

Experimental Analysis of Carbon/Glass Fiber Reinforced Epoxy Hybrid Composites with Different Carbon/Glass Fiber Ratios

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ABSTRACT: Hybrid composite materials have replaced most of the commonly used composite materials due to its advantages over the other materials, the manufacturer using hybrid composite can obtain required properties by choosing different fibers and matrix according to his need, the properties are combined together in one material by using different fibers in one resin matrix, the prime objective of this paper is to fabricate and analyse the carbon/glass fiber reinforced epoxy hybrid composite with different carbon/fiber proportions, the hybrid composite material is fabricated using vacuum bagging technique, the laminated specimen are tested as per ASTM standards to study various mechanical properties like flexural strength, ultimate tensile load, impact strength,. Thus the paper will assist you to understand the improvement in the mechanical properties as the carbon fiber reinforcement content is increased in the matrix material.

KEYWORDS: Hybrid composite, ASTM, Vacuum bagging, Mechanical properties

I. INTRODUCTION

Modern day engineers are focusing their work on improving the material strength without increasing its weight, composite material which has a huge advantage over other materials like low weight 25% weight of steel, 30% lighter than aluminum, strength, less heat and electrical conductivity, resistance to wide range of chemical agents. Further experiments or conducted in composite sector for improving its strength to new height, one of the advanced material system is called hybrid composite which shows great diversity of material properties. The combination of different fibers into a single matrix has led to the discovery of hybrid composites, the properties of the hybrid composite is a total of individual components in which there is a more favourable balance between the inherent advantages and disadvantages. When a hybrid composite contains two or more type of fiber, the advantages of one fiber would compliment with other fiber which lack this advantage. The properties of the hybrid composite depends on the fiber content, fiber length, orientation, fiber to matrix bonding and arrangement of all the fibers, the strength of the hybrid composite depends on the failure strain of individual fiber used in the hybrid (John, MJ, Anandjiwala 2009). In hybrid composite the hybrid effect and failure strain enhancement of up to 50% for the glass fiber/carbon fiber/epoxy composite, as the failure strain increases as the relative proportion of carbon fiber in decreased as well as the carbon fiber were dispersed throughout the material equally (manders and bader 1981) . adding a new layer of glass fiber into a matrix thus produces a composite material with great physical and mechanical properties which cannot be obtained for normal alloys (Schwartz 1984). The properties of the reinforcement depends on the bonding between the matrix and fiber it plays a major role in determining the mechanical properties of the hybrid materials (Yosoyima et al 1984, 1990 and pukzky et al 1995). thus this study focuses on the impact on the mechanical properties of the carbon/glass fiber reinforced hybrid composite due to different carbon/glass fiber proportions. Vacuum bag technique is carried out for fabricating three laminates. Mechanical properties like flexural strength, ultimate tensile strength and impact strength were studies by testing experimentally as per ASTM standards.

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II. RELATED WORK

Different authors have researched on Hybrid Composites with various combinations and ratios of fibers in different resin reinforcements. They are as follows.

Nilgun becenen (1989) in this study, two different types of resin as matrix and glass fibers in form of scrap, woven and felt as supplementary material were used in manufacturing plastic matrix composite material supplemented with fiber being used in tractor hood manufacturing. Fiber type and ratio was kept constant in the resulted samples and their situations were examined after they hardened at room temperature. The materials hardened at room temperature and one group was not cured and the other was exposed to post-curing process and they were tested. The result indicates that the Glass fiber addition increased thermal strength of the epoxy material and it increases as the fiber ratio increases.

Ashori (2014) in this study we can understand that the mechanical properties of the carbon fiber reinforced epoxy resin composites changes upon the effects of fiber orientation, resin types, number of laminates. They have proven that the composite made with EM500 epoxy resin showed the highest mechanical properties. The result indicate that the mechanical properties of the component made with five-ply were generally slightly greater than three-ply composite it can be concluded that the order of increment parameters in the mechanical properties of the composites is fiber orientation > number of laminates > resin type. At a similar fiber orientation, the composites made with EM500 epoxy resin showed the highest mechanical properties. Mechanical properties of the component made with five-ply were generally slightly greater than three-ply composite

T D Jagannatha (2015) in this study the inclusion of carbon fiber mat reinforcement composite significantly enhanced the ultimate tensile strength, yield strength and peak load of the composite. the micro hardness and ductility of the hybrid composite were also found by doing experiments like tensile test and hardness test as per ASTM standard.

sS.y.fu, B.Lauke, E.Mader (2000) in this study the tensile properties of injection melded composites reinforced with SGF and SCF have been investigated and the result indicate that the mean glass and carbon fiber lengths decrease with increasing fiber volume fractions and the combined effect of fiber volume fraction and fiber length determines the final tensile properties of the composites.

