

Experimental Optimisation of Composite Tube

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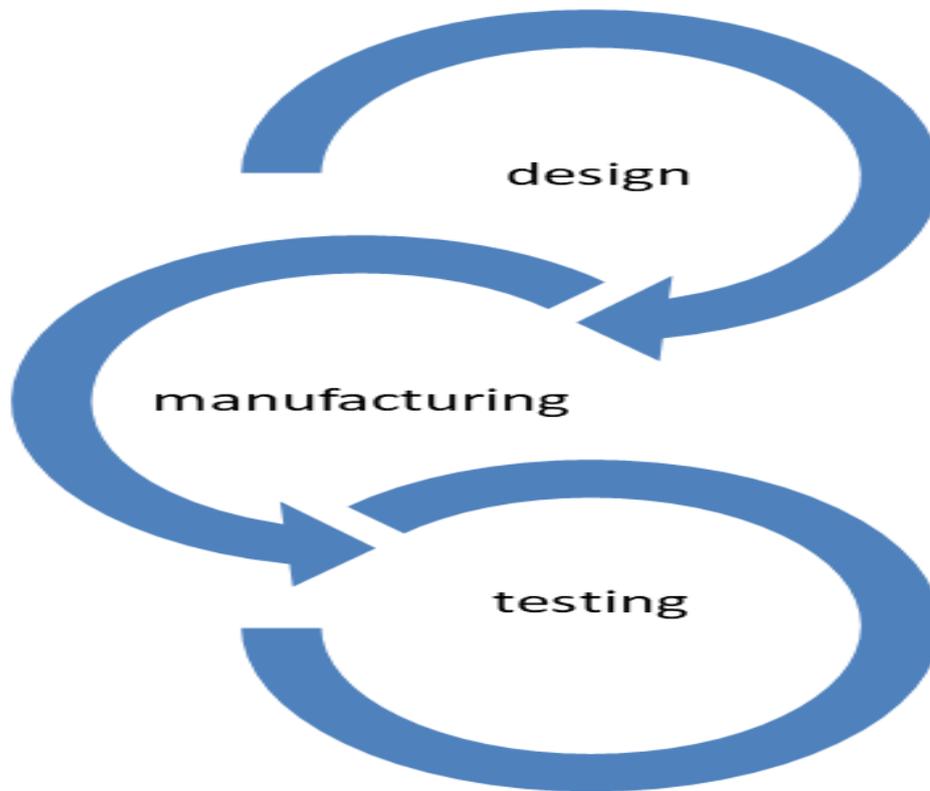
ABSTRACT: This experiment deals with the manufacturing and testing of E glass/Epoxy based composite cylindrical shell. The Laminated cylindrical shells are being used in submarine, underground mines, aerospace applications and other civil engineering applications. The stiffened and unstiffened shells made up of metallic and laminated composite materials (large diameter to thickness ratio) are extensively used in underwater, surface, air and space vehicles as well as in construction of pressure vessels, storage vessels, storage bins and liquid storage tanks. The geometric imperfections due to manufacturing processes takes dominant role in decreasing the buckling load of cylindrical shells. Pressure vessels are used for various industrial applications. To ensure safe operation of pressure vessels, it is important to know its burst pressure. Burst pressure is the pressure at which vessel burst/crack and internal fluid leaks. For light weight application pressure vessel are made of composite material. Payload performance /speed /operating range depends up on weight. Use of composites for pressure vessels improves performance and also offer significant amount of material savings. Stacking sequence is very crucial to strength of composite pressure vessels. In present study the influence of composite cylindrical shell diameter and stacking sequence on tensile load has investigated and from the results the burst pressure for the composite shell is predicted

KEYWORDS: E glass/E epoxy based composite cylindrical shell, Laminated cylindrical

