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Characterization of Hybrid tubular Composite structures

K.Susheela[1], Dr.P.Ramesh Babu[2]

[1]Research Scholar, Department of Mech. Engg., O.U, Hyderabad.

[2] Professor, Department of Mech. Engg., O.U, Hyderabad.

***ABSTRACT*:**

Filament winding composite tubes become more popular in structural applications and have been preferred over metal tubes in many cases such as transmission and driving shafts, composite rocket motor casing, Airframe structures and payload fairings. Mechanical fasteners like rivets and adhesive bonding are two techniques used for interconnecting the composite structure to metallic end rings. The hybrid tubular lap joints being used in the design of mechanical structures because of their significant advantages. This paper delineates the effect of percentage variation of reinforcement on tensile and inter-laminar shear properties of the hybrid composite laminates. These laminates are prepared by filament winding method with interlayer hybrid combination of Carbon fibre/epoxy and Glass/epoxy. The hybrid laminates is tested according to ASTM standards. From the experimental results it is observed that the hybrid laminate with 60:40 having high strength and moderate modulus and this combination can be used in hybrid tubular joints.

KEYWORDS: *Filament winding process, hybrid composite laminates, hybrid tubular lap joints*

1. Introduction

Composite structures are widely used in the aerospace, automotive, and marine industries due to their high strength-to-weight ratio. Composite laminates containing plies of two are more different types of materials are called hybrid composites. Hybrid composites are designed in various configurations such as Interlayer or layer-by-layer,I ntralayer or yarn-by-yarn, Intra yarn or fibre-by-fibre. Hybridization is one of the efficient methods to develop hybrid composite by fibre hybridization or matrix hybridization to enhance the desired mechanical properties of composite materials. In some literatures, it is reported that in order to improve the failure strains of CFRP composites, it is promising to incorporate the carbon fibre with glass fibre. Purpose of hybridization is to make such that increase a resistance against the inter-laminar toughness that cannot be obtained with only conventional composite material.

2. Theoretical Background

Hybrid composite structures have several advantages, such as the improvement of crack-arresting properties, fracture toughness, and cost reduction by decreasing the amount of the more expensive fibre. [1] Was the first author using an extended shear lag model for hybrid composites and it was used to determine the hybrid effect as a function of the fibres properties.[2]Investigate stress concentrations in an intermingled hybrid composite by using Eigen vector expansion method.[3] noticed the positive hybrid effect in such materials as the load could still be bridged to the surrounding high elongation fibres upon the fracture of the fibres having low elongation, thus resulting in enhanced mechanical properties of the composites. Hybrid Composite pipes have also been utilized in waste water treatment system, power and petroleum productions and other industries for transportation of various fluids.[4] Investigate the effect of hybridization and stacking sequence composite tubes subjected to quasi static indentation. From results axial and circumferential strains for inner and outside of hybrid tubes dependent on the type of fiber used and on the stacking sequence. Hybridization allows the designer to obtain benefits of each reinforcing material while potentially reducing cost by applying the most expensive material only where needed. In the present work tensile strength and tensile modulus and inter laminar shear strength of hybrid laminates is estimated by experimental method. The aim of the work is to assess suitable combination of hybrid laminates for hybrid tubular structures.

3. Materials. Carbon fibres are the most widely used for advanced composites and come in many forms with a range of stiffness and strengths depending on the manufacturing process. Carbon-fibre has high tensile strength and elasticity and less fracture toughness

Glass fibres are the most commonly used in low-to-medium performance composites because of their high tensile strength and low cost. E-glass fibre is particularly characterized with high toughness resistance and lower elasticity. More importantly, the incorporation of glass fibres with carbon fibres can enhance the mechanical properties of composites.

For hybrid tubular joints requires hybrid structure behaviour needs to be carried out the mechanical testing by varying hybrid combinations.

3.1 Material properties: Elastic properties of Carbon T-700/epoxy and E-glass/epoxy materials are shown in Table.1.Which are referred from literature.

Table.1.