III. EXPERIMENTAL DETAILS

Material selection

Carbon fiber and E-glass fiber were selected as reinforcement and epoxy and matrix material

Reinforcement : Uni-directional carbon fiber 330 GSM
Bi-directional glass fiber 600 GSM

Matrix : Epoxy resin - Araldit LY 556
Hardener - Araldit HY 951

Fabrication of composites

Three different laminates with different carbon/glass fiber proportions are fabricated using vacuum bag technique.

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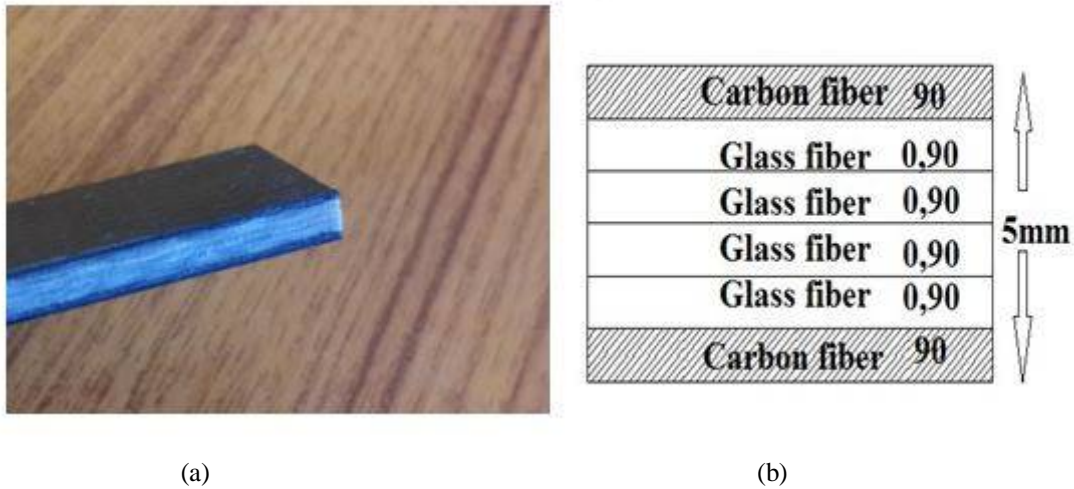


Fig 1. (a) Laminated hybrid composite plate 1 (b) Sketch showing the orientation of Laminated hybrid composite plate 1

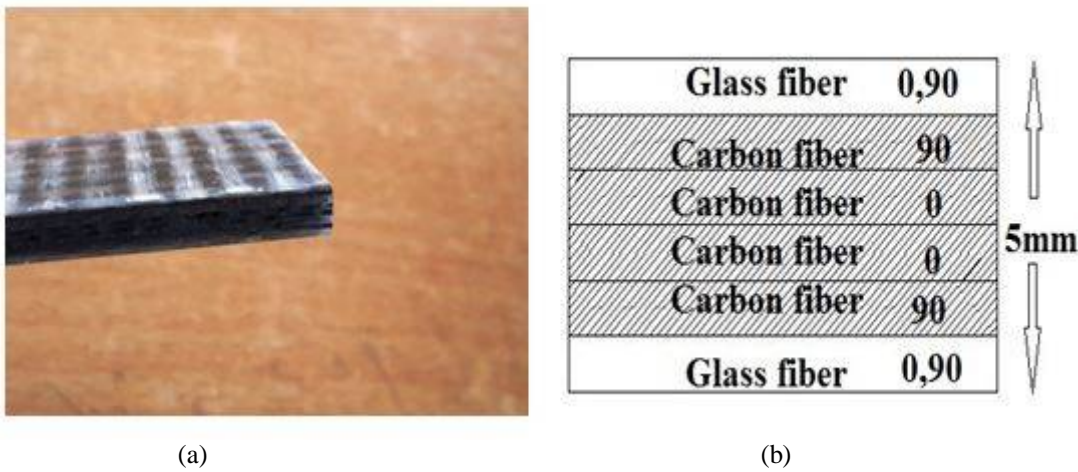


Fig 2. (a) Laminated hybrid composite plate 2 (b) Sketch showing the ply orientation in Laminated hybrid composite plate 2

