ISSN No:-2456-2165

An Experimental Investigation on Flexural and Tensile Strength Behaviour of Hybrid Polymer Composite Materials (Carbon Fibre- Particulate Graphite - E-Glass Fibre) by Varying its Thickness with Epoxy Resin 5052

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Abstract:- The Hybrid composite Materials have extensive engineering application where strength to weight ratio, low cost and ease of fabrication are required. Hybrid composites materials provide combination of properties such as tensile strength, compressive strength and impact strength which cannot be realized in composite materials. In recent times hybrid composites have been established as highly efficient, high performance structural materials and their use is increasing very rapidly. Different types of Hybrid composite fibres are used with the combined properties when longitudinal and lateral mechanical performances are required.

This paper presents a review of the mechanical properties of a hybrid composite [carbon fibre (36%) – Epoxy resins LY 5052(29%)-E glass fiber (29%) –Graphite particulate (3.5%)].

Keywords:- *E-Glass- Carbon- Graphite Composite, Optimization of Thickness of Composite, Strength, Stiffness, Tensile Modulus.*

I. INTRODUCTION

There is a gradually increase both in the number of applications being found for fibre reinforced plastics and in the variety of fibre-resins systems that are available to designers. Some of these systems are useful, however, only in highly specialized situations where limitations such as high investment and brittle failure behavior are considered secondary to such qualities as low density, high rigidity and high strength. By mixing 2 or more varieties of fibres in a resin to form a hybrid composite it may be possible to create a material possessing the combined advantages of the individual components and at the same time mitigating their less desirable qualities [1]. In addition it is possible to fulfill the properties of such materials to suit specific necessities.

A. Hybrid Composites

Hybrid composites contain more than one type of fiber in a single matrix material. In principle, several different fiber types may be incorporated into a hybrid, but it is more likely that a combination of only 2 kinds of fibres would be most useful [2]. They have been developed as a logical sequel to conventional composites containing one fiber. Hybrid composites have unique features that can be used to meet various design requirements in a more economical way than conventional composites. This is because expensive fibers like graphite and boron can be replaced to some extent by less expensive fibres such as Kevlar [3].

Few of the specific applications of hybrid composites over conventional composites include balanced strength and stiffness, balanced bending and membrane mechanical properties, balanced thermal distortion stability, reduced weight and/or investment, development in resistance to fatigue failure and reduced notch.

B. Case Study

The main intention of the research work is to hybridize the E-glass fibre (29%)-Graphite Particulate (3.5%) - Carbon fibre (36%)- Epoxy resin LY5052 (29%) by using Hand layup technique and Room temperature Vacuum bag molding.

The research work on the above polymer hybrid composites are carried out in order to achieve optimal strength with cost effectiveness for different applications [4]. Various tests like tensile, compression are considered to study the properties of the above Hybrid Composites.

II. METHODOLOGY

The basic engineering properties of a composite material can be determined by either experimental stress analysis (testing) or theoretical mechanics (micromechanics). The micromechanics approach utilizes knowledge of the individual fibre and resin characters and proportionality of the fibres to the resins in the lamina. A rule of mixtures principle can be applied to derive the maximum of the composite lamina properties [5]. For example the lamina axial modulus is derived from:

$E_x = E_m V_m + E_f V_f$
Where: E_f -fibre modulus of elasticity
E_m -matrix (resin) modulus of Elasticity
V_f -fibre volume ratio
V_m -matrix volume ratio
$V_f + V_m = 1$ with zero voids

The fabrication of composite material consists the selection of the required fibre and matrix material, and collects the appropriate amount of matrix(For example, the called-out ratio of say 70.0:30.0, requires a ratio of 70.0% fibre weight to 30.0% resin weight).

A. Weight Ratio and Fibre Volume Relationship

While the fibre weight ratio is easily determined by simple weighing, the fibre volume ratio is very difficult to calculate. Typically an ASTM test method is employed which requires destruction of a small sample. However the finding of fibre volume ratio can be derived from the fibre/resin weight ratio.

