



An Investigation on Hybrid Polymer Based Composites (E Glass fibre – Carbon fibre – Graphite Particulate with Epoxy resin 5052) for Flexural and Inter Laminar Shear Stress for Different Thickness

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Abstract: Hybrid composites are considered materials of great potentials for engineering. One advantage of hybrid polymer composite materials for the designer is that the properties of a composite can be controlled to a considerable extent. The present experimental study aims at learning the flexural behavior and ILSS of hybrid polymer based reinforced composite (E Glass fiber – Carbon fiber – Graphite Particulate with Epoxy resin 5052) by varying the thickness of the composite. Vacuum bagging technique was adopted for the fabrication of hybrid composites. Flexural and ILSS test is carried out as per ASTM standards.

Keywords: ILSS, Flexural Strength, Hybrid Polymer Composite, Curing, Epoxy Resin 5052, Vacuum Bagging.

I. Introduction

Hybrid composites are manufactured by combining two or more fibers in a single matrix. Hybridization in order to use to tailor the material to exact needs under design [1]. Epoxy resin is used in this hybrid composite because it provides a unique balance of chemical and mechanical properties combined with extreme processing versatility. In all cases, thermoset resins may be tailored to some degree to satisfy particular requirements [2]. Epoxies are one type of thermosetting polymer that are more expensive and have better mechanical properties and resistant to moisture than the polyester and vinyl resin [3]. At present epoxy resins are widely used in various engineering applications, such as electrical industries, commercial and military aircrafts industries. In order to improve their processing and product performances and to reduce cost, various fillers are introduced into the resins during processing [4]. Hybrid laminated composite are prepared by stacking sheets of Glass/carbon fibers to required orientation to form angle ply laminates. An individual structural glass fibre is both stiff in tensile and compression [5].

They found from the detailed shear stress contour it was possible to discover the point of maximum stress in a region within one thickness away from the supporting roller for all three laminates. Experiment carried out on inter laminar shear behavior of typical polymer matrix composites under high strain rate shear loading by N.K. Naik et al [6]. It is observed that the inter-laminar shear strength increases with increasing shear strain rate within the range of shear strain rate considered. The classical laminate theory and the higher-order shear deformation theory, are used to predict the inter-laminar shear stresses in the cross-ply laminate by C.Y. Lee et al [7]. They found that the approach using the higher-order shear deformation theory has improved accuracy for the analysis of thick symmetric laminate over the approach using the classical laminate theory.

II. Experimental Procedure

Material

Carbon fiber (37%) – E glass fiber (30%) – Graphite particulate (3%) – Epoxy resin LY 5052 (30%) were used to fabricate hybrid polymer composite laminate.

Preparation of hybrid polymer composite

The fibres (reinforcement materials) and matrix material (Resin and Hardener) contains moisture absorbed from atmosphere. Therefore the fibres, resin & hardener should be heated for approximately 60 minutes at the temperature of 60°C in an oven, so that the moisture absorbed can be removed.

Preparation of Fibre

Now, the volume fraction of fibres and resin is calculated based on matrix to reinforcement ratio and then calculate the weight based on density. After this, the ratio of reinforcements (In case of hybrid composites) is evaluated and the number of fabric layers required for each fibre to obtain the required thickness, with matrix material is calculated.

Preparation of Reinforcement

Based on the prescribed resin – hardener ratio, weight of resin and hardener required obtaining the desired volume fraction of matrix and reinforcement is calculated. The resin and hardener is taken in a cleaned container and is stirred for about 5 minutes, so that the resin is mixed completely with the hardener. Now the matrix (Resin + Hardener) is ready for fabrication. In case of the hybrid composites, mix the particulate reinforcement with the resin (in this study, particulate graphite is taken).