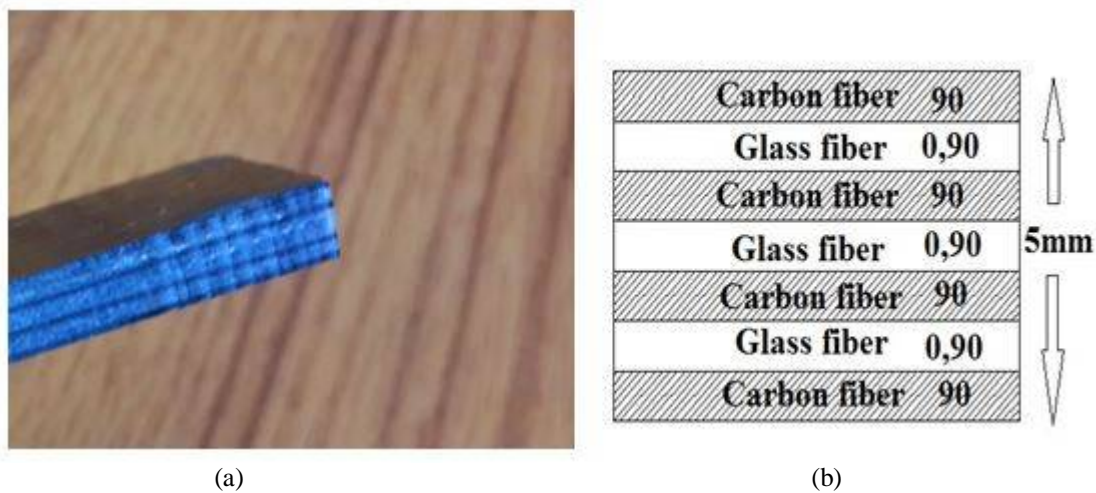


Fig 3. (a) Laminated hybrid composite plate 3 (b) Sketch showing the ply orientation in Laminated hybrid composite plate 3

Density, specific gravity and mass are the key factors for calculating the weight fraction of fibers and matrix. At first the fabrication of laminates or done by hand layup technique at room temperature. Required layers of fibers were taken and weighed with a dimension of 300x300 mm. equal amount of epoxy resin is taken in a beaker, at a ratio of 100:45 hardener is added to the resin and stirred well. The fibers were positioned in the open mold and the mixture made of resin and hardener is brushed uniformly over the glass and carbon plies alternatively. The mold surface must be cleaned with acetone so that it does not bond with the laminate. The excess amount of mixture and trapped air is removed by roller to complete the laminate structure. Then vacuum bagging technique is carried out on the laminate to uniformly distribute the resin and also to remove any trapped air. The composite is cured at room temperature for more than one day.

Specimen preparation

The laminates are removed from the mold and the specimens of suitable dimension were cut from the laminates according to the ASTM standards. The specimen from the laminates were cut using water jet cutting. Test specimens were cut from the laminates according to the ASTM standard for the required mechanical testing. Two identical specimens were prepared for each test.



Fig 4. Laminated plate subjected to water jet cutting

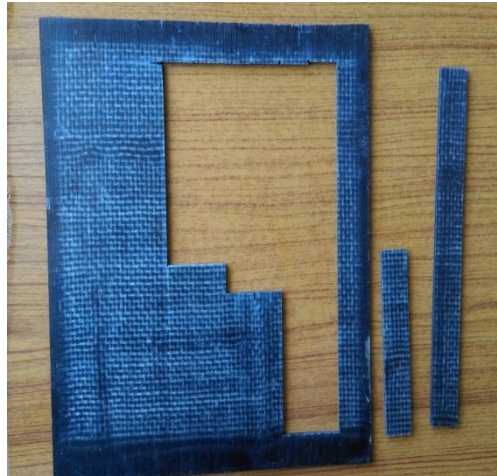


Fig 5. Specimen cut from the laminated plate

Testing of created specimens

Mechanical properties like flexural strength, ultimate tensile strength and impact strength will be evaluated by mechanical testing's like three point bending test, tensile test and charpy impact test. The created specimens were prepared for the testing by smoothening the edges using file and emery sheet.