I. INTRODUCTION

A composite is when two or more different materials are combined together to create a superior or unique material, or composite describes as reinforced plastics. An increasing number of structural designs, especially in the aerospace, automobile, and petrochemical industries are extensively utilizing fiber composite laminated plates and shells as structural elements. The laminated orthotropic shell belongs to the composite shell category. One of the important factors in the analysis of the layered shells is its individual layer properties, which may be anisotropic, orthotropic or isotropic. A shell is a curved, thin walled structure. Two important classes of shells are plates (shells which are flat when un-deformed) and membranes (shells whose walls offer no resistance to bending). Shells may be made of a single homogeneous or anisotropic material or may be made of layers of different materials. The primary function of a shell may be to transfer loads from one of its edges to another, to support a surface load, to provide a covering, to contain a fluid, to please the eye or a combination of these. A thin shell is defined as a shell with a thickness which is small compared to its other dimensions and in which deformations are not large compared to thickness. A primary difference between a shell structure and a plate structure is that, in the unstressed state, the shell structure has curvature as opposed to plates. Membrane action in a shell is primarily caused by in-plane forces (plane stress), though there may be secondary forces resulting from flexural deformations. Where a flat plate acts similar to a beam with bending and shear stresses, shells are analogous to a cable which resists loads through tensile stresses. The ideal thin shell must be capable of developing both tension and compression. Thin shell structures are light weight constructions using shell elements. These elements are typically curved and are assembled to large structures. Typical applications are fuselages of aero planes, boat hulls and roof structures in some buildings. Shell structures are mainly used in industrial applications such as automobile, civil, aerospace and petrochemical engineering. Various types of shells are used in civil field such as conoid, hyperbolic paraboloid and elliptical paraboloid shell. All are used for roofing to cover large column-free areas. Laminated composites are such type of material which has high strength to weight and strength to stiffness ratios. The mechanical properties of the laminated composites depend on the degree of orthotropy of the layers, ratio of the transverse shear modulus to the in-plane shear modulus and stacking sequence of laminates.

II. PLAN OF WORK



Results have been indicated that composite shells can be used by replacing metallic shells due to light weight and non-corrosive cells.

III. BUILDING DESCRIPTION

Manufacturing of fiberglass

The manufacturing process for glass fiber's suitable for reinforcement uses large furnaces to gradually melt the silica sand, limestone, kaolin clay, fluorspar, colemantite, dolomite and other minerals to liquid form. Then it is extruded through bushings, which are bundles of very small orifices (typically 5–25 micrometre in diameter for E-Glass, 9 micrometres for S-Glass). These filaments are then sized (coated) with a chemical solution. The individual filaments are now bundled together in large numbers to provide a roving. The diameter of the filaments, as well as the number of filaments in the roving determines its weight. This is typically expressed in yield-yards per pound (how many yards of fibre in one pound of material, thus a smaller number means a heavier roving, example of standard yields are 225yield, 450yield, 675yield) or in tex-grams per km (how many grams 1 km of roving weighs, this is inverted from yield, thus a smaller number means a lighter roving, examples of standard tex are 750tex, 1100tex, 2200tex). These roving's are then either used directly in a composite application such as pultrusion, filament winding (pipe), gun roving (automated gun chops the glass into short lengths and drops it into a jet of resin, projected onto the surface of a mould), or used in an intermediary step, to manufacture fabrics such as chopped strand mat (CSM) (made of randomly oriented small cut lengths of fiber all bonded together), woven fabrics, knit fabrics or uni-directional fabrics. In present study the composite cylindrical shell is selected and design & optimization of two influential manufacturing parameters, such as cylindrical shell diameter and stacking sequence were considered, each of which has three different levels (high, medium and low levels) as shown in table 3.1



Table 3.1. Process Parameters with levels

Parameters/Levels	L1	L2	L3
P1 (Diameter of mandrel -mm)	76.2	101.2	152.4
P2 (Stacking Sequence)	[90/90/90]	[90/45/90]	[45/45/45]

To increase the experimental efficiency, the L9 mixed orthogonal array table in the Taguchi quality design is prepared as shown in table 3.2.