The determination of fibre volume ratio can be derived from the fibre/resin weight ratio. The approach is as follows:

Data

Carbon fibre: 204gsm

Glass fibre: 202gsm

Specimen calculation for the preparation of Lamina

Weight calculation of Composite Prepared

Table1 - Weight calculation for specimen preparation of Carbon fibre, E-glass fibre, Graphite particulate with Epoxy resin.

composition	Required Thickness of lamina (mm)	Weight of carbon fibre			Weight of glass fibre			Total weight of fabric (gsm)	Weight of matrix = 30% of total weight of fabric (gsm)	weight of graphite particulate = 3% of total weight of fabric (gsm)	Total weight of the laminate (gsm)
		No of layers	Weight Of each layer (gsm)	Total Weight (gsm)	No of layers	Weight Of each layer (gsm)	Total Weight (gsm)				
Carbon fibre + E - glass fibre + graphite particulate + Epoxy	2	4	204	816	3	202	606	1422	426.6	42.7	1891
	3	6	204	1224	5	202	1010	2234	670	67	2971
	4	8	204	1632	7	202	1414	3046	913.8	91.4	4051

Thickness calculation of composition

Table 2: Thickness calculation for specimen preparation of carbon fibre, E-glass fibre and graphite particulate with epoxy resin

Composition	Required Thickness of lamina (mm)	Thickness of carbon fibre			Thickness of glass fibre			Total thickness of fabric (mm)	Thickness of matrix = 30% of total thickness of fabric (mm)	Thickness of graphite particulate = 3% of total thickness of fabric (mm)	Total thickness of the laminate (mm)
		No of layers	Thickness of each layer (mm)	Total thickness (mm)	No of layers	Thickness of each layer (mm)	Total thickness (mm)				
Carbon fibre + E - glass fibre + graphite particulate + Epoxy	2	4	0.22	0.88	3	0.18	0.54	1.42	0.426	0.0426	2
	3	6	0.22	1.32	5	0.18	0.9	2.22	0.666	0.0670	3
	4	8	0.22	1.76	7	0.18	1.26	3.02	0.906	0.0906	4

The composites are manufactured using Vacuum Bag Moulding process. The set up of Vacuum bag Moulding and composite is shown below.



a) Vacuum Bag Moulding

Post Fabrication Procedure:

After the fabrication of laminates, it has to be subjected to post curing, so lamina has to be kept under two pressure plates and subjected to curing in a programmable oven, the post curing cycle for the polymer composites is as discussed here.

Post Curing:

In general, uncured epoxy resins have only poor mechanical, chemical and heat resistance properties. However, good properties are obtained by mixing the linear epoxy resin with suitable curatives to form three-dimensional cross-linked thermo set structures. This process is commonly referred to as curing. Curing of epoxy resins is an exothermic reaction and in some cases produces sufficient heat to cause thermal degradation if not controlled.



b) Epoxy curing furnace (for post curing of composite laminates).

Post Curing Cycle for Epoxy Resin

The FR Composite laminate is kept in an oven at room temperature and program the oven to ramp up and dwell for post curing of lamina according to the schedule as follows:

1. Ramp up the temperature to 50°C from room temperature in 15 minutes
2. Now maintain the constant temperature of 50°C till next 30 minutes
3. Then again raise the temperature from 50°C to 70°C in next 15 minutes
4. Now maintain the constant temperature of 70°C till next 60 minutes
5. Then ramp up the temperature from 70°C till 85°C in next 15 minutes
6. Now again maintain the constant temperature of 85°C till next 120 minutes
7. Now switch off the heater and keep the laminate to cool down to room temperature in the oven itself.

III. Flexural Test

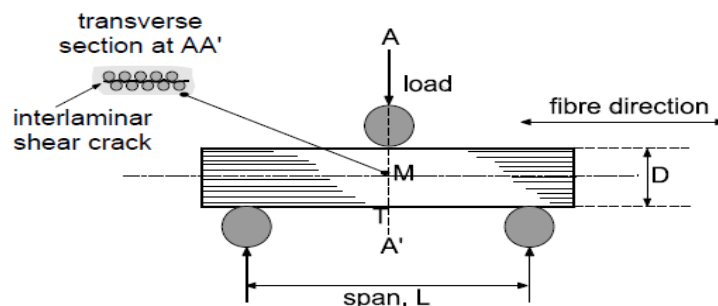
This was performed according to ASTM D 790 test method. The slot used for testing consisted of five samples for different constitutions. The test was conducted on three samples of 2mm, 3mm and 4mm each. The data Obtained from the mechanical testing was used to calculate the elastic properties and bending strength of the laminates. Peak load & bending strength were determined.



c) 3 point bending test of composites, Specimen loaded in machine.

