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ANALYSIS OF CNC FILAMENT WOUND COMPOSITE CYLINDER UNDER PURE AND COMBINED LOADING

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Abstract: A study was made to determine the characteristics of CNC filament wound composite cylinder under pure and combined loading. We have used boron-- epoxy and E-glass—epoxy filament wound cylinders. These cylinders are fabricated in orthotropic winding pattern. A Computational tool, Finite Element Method (FEM) has been used to analyse the result. Results of the FEM are examined in order to investigate characteristics of Filament wound cylinders under different combined loading condition. Winding angle, level of Orthotropy and various combined loading condition have been studied. Analyses are performed separately for pure and combined loadings. Finally the required data is obtained for the design of filament wound composite cylinders under combined loading.

Key words: Orthotropic, Finite Element method, Winding angle, Filament wound.

I. INTRODUCTION

The utility of conventional composite materials made by imbedding fibrous glass in a suitable resinous matrix is universally recognized .E—Glass reinforced Epoxy or polyster materials ,which are strong ,lightweight , inexpensive , and easily fabricated , are used in many commercial and military structural applications . However , one inherent , often undesirable , characterstic of E—Glass reinforced composites is their low stiffness . Boron Filaments with about half with about half the tensile strength ,nearly equal density and 5 to 6 times the stiffness of glass filaments have recently been developed .Boron –reinforced composites may therefore be more applicable than E –glass reinforced composites to structures where stiffness is a primary design consideration. Composites are the materials that are composed of at least two components and form a new material with properties different from those of the components. The reinforcement materials usually have extremely high tensile and compressive strength. However, these theoretical values are not achieved in structural form. This is due to the surface flaws or material impurities, which results in crack formation and failure of the piece below its theoretical strength [1].In order to overcome this problem, reinforcement is produced in fiber form, which prevents crack formation through the whole body. However, a matrix should be used to hold these fibers together, and improve material properties in the transverse direction of the fiber. The matrix also protects the fiber from damage, as well as spreading the load equally to each individual fiber. Composites have an increasing popularity in engineering materials, with their stiffness and strength combined with low weight and excellent corrosion resistance [1]. By studying the variable properties of composite materials, engineers use the advantage of anisotropy included within composite materials. By building a structure by properly selected resin, fiber, layer orientation and curing, optimization is successful in most cases.

II. MODELING OF COMPOSITE TUBES

Structural analysis is performed in order to investigate the behavior of layered orthotropic tubes with different materials in Table 1. Under pure and combine loading. The model is prepared with Shell 99 element with rigid region at other end with Mass 21 element in Ansys. As shown in Fig.1 this model is constraint with for all degrees of freedom at one end and load applied to the rigid region of the tube at other end as shown in Fig 2. The internal pressure is applied on the inner surface of the tube. Dimensions of the tube used in the study are given in Table 2.

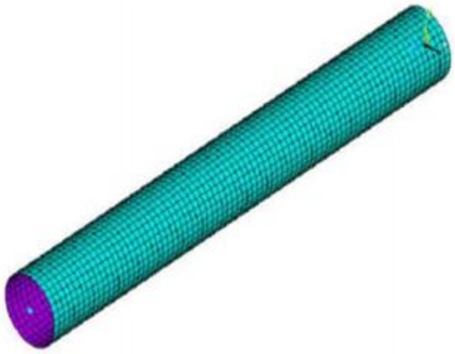

Fig 1. Finite element model of composite tube

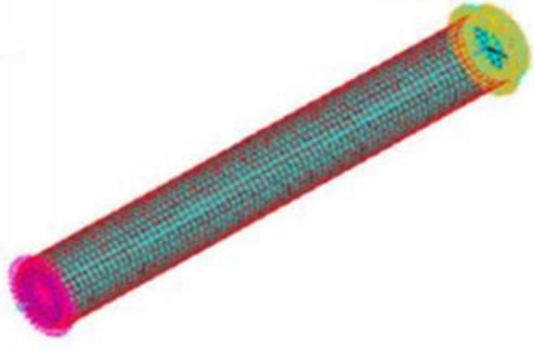

Fig 2. Boundary conditioned for composite tube

III. MATERIALS USED FOR ANALYSIS

Table.1 Materials used for analysis

Mechanical Properties of Fiber Glass Epoxy Resins	**E-Glass / Epoxy (MPa)**	**Boron/ Epoxy (MPa)**
Elastic Constant		
Elasticity Exx	45600	127700
Elasticity Eyy	16200	7400
Elasticity Ezz	16200	7400
Poisson Ratio xy	0.27	.0300
Poisson Ratio yz	0.27	0.188
Poisson Ratio zx	0.27	0.188
Shear Modulus Gxx	8500	6900
Shear Modulus Gyy	5500	4300
Shear Modulus Gzz	5500	4300
Stress Constant		
Tensile Stress Sxx	1243	1717
Tensile Stress Sxx	40	30
Tensile Stress Sxx	40	30
Compressive Stress xx	525	1200
Compressive Stress yy	145	216
Compressive Stress zz	145	216
Shear Stress Sxy	73	33
Shear Stress Syz	73	33
Shear Stress Szx	73	33