Table 3.2. Process Parameters arranged in L9 orthogonal Array:

Experiment No.	P1 (Diameter of mandrel -mm)	P2 (Stacking Sequence)
1	76.2	[90/90/90]
2	76.2	[90/45/90]
3	76.2	[45/45/45]
4	101.2	[90/90/90]
5	101.2	[90/45/90]
6	101.2	[45/45/45]
7	152.4	[90/90/90]
8	152.4	[90/45/90]
9	152.4	[45/45/45]

By considering the parameters mentioned in table3.2 the composite cylindrical shells were prepared

Material selection:

From the table 3.3 the E-glass was considered as fiber material for its cheaper cost and lower weight compared with steel and aluminum. Epoxy (LAPOX L-12) is considered as matrix and suitable hardener of (K-6) was used for curing of resin at room temperature. The properties of selected material are shown in table.

Table 3.3. Comparison of material for selection:

	Tensile strut	Beam	Plate	
Material	E/ρ [MPa/kg/m ³]	$E^{1/2}/\rho$	$E^{1/3}/\rho$	σ_f/ρ [MPa/kg/m ³]
Steel	27	1.9	0.7	0.05-0.1
Aluminum	26	3.1	1.5	0.07-0.2
E-glass	27	3.2	1.6	0.8-1.4
S-Glass	36	3.8	1.8	1.6-2.0

Table 3.4. Properties of material.

S.No.	Property	Unit	value
1	Flexural strength	Kg/mm ²	40-50
2	Impact strength	KJ/mm ²	100-150
3	Modulus of elasticity	Kg/mm ²	2500-3500
4	Water absorption	% w/w	0.020-0.20
5	Martens value	°c	100-130

IV. MODELLING OF STRUCTURE

MANUFACTURING OF COMPOSITE LAMINATED CYLINDRICAL SHELLS

MANDRELS:

Mandrels of about 76.2mm, 101.2mm, and 152.4mm in diameter made of PVC were selected because they were readily available in market.

Preparations of samples:

Procedure to prepare composite laminated cylindrical shells.

In the present work composite templates are prepared as per the required dimensions according to the required dimensions the glass fiber mat has been cut into various orientations by making use of different mechanical equipment and measuring equipment .the mandrel surface is cleaned thoroughly and poly vinyl alcohol viscous liquid is applied on the surface of the mandrel uniformly and left for drying about 15 minutes as shown in figure 1 this liquid creates an invisible film which works as impervious layer prevents sticking to the mandrel surface as shown in fig 1



Fig 1. Poly vinyl alcohol viscous liquid applied on mandrel

After drying of polyvinyl alcohol viscous liquid, a glass fiber mat which was cut as per the required dimension is placed on a flat surface resin is applied uniformly on the mat after completion of distribution of resin on to the layer one end of first layer is stickled upon to the mandrel and mandrel is rotated in forward direction by pressing .the same process have done for various orientations of sandwich composite laminated shells and finally cut the laminated shells by using cutter machine (or) hacksaw into a require ASTM standard dimensions.

STEP BY STEP PROCEDURE FOR THE PREPARATION OF COMPOSITE LAMINATED CYLINDRICAL SHELLS IS SHOWN IN FIGURES BELOW:

Initially required dimensions marked on the E-Glass fibre mat by using steel rule as shown is figure 2.



Fig: 2 Marking the fibre in to the required dimension.

By the help of Bevel protractor, the helical angles are maintained in the fibre mat for different orientations to be wound on the mandrel. Fibre mat is prepared as E-Glass tapes as per the mandrel required dimensions marked on the mat as shown in figure 3.