IV. Shear Test

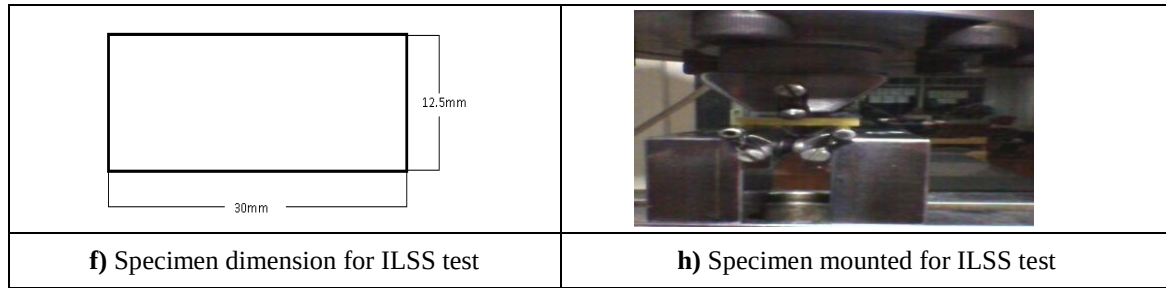
Inter laminar shear failure is most readily seen in the three-point bending of short beams, a method commonly used to measure what is usually referred to as the inter laminar shear strength, or ILSS, although this is often regarded as unsatisfactory because the state of stress is not pure shear. In the diagram in Figure (d), if the level of horizontal shear stress at the mid plane point M reaches the inter laminar shear strength, τ_{IL} , of the composite before the tensile stress level at T reaches the composite strength, σ_c , then the beam will fail as shown. If the beam is longer than a certain critical length, however, it will fail in a normal bending mode by a tensile failure initiating at the mid-point of the outer face.



d) Schematic illustration of inter laminar shear failure in a unidirectional laminate.

Specimen preparation of Inter Laminar Shear Stress (ILSS) Test:

According to ASTM 397 for ILSS test, the specimen preparation and dimensions are as follows:



Test Procedure:

The thickness and width of the test specimen are measured before conditioning. The specimen is placed on a horizontal shear test fixture so that the fibers are parallel to the loading nose. The loading nose is then used to flex the specimen at a speed of 0.05 inches per minute until breakage. The force is then recorded. Calculations are performed to determine shear strength.

V. Observation Table

FLEXURAL TEST

Flexural test data for Carbon fiber (37%) – E glass fiber (30%) – Graphite particulate (3%) – Epoxy resin LY 5052(30%) hybrid polymer composite laminate by varying thickness of laminate.

Table 3 Flexural test data of Hybrid Polymer Composite laminates.

Specimen no.	Thickness (mm)	Maximum load (N)	Average (N)	Bending Strength (N/mm ²)	Average Bending Strength (N/mm ²)
1	2	654.7	749.33	716.8965	820.52
2		611		669.045	
3		982.3		1075.619	
4	3	982.1	978.86	521.8879	520.17
5		1003.7		533.3'662	
6		950.8		505.2551	
7	4	1818.9	1869.00	614.7882	631.722
8		1934.9		653.9962	
9		1853.2		626.3816	

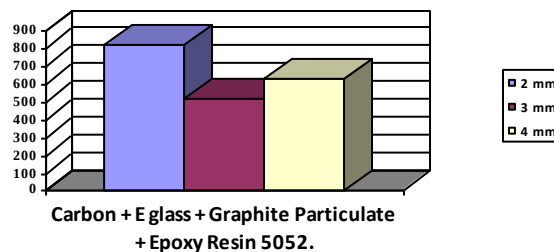
INTER LAMINAR SHEAR TEST

ILSS test data for Carbon fiber (37%) – E glass fiber (30%) – Graphite particulate (3%) – Epoxy resin LY 5052(30%) hybrid polymer composite laminate by varying thickness of laminate.

