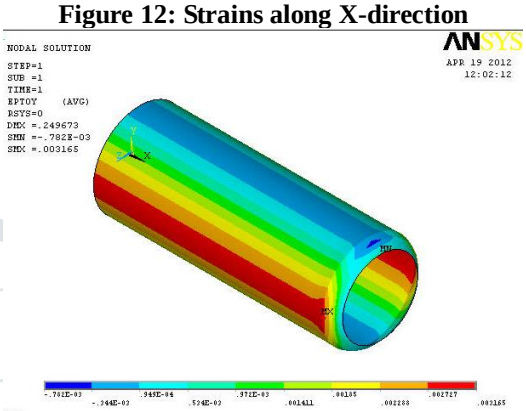

Figure 13: Strains along Y-direction

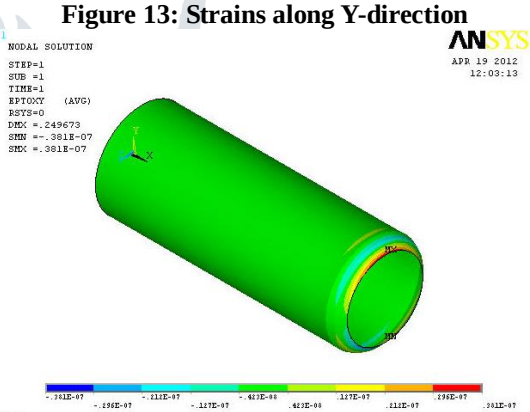

Figure 14: Strain along XY – direction

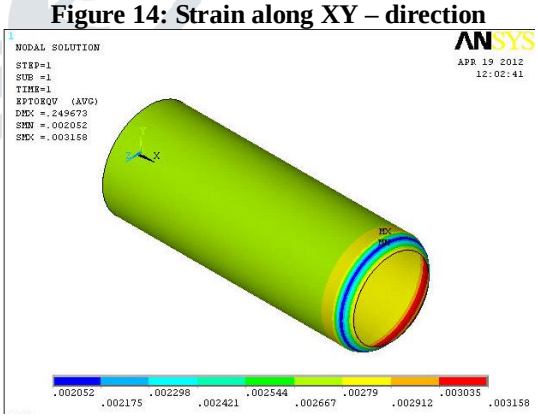

Figure 15: Von Mises Strain

4. RESULTS & DISCUSSION

Here deformation is at its highest value i.e. peak value at helical angle of 35˙ with a value of .425 approximately and it's lowest at 0˙ with a value of 0.12. The shear stress values reach their peak at helix angle 40˙ with a value of 18 and their lowest points at 0˙ and 90˙ with values reaching 0. The shear strain is the highest when the fiber is laid at an angle of 30˙ with value approaching 0.0005 and the curve reaches

its lowest point at 90˙ with value approaching 0.

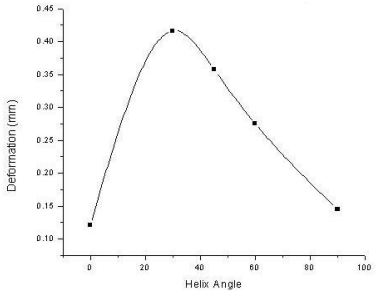

Figure 16: Deformation v/s Helix Angle

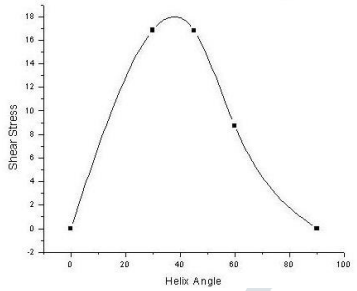

Figure 17: Shear Stress v/s Helix Angle

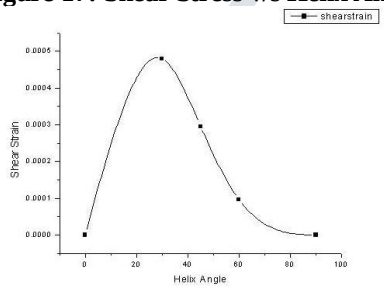

Figure 18: Shear Strain v/s Helix Angle

5. CONCLUSION

Analysis of a cylindrical orthogonal shell made with glass epoxy. Finite Element Analysis is performed to determine its behavior and to measured deformation stresses and strains for dissimilar winding angles by applying various loading conditions on the cylindrical shell. It has been observed that fiber angle of 90 degree is the optimum as its overall stresses and strains were determined to be the least and hence, the shear strength is maximum. Therefore, in hoop winding pattern a helix angle of 90˙ is recommended for the manufacture the components. These results are subject to change upon change in the shape factor, material etc. of the model. The analysis needs to be evaluated with experimental results obtained after the manufacture of the shell and testing of the shell. Based on previous studies, we expect the experimental data to be in agreement with the FEA analysis.

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REFERENCES

[1] Introduction to Composites - Reference Handbook, 4th Edition, Composites Institute, NY, 1990

[2] N. L. Hancox, R. M. Mayer, Design Data For Reinforced Plastics, Chapman&Hall, London, 1994

[3] Tsai, Stephen W., "Theory of Composites Design", Think Composites, Dayton,1992

[4] Mallick P. K. , Fiber –Reinforced Composites, Materials, Manufacturing, and Design, Marcel Dekker INC.,NY and Basel, 1988

[5] P. D. Soden, R. Kitching, P. C. Tse, Y. Tsavalas. Influence Of Winding Angle On The Stregth And Deformation Of Filament-Wound Composite Tubes Subjected To Uniaxial And Biaxial Loads, Composites Science and Technology 46 (1993) pp. 363-378

[6] P. D. Soden, R. Kitching, P. C. Tse, Experimental Failure Stresses For ±55° Filament Wound Glass Fibre Reinforced Plastic Tubes Under Biaxial Loads, Composites, Volume 20, Number 2, March 1989.

[7] Levend Parnas, Nuran Katırcı. Design Of Fiber-Reinforced Composite Pressure Vessels Under Various Loading Conditions, Composite Structures, 58 (2002) pp. 83-95

[8] M. Xia, H. Takayanagi, K. Kemmochi. Bending Behaviour Of Filament-Wound Fiber-Reinforced Sandwich Pipes, Composite Structures 56 (2002) pp. 201-210

[9] C. Cazeneuve, P. Joguet, J. C. Maile and C. Oytana, Predicting The Mechanical Behavior Of Kevlar/Epoxy And Carbon/Epoxy Filament Wound Tubes. Composites, Volume 23, Number 6, (November 1992) pp. 415-424

[10] http://nptel.ac.in/courses/112107085/module5/lecture7/lecture7.pdf