The approach is as follows:
Data:
Caron fibre thickness: 0.22mm
Kevlar fibre thickness: 0.27mm
Glass fibre thickness: 0.18mm
Carbon fibre: 204gsm
Kevlar fibre: 200gsm
Glass fibre: 202gsm

Volume ratio plays an important role; the engineering designer uses the ratio of fibre volume to derive the lamina properties and thus after lamination, structural properties. But to achieve the required ratio of fibre volume in wet lay-up processe the fabricator requires the fibres (Reinforcement) weight to resin (Matrix) weight ratio. The expression is dependent on the ratio of the fibre and resin densities. This relationship clearly identifies the importance of low fibre densities when compared with the resin density.

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)	Composition	Required Thickness 0f lamina (mm)	Weight of the carbon fibre			Weight of the 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 laminate (gsm)
					No of Layer	Weight Of each layer	Total Weight (gsm)	No of Layer	Weight Of each layer (gsm)	Total Weight (gsm)				
0.426	0.0426	2	Caron fibre + E - glass fibre + graphite particulate + Epoxy	2	4	204	816	3	202	606	1422	426.6	42.7	1891
0.666	0.0670	3		3	6	204	1224	5	202	1010	2234	670	67	2971
0.906	0.0906	4		4	8	204	1632	7	202	1414	3046	913.8	91.4	4051

Composition	Required Thickness 0f lamina (mm)	Thickness of carbon fibre			Thickness of glass fibre			Total thickness of fabric (mm)
		No of Layer	thickness of each layer (mm)	Total thickness (mm)	No of Layer	thickness of each layer (mm)	Total thickness (mm)	
Caron fibre + E - glass fibre + graphite particulate + Epoxy	2	4	0.22	0.88	3	0.18	0.54	1.42
	3	6	0.22	1.32	5	0.18	0.9	2.22
	4	8	0.22	1.76	7	0.18	1.26	3.02

Table 1. Weight calculation for specimen preparation of carbon fibre, particulate graphite, E-glass fibre with epoxy resin.

III. EXPERIMENTAL PROCEDURE

A. Pre-Fabrication Process

Before fabrication the fabrics and matrix (appropriate quantity of resin with its hardener based on calculations done for the required thickness and reinforcement-matrix ratio to be taken) has to be kept in oven setting the temperature at 59^0C so that the moisture from resin and fabric will be removed, then both resin and the hardener is mixed together and stirred properly.

B. Fabrication Process

For the fabrication of polymer matrix composite required fibres and Epoxy resin are to be collected then by applying releasing agent on the work table mount the releasing layer then again apply the releasing agent and place the first layer of fabric and wet it then apply the next layer and again wet that follow the same procedure for all remaining layers, the wetting should be done in such a way that the resin should be distributed equally on the lamina, care should be taken that there should be no starvation or excess of resin on the lamina. After the last layer again the resin is applied and covered with Teflon sheet and then the dead weight is applied over the mold. Vacuum is applied by covering the mold by vacuum bag, and is left for some time to get set so as excess of resin can be drawn outside. After the vacuum time it is left as it is at room temperature for 23hrs to cure. Therefore it is also called as Room Temperature Vacuum Bag Molding (RTVBM) [1].

C. Post Curing Process

Once if the laminate is ready, it has to be carried out for post curing so that all the layers of lamina bond together. This can be achieved by keeping the lamina in oven and set the oven to increase the temp. gradually to 49^0C in 15 min. from ambient temperature and hold the temperature for half an hour again ramping up to 79^0C in next 15 min. and hold the temperature for half an hour again ramp up to 90^0C in 15 min. and hold for half an hour then ramp up to 120^0C in 30 minutes and hold for 1 hour then let the oven cool down slowly to room temperature.

