A STUDY ON TENSILE AND COMpressive StRENGTH OF HYBRID POLYMER COMPoSITE MATERIALS (E GLASS FIBRE-CARBON FIBRE-GRAPHite PARTICULATE) WITH EPOXY RESIN 5052 BY VARYING ITS THICKNESS

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ABSTRACT

Hybrid composite Materials have extensive engineering application where strength to weight ratio, low cost and ease of fabrication are required. Hybrid composites provide combination of properties such as tensile modulus, 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 rapidly. Hybrid composites are usually used when a combination of properties of different types of fibers have to be achieved, or when longitudinal as well as lateral mechanical performances are required. The investigation of the novel applications of hybrid composites has been of deep interest to the researchers for many years as evident from reports.

This paper presents a review of the mechanical properties of a hybrid composite [carbon fiber (37%) – E glass fiber (30%) – Graphite particulate (3%) – Epoxy resin LY 5052(30%)].

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

There is a steady increase both in the number of applications being found for fibre reinforced plastics and, concurrently, in the variety of fibre/resin systems that are available to designers. Some of these systems are useful, however, only in highly specialized situations where limitations such as high cost and brittle fracture behaviour are considered secondary to such qualities as low density, high rigidity and high strength. By mixing two or more types of fibre 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 simultaneously mitigating their less desirable qualities [1]. It should, in addition, be possible to tailor the properties of such materials to suit specific requirements.

1.1 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 two types of fibers would be most beneficial [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 partially replaced by less expensive fibres such as glass and Kevlar [3].

Some of the specific advantages 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 cost, improved fatigue resistance, reduced notch.

1.2 Case Study

The objective of the research work is to hybridize the carbon fibre (37%)- E glass fibre (30%)-Graphite Particulate (3%) - Carbon fibre (37%)- Epoxy resin LY5052 (30%) 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 carried out to study the properties of the above hybrid composites.

2. 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 properties, and the proportionality of fibres to the resin in the lamina. A rule of mixtures approach can best be used to derive the majority of the composite lamina properties [5]. For example the lamina axial modulus is derived from:

\[ E_x = E_f V_f + E_m V_m \]

Where: \( E_f \) is the fibre modulus of elasticity
\( E_m \) is the matrix (resin) modulus of Elasticity
\( V_f \) is the fibre volume ratio
\( V_m \) is the matrix volume ratio
\( V_f + V_m = 1 \) with zero voids
The fabrication of composite material includes the selection of the required fibre and matrix material, and collects the appropriate amount of matrix (Resin). (For example, the called-out ratio of say 70:30, requires a ratio of 70% fibre weight to 30% resin weight).

2.1 Fibre Volume and Weight Ratio Relationship

While the fibre weight ratio is easily determined by simple weighing, the fibre volume ratio is quite difficult to determine. Typically, an ASTM test method is employed which requires destruction of a small sample. However, the determination of fibre volume ratio can be derived from the fibre/resin weight ratio. The approach is as follows:

Data:
Carbon fibre: 204gsm
Kevlar fibre: 200gsm
Glass fibre: 202gsm
Carbon fibre thickness: 0.22mm
Kevlar fibre thickness: 0.27mm
Glass fibre thickness: 0.18mm

Table 2.1: Weight calculation for specimen preparation of carbon fibre, E-glass fibre, graphite particulate with epoxy resin.

<table>
<thead>
<tr>
<th>Composition</th>
<th>Required Thickness of lamina (mm)</th>
<th>Weight of carbon fibre</th>
<th>Weight of glass fibre</th>
<th>Total weight of fabric (gsm)</th>
<th>Weight of matrix = 30% of total weight of fabric (gsm)</th>
<th>Weight of graphite particulate = 3% of total weight of fabric (gsm)</th>
<th>Total weight of the laminate (gsm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caron fibre + E-glass fibre + graphite particulate + Epoxy</td>
<td>2 4 204 816 3 202 606 1422 426.6 42.7 1891</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 6 204 1224 5 202 1010 2234 670 67 2971</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 8 204 1632 7 202 1414 3046 913.8 91.4 4051</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2.2: Thickness calculation for specimen preparation of carbon fibre, E-glass fibre, graphite particulate with epoxy resin.