Table.2 Dimensions for composite tube

Length of the tube (mm)	400 mm
Fixing length at end	Rigid
Average radius (mm)	25 mm
Tube thickness (mm)	1 mm

IV. RESULTS AND DISCUSSION

In this analysis, E--Glass/Epoxy and Boron/Epoxy tubes are subjected to loading action in pure and multi-axial loading with magnitudes axial, transverse as 1000 kN, torsional 1000 N.mm and internal pressure 10 bar and the analysis is repeated for varying degrees of winding angles from zero to 900 . All deformation and stresses in corresponding directions are collected for pure and combined loading. Multi-axial deformations and stress levels are shown in Figures 3- 7.

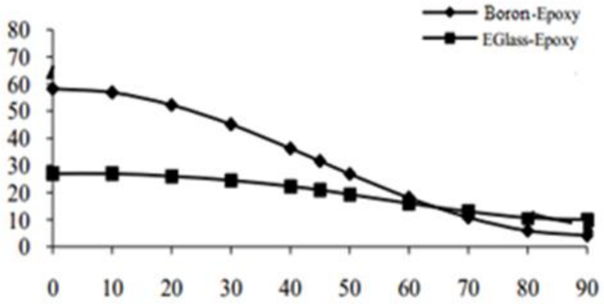

Fig 3. Lateral Deformation Vs Winding Angle

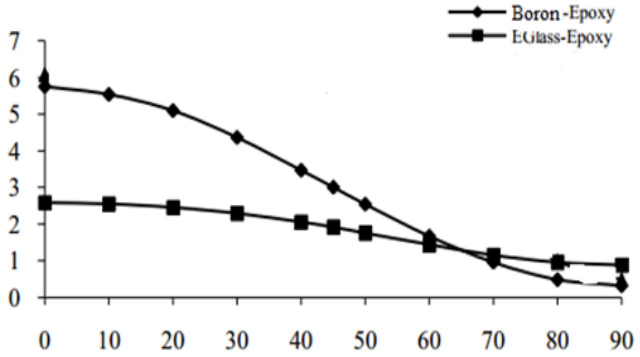

Fig 4. Axial Deformation Vs Winding Angle

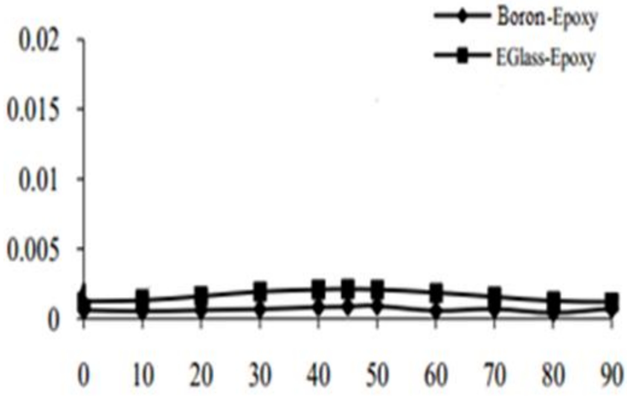

Fig 5 Angle of Twist Vs Winding Angle

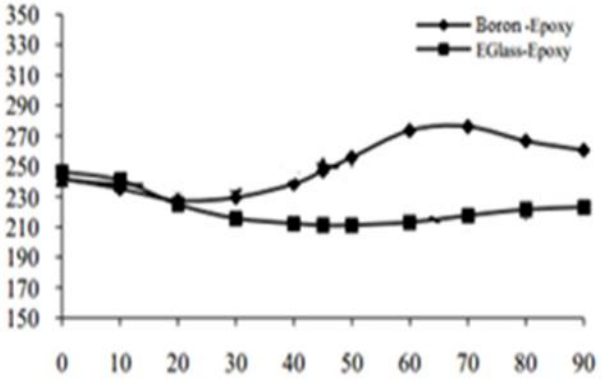

Fig 6. Normal Stress Vs Winding Angle

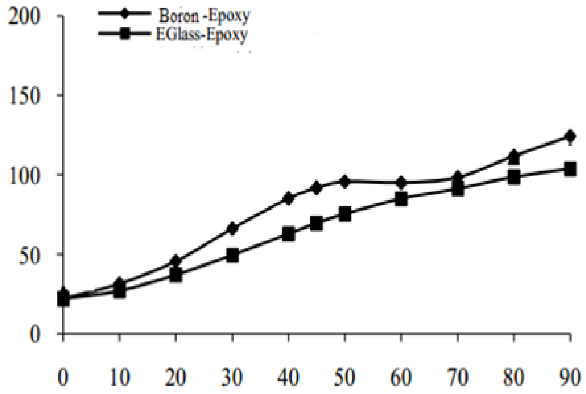

Fig 7. Shear Stress Vs Winding Angle

V. CONCLUSIONS

In order to investigate the effect of winding angle on pure and combined loading. Analyses are performed separately for pure and combined loadings. In the case of pure loading, the results of the analyses were in agreement with the ones given in the literature. Optimum winding angle and material selected is displayed in Table 3-6.