Tensile test



(a)



(b)

Fig 6. (a) Tensile test UTM setup (b) Specimen subjected to tensile test

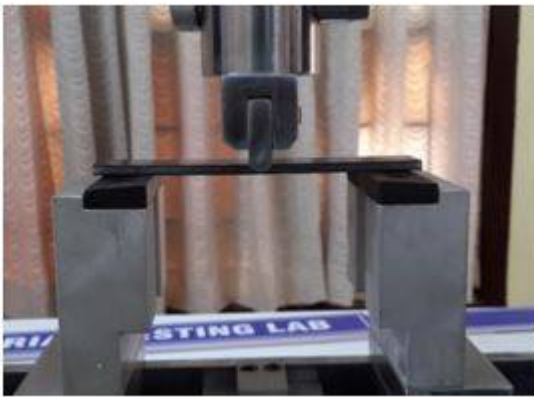
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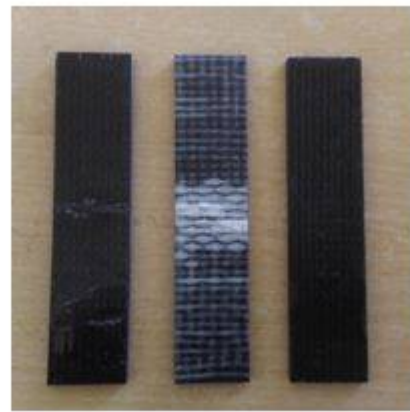
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ASTM D3039 is followed for tensile test. The specimen was fixed between two adjustable grips of 50KN computerized Universal Testing Machine (UTM) at room temperature and load was applied till it fractures. The elongation and maximum load is noted during the experiment. Test is repeated for all the specimens and the values are noted to calculate tensile strength.

3 point bending test



(a)



(b)

Fig 7. (a) 3 point bending test on a specimen (b) Specimen subjected to 3 point bending test

ASTM D790 is followed for the three point bending test. The test is performed to measure the flexural strength of the material, the test is performed in a universal testing machine with a three point fixture. The specimen is placed on a two point support and the stress is applied on the specimen by the third point at the middle of the specimen till it fractures.

Charpy impact test



(a)



(b)

Fig 8.(a) Charpy impact test (b) Specimen subjected to Charpy impact test

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ASTM E23- 12c is followed for Charpy impact test. The test is performed by fixing the specimen at the both ends and the striker impacts the specimen. This test is done to know the energy absorbed by the specimen prior to fracture. All the test or done in Hindustan university and Micro lab Ambattur industrial estate Chennai-58.

IV. RESULT AND DISCUSSION

Tensile strength

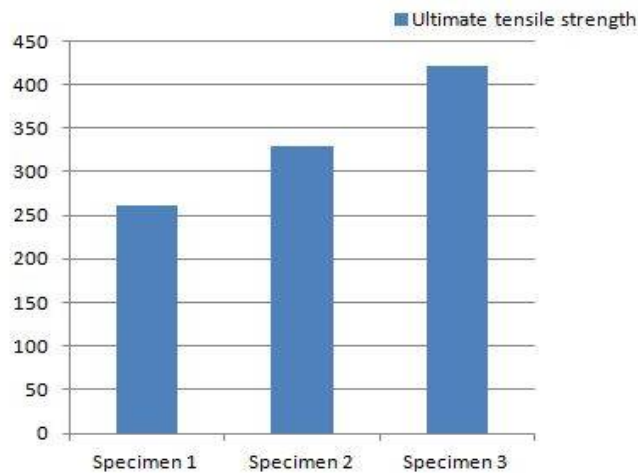


Fig 9. Chart showing the increase in UTS (Mpa or N/mm²) in the laminates due to different carbon/glass fiber proportion.