<table>
<thead>
<tr>
<th>Composition</th>
<th>Required Thickness of lamina (mm)</th>
<th>Thickness of carbon fibre</th>
<th>Thickness of glass fibre</th>
<th>Total thickness of fabric (mm)</th>
<th>Thickness of matrix = 30% of total thickness of fabric (mm)</th>
<th>Thickness of graphite particulate = 3% of total thickness of fabric (mm)</th>
<th>Total thickness of the laminate (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caron fibre + E-glass fibre + graphite particulate + Epoxy</td>
<td>2 4 0.22 0.88 3 0.18 0.54 1.42 0.426 0.0426 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 6 0.22 1.32 5 0.18 0.9 2.22 0.666 0.0670 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 8 0.22 1.76 7 0.18 1.26 3.02 0.906 0.0906 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Volume ratio plays a crucial role. The engineering designer uses the fibre volume ratio to derive the lamina properties and thus after lamination, structural properties. But to achieve the required fibre volume ratio in wet lay-up processes the fabricator requires the fibre (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.

3. EXPERIMENTAL PROCEDURE

3.1 Pre-Fabrication

Before the 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 60°C so that the moisture from resin and fabric (if present) will be removed, then the resin and hardener is mixed together and gently stirred.

3.2 Fabrication

For the fabrication of polymer matrix composite the required fibres (Reinforcement media) and Epoxy resin (Matrix material) are to be collected then by applying releasing agent on the work table mount the releasing layer (Teflon sheet) 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. As the mold is ready it is left to reach the gel time of the resin, as it reaches the gel time, vacuum is applied by covering the mold by vacuum bag, and is left for some time to get set so as the resin should be spread equally on mold and excess of resin can be drawn outside. After the vacuum time it is left as it is at room temperature for 24hrs to cure. Therefore it is also called as Room Temperature Vacuum Bag Molding (RTVBM)[1].

3.3 Post Curing

As the laminate is ready, it has to be subjected to post curing so that all the layers of the lamina bond together. This can be achieved by keeping the lamina in oven and set the oven to increase the temperature gradually to 50°C in 15 minutes from room temperature and hold the temperature for 30 minutes again ramping up to 80°C in next 15 minutes and hold the temperature for 30 minutes again ramp up to 90°C in 15 minutes and hold for 30 minutes then ramp up to 120°C in 30 minutes and hold for 60 minutes then let the oven cool down slowly to room temperature.

4. EXPERIMENTATION

4.1 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 loading in direction of fibre orientation improves the strength drastically. Therefore, to evaluate the strength of composites ASTM standards are followed. According to the ASTM D-3039 for tensile test the following dimensions are used for preparation of specimen.
Fig 4.1.1: Tensile test specimen  
X=2, 3, 4 mm thick

4.2 Universal testing machine

Materials Evaluation Laboratory (MEL) is equipped with closed loop computer controlled servo-hydraulic universal testing machines of 1300 series, Instron make. All the tests were carried out in a closed loop computer controlled servo-hydraulic test machine. Principle of operation involves pumping oil at high pressure through hydraulic power pack, to displace an actuator at a specified rate, through a servo valve.

Fig 4.2.2: Tensile test specimens before and after the test (Carbon fibre - E- Glass fibre – Graphite particulate - Epoxy resin 5052).
4.3 Tensile Test data of hybrid polymer composite laminates of Carbon fibre - E- Glass Fibre – Graphite particulate - Epoxy resin 5052

Table 4.3.1: Tensile test data of Hybrid Polymer Composite laminates of Carbon fibre, E-glass fibre and Graphite particulate with Epoxy 5052 for different thickness.