Property	**CarboT-700/epoxy**	**E-glass/epoxy**
E_1 (GPa)	140	40
E_2=E_3 (GPa)	8	8
$\upsilon_{12} = \upsilon_{13}$	0.25	0.24
υ_{23}	0.32	0.21
G_{12}=G_{13}(GPa)	3.58	5
G_{23}(GPa)	4.5	3.6

4. Fabrication of Hybrid laminates:

Filament winding technique is used to fabricate hybrid laminates. The hybrid laminate consist ofT700 Carbonfibre12K, E-glass fibre, 12Tex, with epoxy resin-1555 and hardener-HY5200.Fabrication work and Experimental work was carried out at Composite Product Development Centre Division, Advanced system laboratory (ASL) Hyderabad. The hybrid composite laminates of 2mm thickness with interlayer hybrid combination of two layers of carbon /epoxy and two layer E-glass/epoxy with stacking sequence of[Carbon /Glass/Glass/Carbon] and orientation of $[0/90]_s$and hybrid combinations of H1-50:50, H2-60:40 and H3-70:30 are fabricated on 4-axis filament winding machine as shown in Fig.1.

Fig.1. 4-axis Filament winding machine

To fabricate laminates first select the mould for required dimensions and clean the mould surface by using emery paper of grade 220 and 320. Subsequently, the mould is cleaned with acetone to confirm that there is no left out resin on the mould surface. Otherwise, it could damage the laminates. Then, releasing agent, i.e., the wax polish is applied to remove the laminate from the mould after the curing process.Take the resin and hardener with weight ratio of 100:27 into the beaker heat at 45^0C and mix it well and pour in resin bath. Maintain the resin bath temperature up to 50^0C during fabrication of laminates. Then fiber from spool was released under tension shown in Fig.2 are impregnated with epoxy resin are wound on rotating mandrel in a controlled manner with specific fiber orientation and Stacking sequence for hybrid laminate are prepared as shown in Fig.3.And Hybrid combinations and layup sequence are shown in Table.2.

Fig.2. Fibre spool and laminate during winding

Fig.3. hybrid laminate

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The prepared hybrid laminates of different hybrid combinations are shown in Fig.4. Diamond wheel cutting machine is used to generate tensile and ILSS specimens from the fabricated hybrid laminates as per the standards 250x15x2mm for ASTM D3039 and 40x10x4mm for ASTMD2344 are shown in Fig .5.

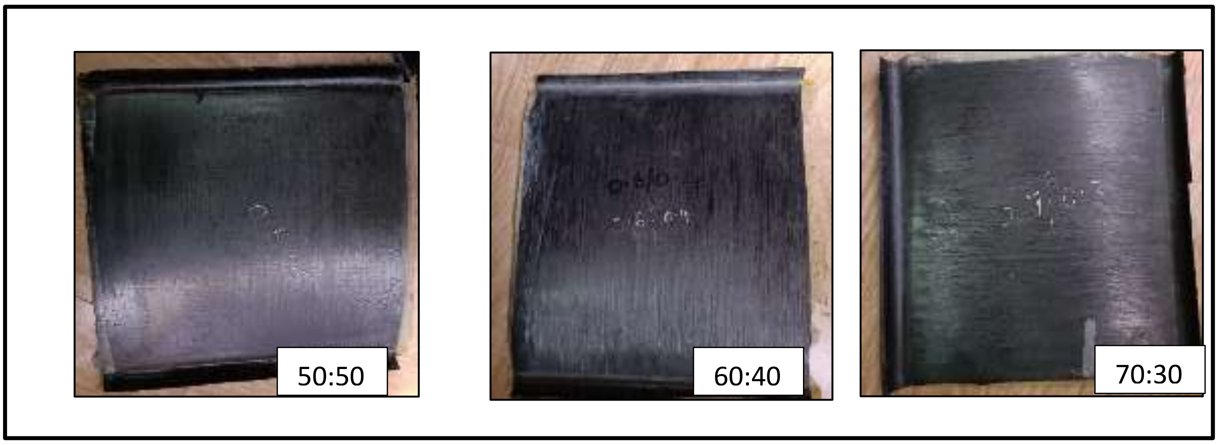

Fig.4. hybrid laminates of different hybrid combinations

Fig.5.Specimen used for testing

Table.2.