The above chart shows the effect of reinforcements on UTS of the Fibers reinforced composites as u can clearly see the increase in the ultimate tensile strength in three different specimens this proves that the strength of the material increases as the carbon content in the material increases

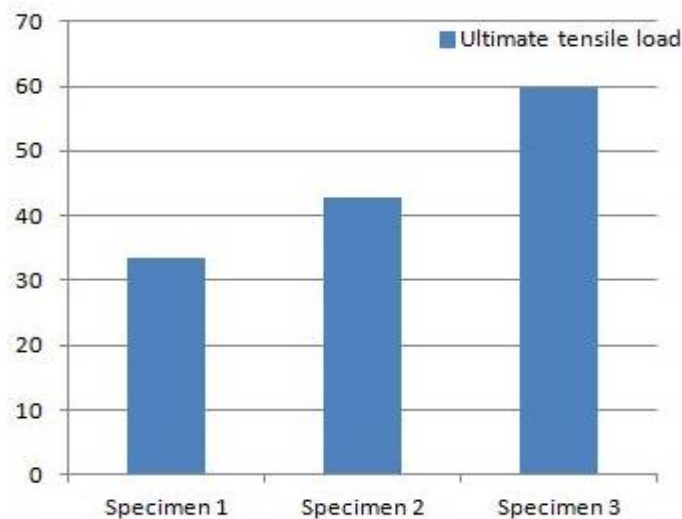


Fig 10. Chart indicates the increase in the UTL of the specimens

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Above chart indicates the increase in the ultimate tensile load of the specimen 1, 2, 3 from the laminates 1, 2, 3 due to the increase in the carbon content in the laminates

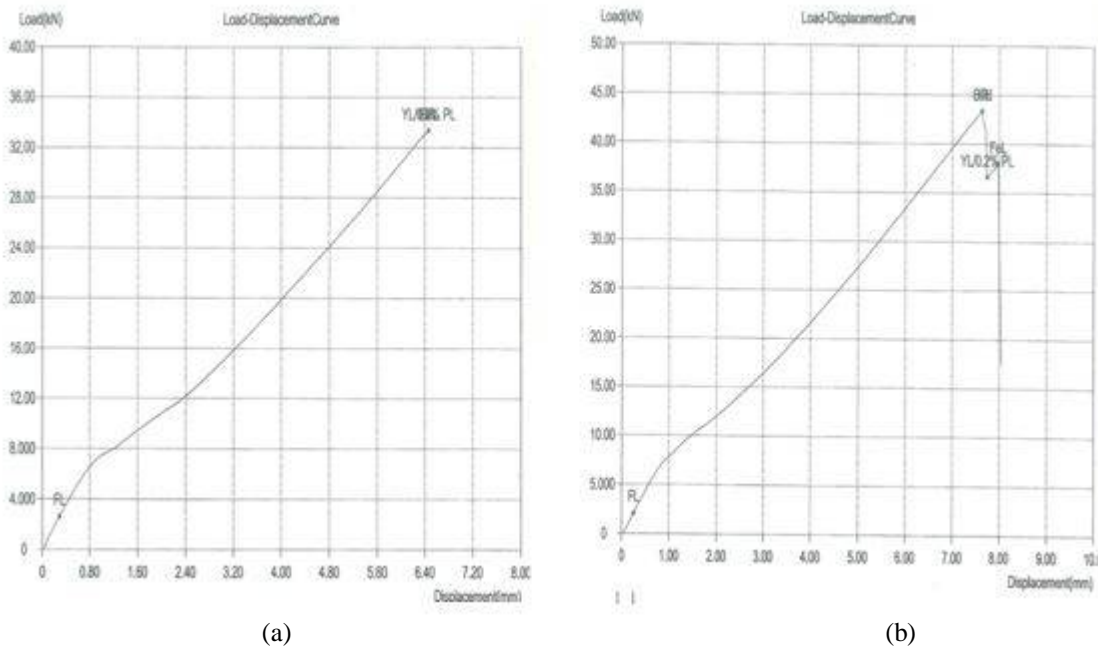


Fig 11. (a) Load-Displacement graph for specimen 1 from laminate 1 (b) Load- Displacement curve graph for specimen 2 from laminate 2