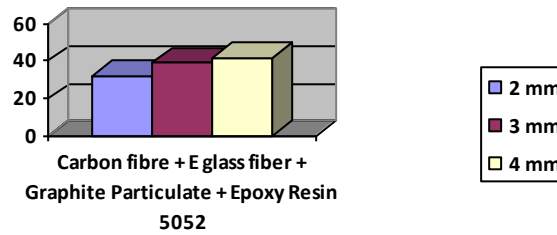
Table 4 - ILSS test data of Hybrid Polymer Composite laminates

Specimen no.	Thickness (mm)	Maximum Shear load (N)	Average (N)	Shear Strength (N/mm ²)	Average Shear Strength (N/mm ²)
1	2	1050.32	1042.63	32.31	32.07
2		985.25		30.31	
3		1092.32		33.60	
4	3	1978.67	2036.86	38.05	39.17
5		2098.56		40.36	
6		2033.36		39.10	
7	4	2774.27	2787.10	41.82	42.02
8		2732.69		41.20	
9		2854.34		43.03	

Graphs:



Graph 1 : Comparison of Flexural strength for different thickness of 2mm,3mm and 4mm.



Graph 2: Comparison of Interlaminar Shear Strength for different thickness of 2mm, 3mm and 4mm.

VI. Results and Discussions

Graph 1: From the Graph 1 it is seen that hybrid polymer composite delivers the high flexural strength, this is because carbon & E-glass fiber with graphite particulate makes the strong inter laminar bond, which resists the bending loads. It is also studied and seen that the bending strength of the composite laminate depends on its thickness, as the thickness of the composite increases, its flexural strength decreases it is because the ratio of deformation of outer face to the inner face is high in thicker sections which causes the tension in lower part and results in failure. But for smaller sections it flexes and tolerates the load acting on it, since the ratio of deformation of outer face to inner face is less it can withstand the higher loads, thus improves the flexural strength. But it can be seen that the 3 mm thick laminate shows lesser strength than the 4 mm one, this is because of the starvation of resin in 3 mm thick laminate.

Graph 2: From the Graph 2, it is seen that the hybrid Polymer Composite exhibits high shear strength as the existence of epoxy 5052 which makes the strong inter laminar bond in the composite, in addition graphite particulate acts as the fillers and fills the space between warps and wefts resulting in strong inter laminar bond and hence increasing the inter laminar shear strength.

It is observed that ILS strength increases with the increase in thickness of the composites.

VII. References

- [1]. G. Kretsis, a review of the Tensile, Compressive, Flexural and shear properties of hybrid fibre reinforced plastics, Composites, Vol 18:1987.
- [2]. J. Harding and L.M Welsh, A tensile testing technique for fibre-reinforced composites at impact rates of strain, JMaster Sci 18:1983.
- [3]. Chawla, K. Kumar, 1999 "Mechanical Behavior of Materials", Prentice Hall, Inc.
- [4]. Callister, W. D. and Rethwisch, D. G., 2007 "Materials Science and Engineering an introduction", 7th Edition, John Wiley and Sons, Inc.
- [5]. J.Cho, Mechanical enhancement of carbon fibre/epoxy composites by graphite nano platelet reinforcement, S. Direct 2007:685-688.
- [6]. N.K. Naik*, Addis Asmelash, Venkateswara Rao Kavala, Veerraju "Interlaminar shear properties of polymer matrix composites: Strain rate effect Structures Panel, Aeronautics Research and Development Board, Ministry of Defense, Government of India, Grant No. DARO/08/1051204/M/I.
- [7]. C.Y.Lee & C.C.Huang Evaluation of interlaminar shear stress by strain measurements on laminate surfaces, Department of Mechanical Engineering, Da-Yeh University, Da-Tsuen, Chang-Hwa, Taiwan 515, and R.O.C.