S.no	Hybrid combination	Thickness of layers/layup sequence	Orientation
1.	H1 -50:50	0.5 Carbon /0.5 E-glass/0.5/E-glass/0.5 Carbon	[90/0/0/90]
2.	H2 -60:40	0.6Carbon /0.4 E-glass/0.4/E-glass/0.6 Carbon	[90/0/0/90]
3.	H3 -70:30	0.7 Carbon /0.3 E-glass/0.3/E-glass/0.7 Carbon	[90/0/0/90]

5. Testing of hybrid specimens: Tensile test and inter-laminar shear test were conducted according to standards. Tensile testing is a fundamental mechanical testing method in which a sample is subjected to uniaxial tension until failure. Tensile test are conducted on ADMET (UTM).The universal testing machine (UTM) is used for testing with higher accuracy, the maximum capacity of machine 200 KN is used for testing, which operated on electronic control servo mechanism. Speed rate is 2mm/min. Specimens are prepared as per ASTM D3039 standards the gauge length is 250 mm, and the cross head speed is 2.5 mm\min. During the test, an extensometer of gauge length 25 mm is used, to measure the strain of the hybrid laminate. Which consists tabs at either ends. The inter-laminar shear strength popularly referred as ILSS is performed with a three-point bending fixture at a crosshead speed of 1 mm/min is applied. The short beam shear strength of the rectangular cross-sectioned hybrid composite laminates is determined from the maximum load (P) values using the mathematical expression as specified with below equation (1).

$$ILSS = \tau = \frac{3}{4}\frac{Pmax}{w*t} \qquad (1)$$

Where τ is the inter-laminar shear strength and P is the maximum load and w, is the width t is the thickness of specimen.The experimental data of tensile test and ILSS test for different hybrid combinations of H1, H2, and H3 are shown in Tables 1, 2, 3.and 4,5,6. And failure tensile specimens are shown in Fig.6.

Fig.6.Failure specimens of hybrid composites

Table.3. TENSILE TEST- H1

S.No	Dimensions W*T mm2	Displacement in mm	load in kN	Tensile strength Mpa	Tensile Modulus Gpa
1	32.5208	4.89	19.73	606	47
2	33.2208	4.4	17.77	535	51
3	32.3463	4.49	20.82	644	49
4	33.0455	5.06	22.93	694	55

Table.4. TENSILE TEST -H2

S.No	Dimensions W*T mm2	Displacement in mm	Load in kN	Tensile strength Mpa	Tensile Modulus Gpa
1	28.9344	7.336	34.37	1188	77
2	27.5448	6.134	29.37	1066	76
3	30.8154	6.157	32.06	1058	82
4	28.5008	6.284	28.89	1014	74

Table.5.TENSILE TEST -H3

S.No.	Dimensions W*T in mm2	Displacement in mm	Load in kN	Tensile strength Mpa	Tensile Modulus Gpa
1	35.1169	7.37	40.307	1147	82
2	34.7886	7.40	44.57	1281	86
3	34.8696	7.09	41.86	1200	84
4	35.8428	7.86	45.347	1266	92

Table.6.ILSS TEST FOR-H1

S.No.	Dimensions W * T in mm^2	Displacement in mm	Load in kN	ILSS Mpa
1	45.87	0.839	2.17	35.54
2	44.37	0.995	2.32	39.28
3	44.92	0.846	2.35	39.30
4	46	0.922	2.38	38.72