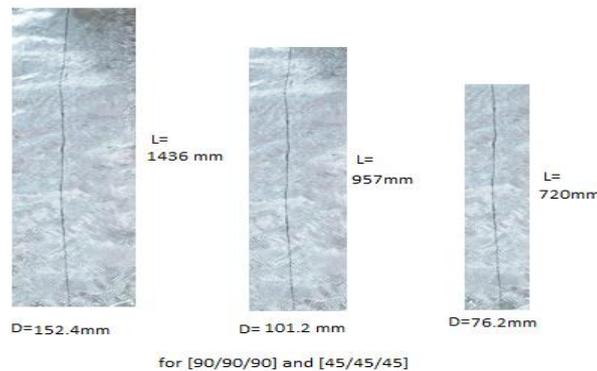


Fig 3 The Fibre is cut into the required dimensions and orientation

The Weight of the E-Glass fiber on the weighing machine are noted for the mixture of resin and hardener. The ratio maintained for fibre and resin is 1:1 and the ratio maintained for resin and hardener is 1:10. E-Glassier weight is 128gm and Epoxy Resin weight is also 128 gm whereas the hardener mixed in resin will be 12.8 gm. Mix the resin and hardener in a jar and stir it, and start applying it on to the tape by means of paint brush and wind the tape on the mandrel. Stick one of the end of the layer on the mandrel and start rolling a mandrel by pressing it in forward direction. Same procedure is repeated for all the shells by arranging layers in different angles for each shell as mentioned in the table 3.2 and finally after completion of all the procedure shells are left for curing. After curing of SHELLS, the mandrels were removed.

V. RESULTS AND DISCUSSIONS

Below table shows two parameters p1 and p2 i.e., diameter of mandrel (mm) and stacking sequence and their compression strength after performing Tensile test. S/N ratio is calculated by using the following formula.

$$\frac{s}{n} = -\log \frac{1}{n} \left[\sum \frac{1}{y^2} \right]$$

Array Table 1 experimental results of L9 orthogonal

Experiment No.	P1 (Diameter of mandrel -mm)	P2 (Stacking Sequence)	Load applied (Kg-F)	Predicted Pressure (N/mm ²)	S/N Ratio	Deflection (mm)
1	76.2	[90/90/90]	2368.21	23208.46	8.73	28.5
2	76.2	[90/45/90]	2357.63	23104.77	8.73	36.25
3	76.2	[45/45/45]	2470.31	24209.04	8.77	31
4	101.2	[90/90/90]	2303.21	22571.46	8.71	47
5	101.2	[90/45/90]	2092.81	20509.54	8.62	46.5
6	101.2	[45/45/45]	2898.89	28409.12	8.91	52
7	152.4	[90/90/90]	2215.75	21714.35	8.67	81
8	152.4	[90/45/90]	2435.37	23866.63	8.76	83
9	152.4	[45/45/45]	1652.91	16198.52	8.42	74

The below tabular column 5.2 shows the average of Tensile strength is calculated by using the following sequence such as



$$L1 = \frac{[90/90/90] + [90/45/90] + [45/45/45]}{3}$$

$$L1 = \frac{23208.46 + 23104.7 + 24209.04}{3}$$

L1=23507.42

And similarly, L2 and L3 of parameter p1 (diameter of mandrel) is calculated and then L1, L2 L3 for parameter p2 (stacking sequence) is calculated by using the following sequence.

Table 2 Response table for Predicted Pressure (N/mm²)

Parameters/Levels	L1	L2	L3
P1 (Diameter of mandrel)	23507.42	23830.04	20593.1647
P2 (Stacking Sequence)	22498.0887	22493.646	22938.89

Table 3 Response table for S/N ratio of Predicted Pressure (N/mm²)

Parameters/Levels	L1	L2	L3
P1 (Diameter of mandrel)	8.74	8.75	8.62
P2 (Stacking Sequence)	8.70	8.70	8.70

$$L1 = \frac{[90/90/90] + [90/45/90] + [45/45/45]}{3}$$

$$L1 = \frac{8.73 + 8.73 + 8.77}{3}$$

L1=8.74

Figure 5.4 explain the response graph for Predicted Pressure which is obtained by taking levels L1,L2 and L3 on x-axis and Predicted Pressure on y-axis. In the graph blue line indicates p1(diameter of mandrel) and red line indicates p2(stacking sequence). By analysing the graph we noticed that when the diameter of mandrel is 4 inches,Predicted Pressure is more. From the line p2(stacking sequence) we noticed that Predicted Pressure is more when Helix layers were wounded i.e, 45/45/45.