IV. EXPERIMENTATION

A. Tensile Test

Tensile test is done on polymer fibre reinforced composites lamina to determine the tensile strength on particular orientation of fibre, reinforced in the composite ply. It is very crucible to determine the tensile strength because the loading in direction of fibre orientation improves the strength drastically. Therefore to evaluate the strength of the composites ASTM standards are followed. According to the ASTM D-3039 for tensile test the following dimensions are used for preparation of specimen.

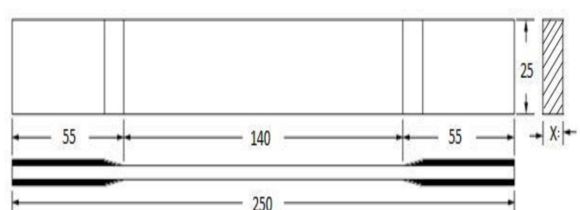


Fig 1:- Tensile test specimen X=2, 3, 4 mm thick

B. Universal testing machine

Fig 2:- Universal Testing Machine

The Materials Evaluation Laboratory (MEL) is equipped with closed loop computer controlled servo-hydraulic universal testing machine.

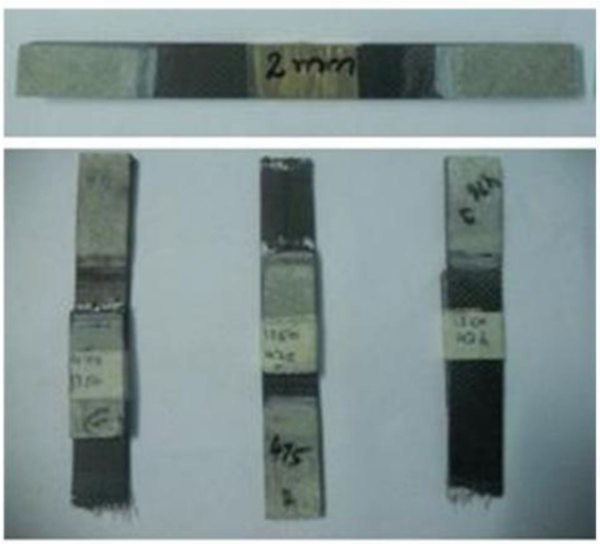


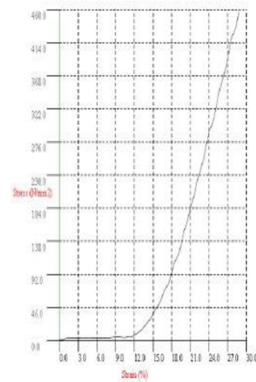
Fig 3:- Tensile test specimens before and after the test (Graphite particulate-Carbon fibre-E- Glass fibre –- Epoxy resin 5052).

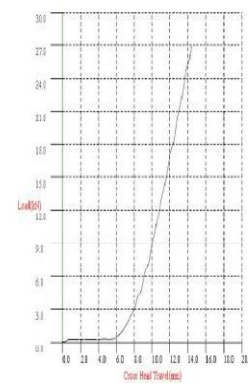
4.3 Tensile Test data of hybrid polymer composite laminates of E- Glass Fibre – Graphite particulate Carbon fibre - Epoxy resin 5052.

Sample No	Thickness (mm)	Tensile strength (N/mm^2)
1	2	456
2	3	431.31
3	4	408.11

Table 2. Tensile test data of hybrid polymer Composite laminates of Carbon fibre, particulate Graphite, E-glass fibre with Epoxy resin 5052 for different thickness.

Sample: 01

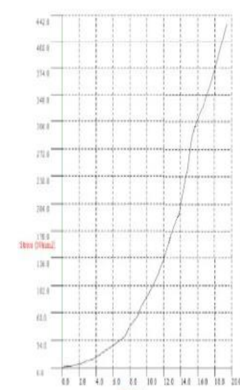


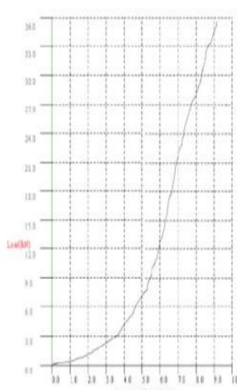


Graph 1. (a): Stress versus Strain relationship of 2 mm thick samples.