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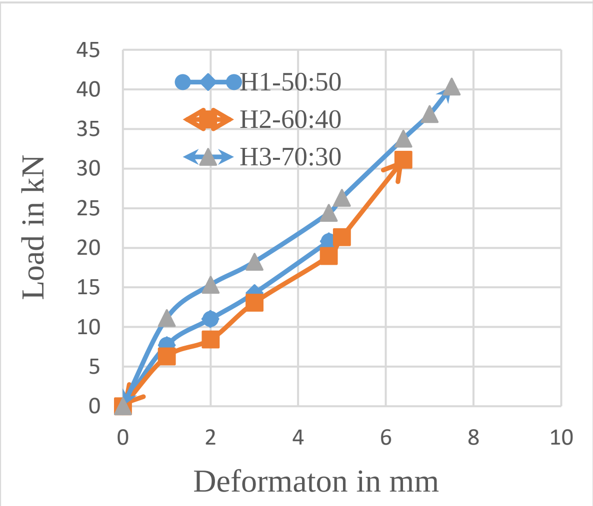
Table.7.ILSS TEST FOR-H2

S.No.	Dimensions W*T in mm^2	Displacement in mm	Load inkN	ILSS Mpa
1	41	1.21	2.27	41.52
2	43.2	1.23	3.1	53.82
3	42	1.623	3.1	55.35
4	41.5	1.263	3.1	56.02

Table.8. ILSS TEST FOR-H3

S.No.	Dimensions W*Tin mm^2	Displacement in mm	Load in kN	ILSS Mpa
1	40.9	1.204	3.06	56.11
2	40.8	1.174	2.63	48.34
3	40.68	1.08	2.75	50.70
4	42.2	1.223	3.2	56.87

6. Results and discussions: Tensile Test of hybrid laminates with different combinations are conducted the results are shown in Fig.7.(a) and (b).It shows while increasing the thickness of carbon layer in hybrid laminates the load is increased.As the volume fraction of carbonincreases the load carrying capacity is increased.For H2 the deformation is low compare to H1 and H3 .The percentage increase deformation for H1 compare to H2is 37% while for H2 to H3 is 15%.



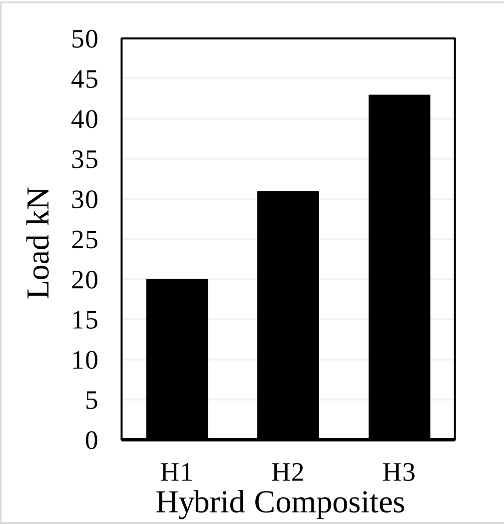


Fig.7. (a) Load/deformation curve of hybrid laminates(b) Load vs. Hybrid composites

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And the percentage increase tensile modulus from H1to H2 is 33% for H2 to H3 is 10% similarly the percentage increase of tensile strength value from H1 to H2 is 42% and for H2 to H3 is 11 % as shown in Fig .8. (a) and (b).