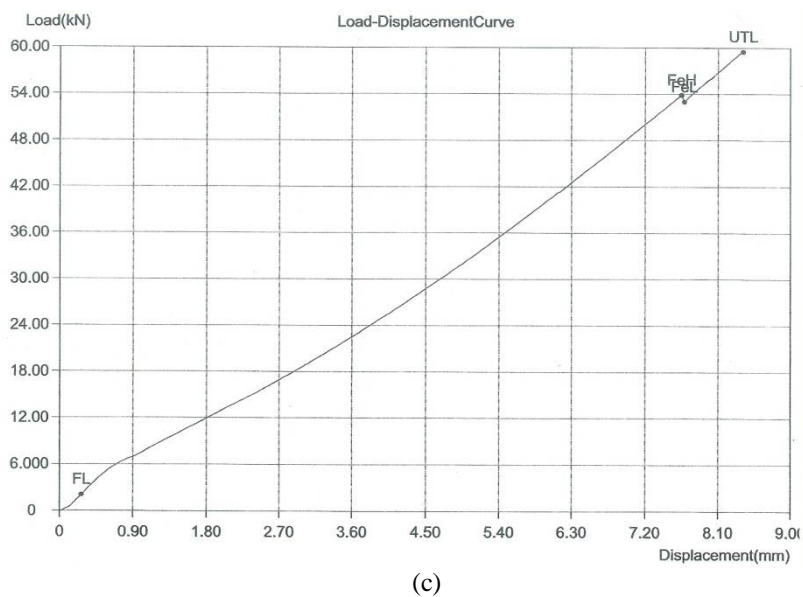


Fig 12 (c) Load-Displacement curve graph for specimen 3 from laminate 3

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Table 1. Tensile Test Result

| Specimen | Ultimate Tensile Strength (Mpa or N/mm) | Ultimate Tensile Load |
|--------------------------|--|-----------------------|
| Specimen from laminate 1 | 261 | 33.35 |
| Specimen from laminate 2 | 330 | 42.8 |
| Specimen from laminate 3 | 421 | 59.78 |

The above table (1) shows the result obtained in tensile test as we can see the increase in tensile strength and ultimate tensile load from laminate 1 to 3 due to increase in carbon fiber content in the laminates

3 point bending test:

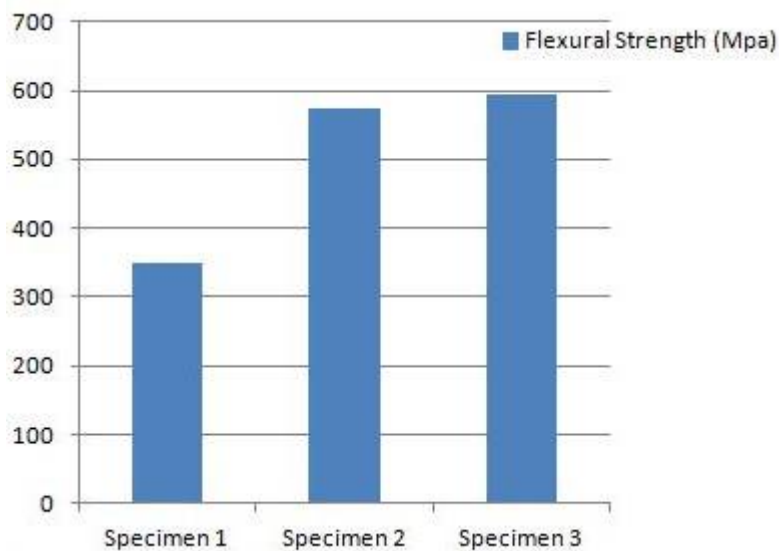


Fig 12. Chart indicating the increase in the Flexural strength of the specimens

The above chart shows the effect of reinforcements on UTS of the Fibers reinforced composites as the ratio of the carbon fiber increases the Flexural strength of the laminates also increases. The flexural strength of the material is calculated using the formula

$$\text{Flexural strength} = 3FL / 2bt^2$$

F = Load (N)

L = Span distance (80mm)