Graph 1. (b): Load versus Displacement relationship of 2 mm thick samples.

Sample: 02

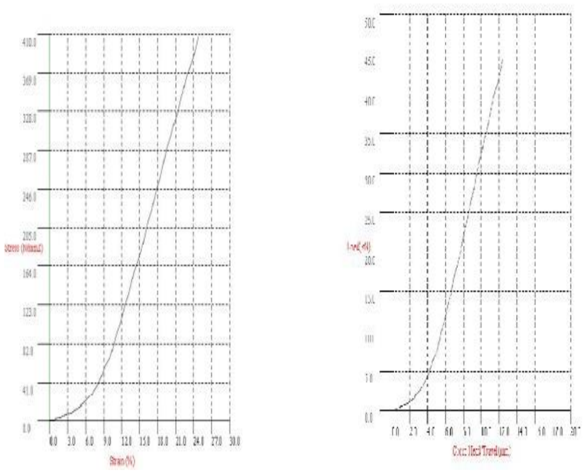




Graph 2. (a): Stress versus Strain relationship of 3mm thick samples.

Graph 2. (b): Load versus Displacement relationship of 3 mm thick samples.

Sample: 01



Graph 3. (a): Stress versus Strain relationship of 4 mm thick sample.
Graph 3. (b): Load versus Displacement relationship of 4 mm thick sample.

V. FLEXURAL TEST

The test was carried out on 3 samples of 2, 3 and 4mm each respectively. The data obtained from the mechanical testing was used to calculate the elastic properties and flexural strength of the laminates. The peak load and flexural strength were determined. The table gives the average flexural characters of multiple samples for each thickness.

- The Flexural test specimens before and after test:

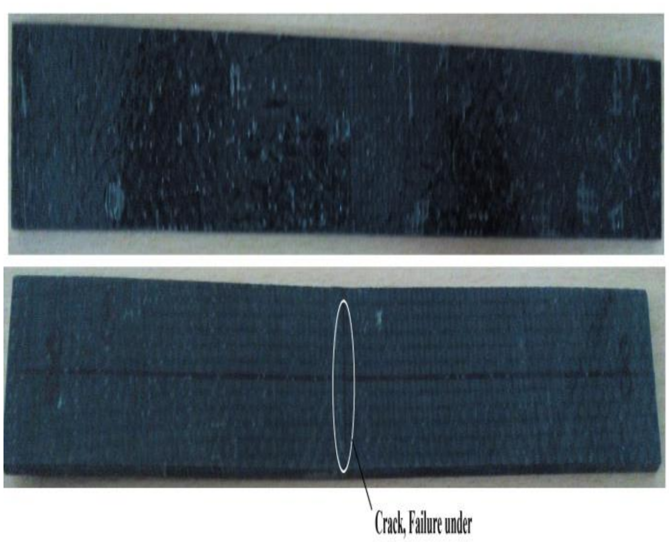


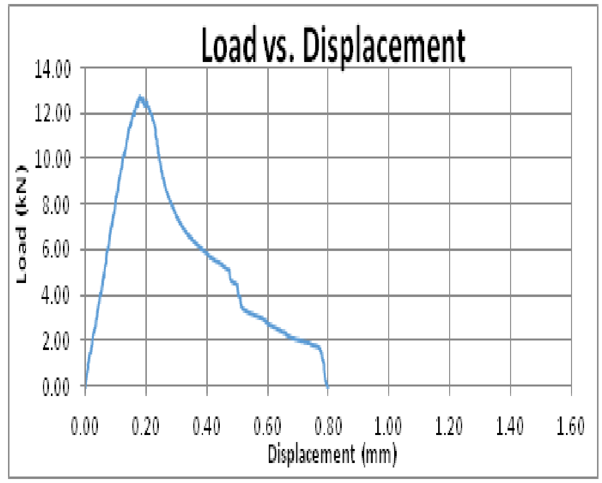
Fig 4:- Flexural test specimens before and after the test