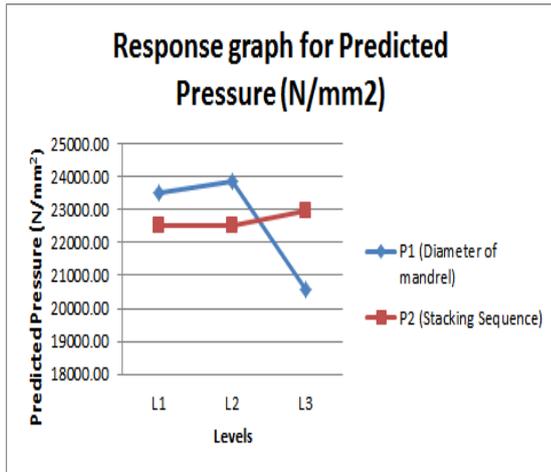


Fig 4 Response graph for Predicted Pressure

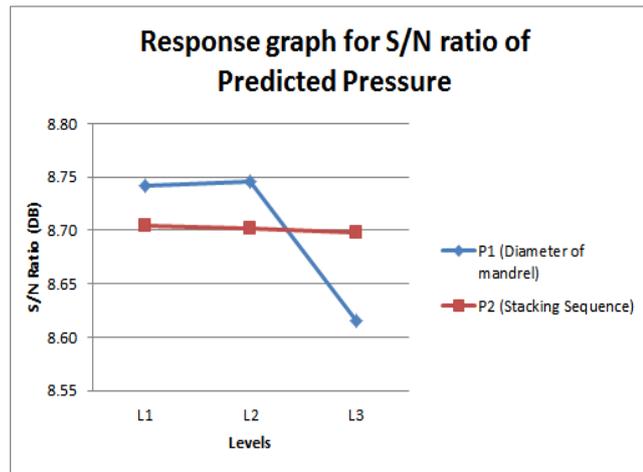


Fig 5 Response graph for S/N ratio Tensile strength

Figure 5.5 shows the response graph for S/N ratio of Predicted Pressure,from this graph we noticed that the value of S/N ratio is more when diameter of mandrel is 4 inches. In the graph red line indicates that S/N ratio is more when Hoop’s and Helix combination were wounded i.e,(45/45/45).

Analysis of Variance:

The purpose of the analysis of variance (ANOVA) is to determine which Tensile strength significantly affects the quality characteristic. Table 5.4 shows the results of ANOVA analysis of raw data for Tensile strength. From Table 5.4, it is apparent that the F values p1 (diameter of mandrel) and p2 (stacking sequence) are all less than F0.01, 2, 4 = 4.325 So we conclude that, assumed parameters p1 (diameter of mandrel) p2 (stacking sequence) are not significant parameters affecting Predicted pressure.

Table 4 ANOVA table for responded raw data

Source of Variation	Sum of square	Degree of Freedom	Mean of square	F Value
P1 (Diameter of mandrel)	19074322.4	2	9537161.2	0.58
P2 (Stacking Sequence)	392571.9	2	196286	0.01
Error	65214453.9	4	16303613.5	
Total	84681348.2	8		

In the above chapter tensile test (UTM) has been done and the results obtained were furnished in the form of Data Sheets and the results were published by performing these testing in the LUCID LABORATORIES PRIVATE LIMITED, Hyderabad

VI. CONCLUSION

The design and manufacturing of E-Glass fiber based cylindrical shell with epoxy resin on circular cross section mandrel was successfully manufactured using hand layup method at room temperature and then tested on UTM for analyzing the Pressure values of shells made by considering two parameters namely p1(diameter of mandrel) and p2(stacking sequence).By the Tensile test results obtained we came to know that when the diameter of mandrel is 4 inch, Radial Tensile strength is more. When Helix layers were separately wounded i.e, 45/45/45 the Radial Tensile strength is more. By the analysis of variance we also concluded that, assumed parameters p1 (diameter of mandrel) and p2 (stacking sequence) are not significant parameters affecting the Radial Tensile strength.

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