Table.3 Optimum angles for Uni-axial loadings

Loading Type	Parameter	Boron	E-Glass	Material Selected
Axial	Stiffness	90	90	Boron
	Stress	90	90	
Transverse	Stiffness	90	90	Boron
	Stress	0	0	
Torsional	Stiffness	0/90	45	E-Glass
	Stress	0	90	
Internal Pressure	Stiffness	0	0	Boron
	Stress	0	0	

Table.4 Optimum angles for Bi-axial loadings

Loading Type	Parameter	Boron	E-Glass	Material Selected
Axial Transverse	Stiffness	90	90	Boron
	Stiffness	90	90	
	Stress	80	90	
	Stress	0	0	
Axial Tortional	Stiffness	90	90	Boron
	Stiffness	90	90	
	Stress	90	90	
	Stress	0	0	
Axial Internal Pressure	Stiffness	90	90	Boron
	Stiffness	0	0	
	Stress	0	0	
	Stress	10	45	

Table.5 Optimum angles for Tri-axial loadings

Loading Type	Parameter	Boron	E-Glass	Material Selected
Axial Transverse Torsional	Stiffness	90	90	Boron
	Stiffness	90	90	
	Stiffness	80	90	
	Stress	80	90	
	Stress	0	10	
	Stress	0	0	
Axial Transverse Internal Pressure	Stiffness	90	90	Boron
	Stiffness	90	90	
	Stiffness	0	0	
	Stress	20	45	
	Stress	0	0	
	Stress	0	0	
Axial Torsional Internal Pressure	Stiffness	90	90	Boron E- Glass
	Stiffness	40	50	
	Stiffness	90	0	
	Stress	0	0	
	Stress	0	90	
	Stress	10	45	

Table.6 Optimum angles for Multi-axial loadings

Loading Type	Parameter	Boron	E-Glass	Material Selected
Axial Transverse Torsional Internal Pressure	Stiffness	90	90	Boron E- Glass
	Stiffness	90	90	
	Stiffness	80	0	
	Stiffness	0	0	
	Stress	20	70	
	Stress	0	0	
	Stress	0	0	
	Stress	0	0	

VI. RECOMMENDATIONS TO TUBE/PIPE MANUFACTURER

Pipe (or) Tubes manufacturing industries can look into this work for that there is lots of effect on the winding angle and level of orthotropy on deformation and level of stresses. The Schematic View of a Filament Winding Machine is shown in Fig 8. Select by analysis of this type optimum winding angle and material, based on cost economy in mass production for actual loading condition on the pipe (or) tubes requirements. This presented winding angles and level of orthotropy are suitable for all lengths and loading magnitudes for them to be optimum for single layer.

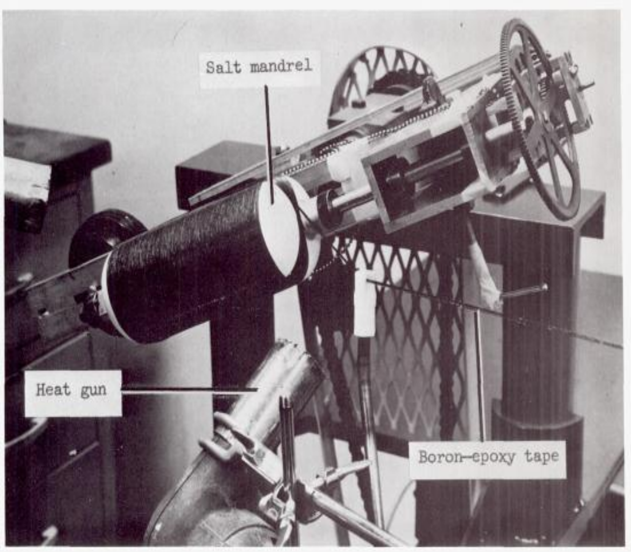

Fig 8 – Schematic View of a Filament Winding Machine

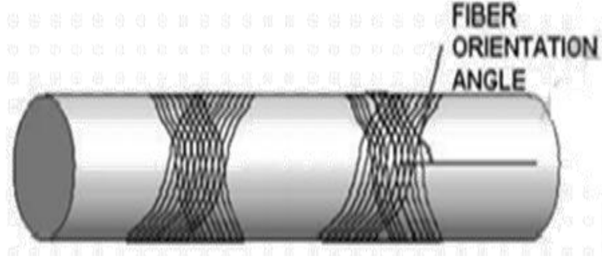

Fig 9 - Fiber orientation for 45 and -45

VII. SCOPE OF FURTHER WORK

Above work is done only for single layer it can be extended for multi-layer for better optimum winding angles and level of orthotropy.

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