5.2. E-Glass fibre – particulate graphite carbon fibre — Epoxy resin 5052:

Sample No	Thickness (mm)	bending strength (N/mm^2)
1	2	237.16
2	3	331.89
3	4	795.29

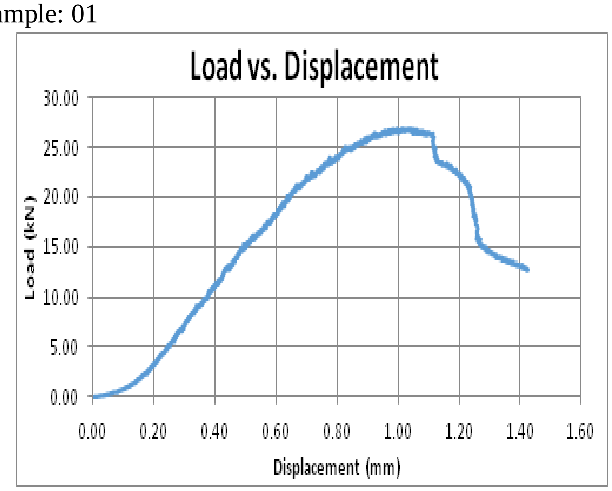
Table 3. Flexural test data of hybrid polymer composite laminates of E-glass fibre, carbon fibre, and particulate graphite with Epoxy 5052.

Sample: 01



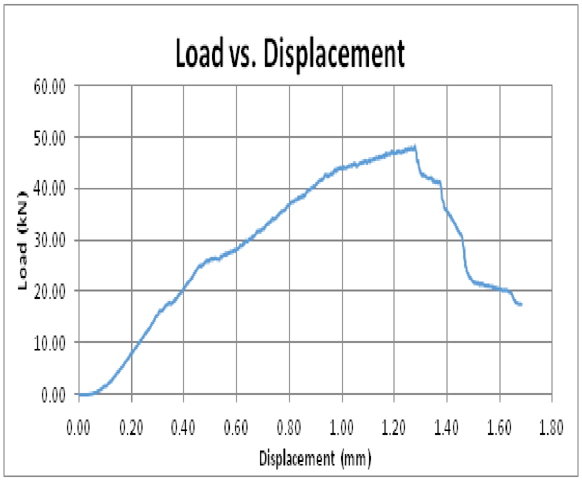
Graph 4. (a): Load versus Displacement relationship of 2 mm thick samples.

Sample: 01



Graph 4. (b): Load versus Displacement relationship of 3 mm thick samples.

Sample: 01



Graph 4. (c): Load versus Displacement relationship of 4 mm thick samples.

VI. RESULTS AND DISCUSSIONS

The investigation is also done to examine the strength on different thickness of plies, where it is observed that the strength of the thinner plies is high and as the thickness varies, the strength goes down, this is because of the improper adharance of matrix between the layers resulting in tension within the layers of composites. As the less thicker plies requires less number of layers of reinforcement, the inter laminar bonding strength will be more, making the composite reacts uniformly against the tension, where as in thicker sections, because of the multiple (more number of layers) the bonding strength will not be uniform across the section resulting in improper distribution of load among the layers of reinforcement tending it to fail.

From the above investigation it is also studied and observed that the flexural strength of the composite laminate is depends on its thickness, due to starvation of the resin in 3mm laminates it shows lesser strength than the 4mm, in composition 1 but composite 2 the 3mm thick laminate shows the strength higher than the 2mm ply of the same composition, which causes because of the excess resin in the laminates.