<table>
<thead>
<tr>
<th>Sample No</th>
<th>Thickness (mm)</th>
<th>Tensile strength (N/mm²)</th>
<th>Yield stress (N/mm²)</th>
<th>Ultimate Load (kN)</th>
<th>% Elongation</th>
<th>Elasticity Modulus (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>456</td>
<td>400.22</td>
<td>26.88</td>
<td>06.68</td>
<td>4494.20</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>431.31</td>
<td>305.00</td>
<td>34.93</td>
<td>13.00</td>
<td>6563.41</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>408.11</td>
<td>365.05</td>
<td>44.28</td>
<td>10.74</td>
<td>4645.15</td>
</tr>
</tbody>
</table>

Sample: 01

Graph 4.3.1(a): Stress v/s Strain relationship of 2 mm thick samples.
Graph 4.3.1(b): Load v/s Displacement relationship of 2 mm thick samples.

Sample: 02

Graph 4.3.2(a): Stress v/s Strain relationship of 3 mm thick samples.
Graph 4.3.2(b): Load v/s Displacement relationship of 3 mm thick samples.
Sample: 03

Graph 4.3.3(a)  
Graph 4.3.3(b)

Graph 4.3.3(a): Stress v/s Strain relationship of 4 mm thick samples  
Graph 4.3.3(b): Load v/s Displacement relationship of 4 mm thick samples

4.4 Compression Test
A fixture is used to align the specimen in the wedge grips and the grips are therefore tightened. The wedges are inserted into the compression fixture, and if an extensometer is being used to measure strain, it is attached to the specimen. The specimen is compressed to failure.

Fig 4.4.1.: Compression Test specimen According to ASTM D 1621

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 strength of the laminates. Compression strength, peak load, breaking load were determined. The table shows the average Compression properties of multiple specimens for each thickness.

4.5 Compression Test data of hybrid polymer composite laminates of Carbon fibre - E-Glass Fibre – Graphite particulate - Epoxy resin 5052:

Table 4.5.1: Compression Test data for different thickness of Carbon fibre - E-Glass fibre - Graphite particulate - Epoxy resin 5052 for different thickness.

<table>
<thead>
<tr>
<th>Sample number</th>
<th>Thickness (mm)</th>
<th>Compressive load (kN)</th>
<th>Compressive strength (N/ mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>2.35</td>
<td>20.08</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>7.80</td>
<td>48.30</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>19.24</td>
<td>91.40</td>
</tr>
</tbody>
</table>
5. 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.

5.1 Characterization of Hybrid FRP Laminates

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

![Fig 5.1.1 SEM images of Carbon fibre – E-Glass – Graphite particulate - Epoxy resin 5052 after conducting tensile test.](image1)

From fig 5.1.1 the microstructure of tensile test specimen shows E glass fibres 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 fibres thus strengthening the composite whereas epoxy resin 5052 bonds the reinforcement and offers resistance to the acting tensile load.

![Fig 5.1.2 SEM images of Carbon fibre – E-Glass fibre – Graphite particulate - Epoxy resin 5052 after conducting compression test.](image2)

From fig. 5.1.2 it is seen that rich mixture of epoxy resin bonding the fibres, and since the concentration of resin is more, thus holding/bonding of the fibres and failure experiences in the extreme conditions, as the thickness increases, it offers resistance more and more to the compression loading.

6. CONCLUSION

From the experimentation and results obtained after testing the following conclusion are drawn.

1. Composite (Carbon fibre + E glass fibre + Graphite particulate with Epoxy resin 5052) delivers the high tensile strength in comparison. As the tensile strength of carbon fibre is high, overall tensile strength of the composite will be high, with which the graphite particulate acts as the fillers which fills the space in between the fabric warps and wefts, in turn 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.

2. As the composites are fabricated by laminar bonding (layer by layer), sections (thickness) of plies affects on strength. It is observed that the strength of the thinner plies is high. As the thickness varies, the strength goes down, this is because of the improper adharance of matrix between the layers of fibre reinforcement, causing inter laminar tension within the composite. As the less thicker plies requires less number of layers of reinforcement, the inter laminar bonding strength will be
high, making the composite to react uniformly against the tension, where as thicker sections requires multiple/ more number of layers, bonding strength will not be uniform across the section leading improper distribution of load among the layers of reinforcement resulting in early failure.

3. The compression strength of the composites increases with the increase in thickness of the ply. Because compressive forces are acting normal to the section hence the loads are uniformly distributed in the section thus the reinforcement material carries the load, hence the compression strength increases with the increase in thickness.

REFERENCES

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