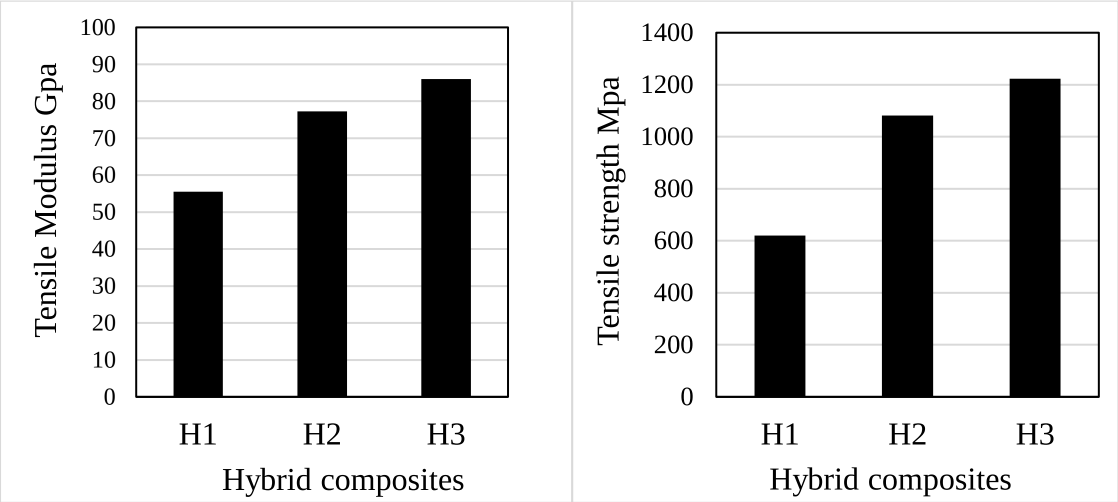

Fig.8.(a) Tensile modulus of hybrid composites (b) Tensile strength of hybrid composites

The combination of tensile modulus and tensile strength graph as shown in Fig.9.From Fig.10 the increased percentage value of Interlaminar shear strength from H1 to H2 is 25% and for H2 to H3 3% .From the results the tensile properties and inter-laminar shear strength properties of hybrid composites .It was suggested that H2 is the suitable hybrid configuration for hybrid tubular structures..

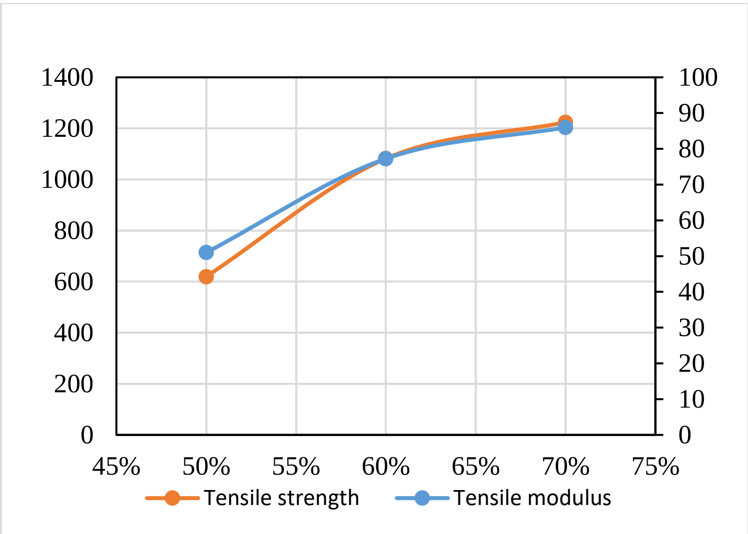

Fig.9.(a) Tensile strength and Tensile modulus of hybrid composites.

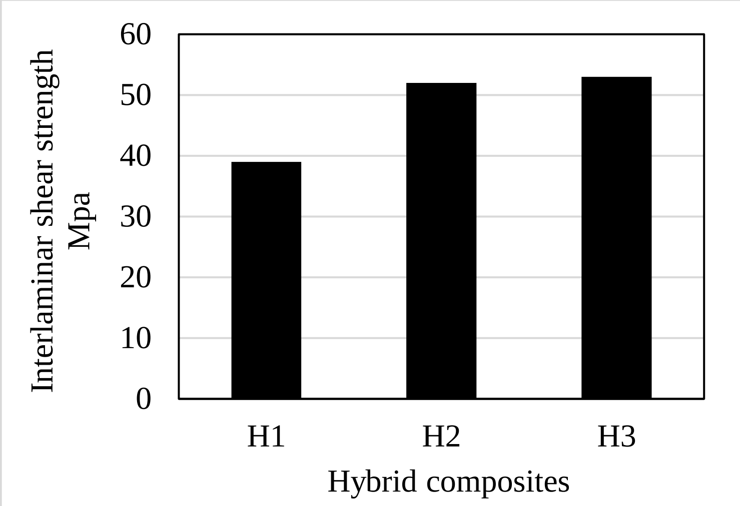

Fig.10.ILSS of hybrid composites

7. Conclusions: Experimentally investigated the tensile strength and inter-laminar shear strength of filament winding hybrid composite laminates of different hybrid combinations of H1, H2, and H3. From the test results hybrid laminate H2 is giving the required strength and stiffness for the hybrid tubular composite structures

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