A. Characterization of Hybrid FRP Laminates

The micro structural study shows the failure modes of the different hybrid composites for different loading conditions.

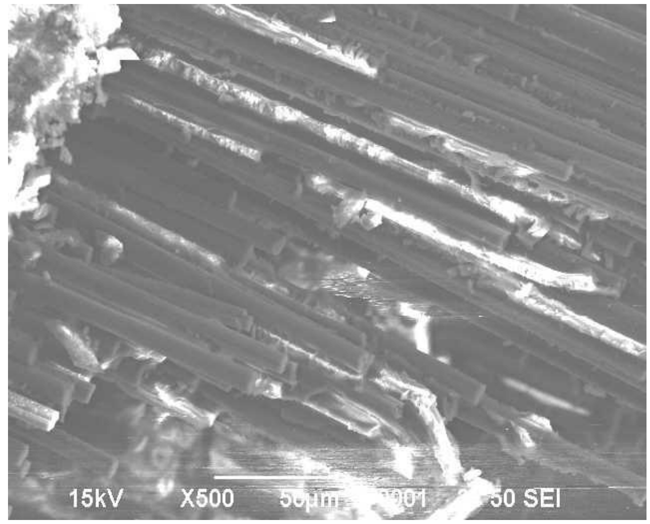


Fig 5:- SEM images of the Graphite particulate E-Glass-Epoxy resin 5052 after conducting tensile test.

From figure 5. the microstructure of tensile test specimen shows E glass fibers are getting break by inter laminar tension by peeling itself off, whereas carbon fibres are under tension and failed under extreme conditions. In this, particulate graphite fills the gap between the fibers thus strengthening the composite whereas epoxy resin 5052 bonds the reinforcement and offers resistance to the acting tensile load.

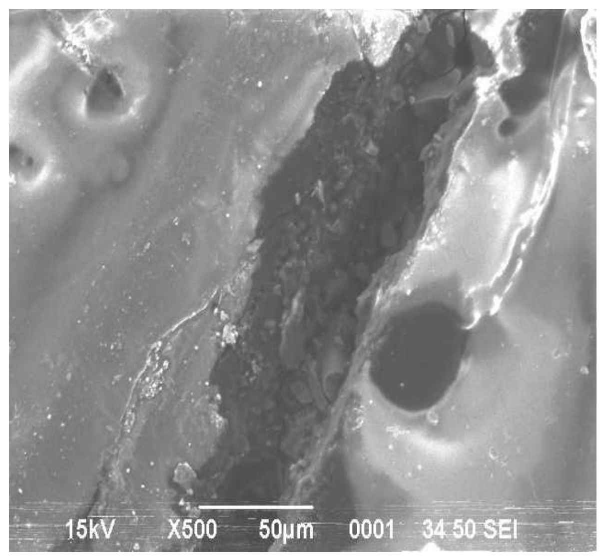


Fig 6:- SEM images of E-glass fibre- carbon fibre – particulate graphite and Epoxy resin 5052 after conducting Bending test.

VII. CONCUSION

- Composite 1 (E glass fibre + carbon fibre + particulate graphite with Epoxy resin 5052) delivers the high tensile strength in comparison with the other three composites. As the tensile strength of carbon fibre is high, overall tensile strength of the composite will be high, with which the particulate graphite acts as the fillers which fills the region in between the fabric joints, which results in improving the resistance to tensile loads. Epoxy resin 5052 has the property to set steadily (setting time is 3 hours) causing easy penetration of liquid matrix into the reinforcement fibre layers, making the strong inter laminar bond, which results in enhancement of tensile strength to greater extent.

- Due to the ratio of change in dimensions of outer face to the inner face is high in thicker sections which cause the tension in lower parts and results in failure. Therefore the flexural strength decreases due to increase in thickness of laminates. But for smaller sections its tolerances the force 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 bending strength.

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