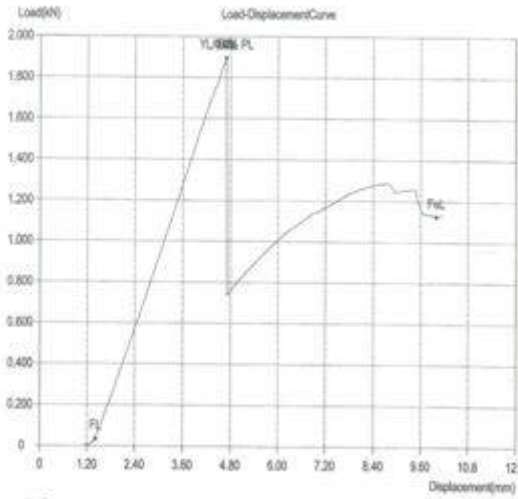
b = Width

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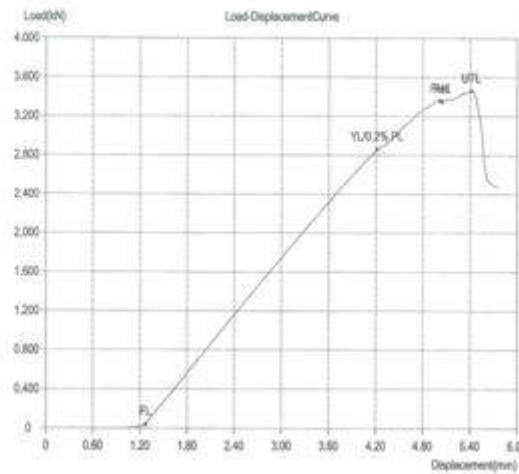
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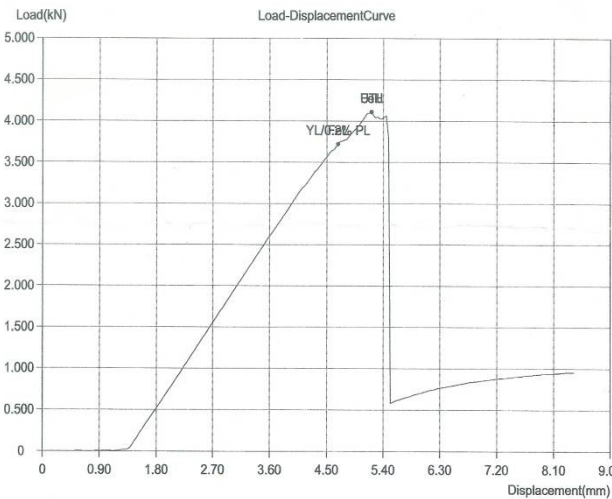
t = Thickness



(a)



(b)



(c)

Fig 13. (a) Load- displacement curve graph for sample 1 from laminate 1 (b) Load- Displacement curve graph for sample 2 from laminate 2 (c) Load-Displacement curve graph for specimen 3 from laminate 3

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Table 2. 3 Point Bending Test Results

| Specimen | Flexural Load(kN) | Deflection At Peak (mm ²) | Flexural Strength (Mpa) |
|----------------------------|-------------------|---------------------------------------|-------------------------|
| Specimen 1 from Laminate 1 | 1.90 | 4.713 | 348.54 |
| Specimen 2 from Laminate 2 | 3.46 | 5.542 | 574.30 |
| Specimen 3 from Laminate 3 | 4.11 | 6.810 | 593.14 |

The above table (2) shows the result obtained from 3 point bending test as we can see the increase in the Flexural load, deflection at peak and the flexural strength of the specimens from laminate 1 to 3 due to the increase in the carbon fiber ratio

Charpy impact test:

Charpy impact testing involves striking a standard specimen with controlled weight pendulum swung from a particular height. The specimen is fixed in a anvil and struck by the pendulum. The amount of energy absorbed in fracturing the test piece is measured.

Table 3. Charpy Impact Test Results

| | Specimen from Laminate 1 | | Average |
|---------------------------|--------------------------|--------------|---------|
| | Specimen 1.1 | Specimen 1.2 | |
| Absorbed Energy (joules) | 10 | 10 | 10 |
| | Specimen from Laminate 2 | | |
| | Specimen 2.1 | Specimen 2.2 | |
| Absorbed Energy (joules) | 10 | 12 | 11 |
| | Specimen from Laminate 3 | | |
| | Specimen 3.1 | Specimen 3.2 | |
| Absorbed Energy (joules) | 12 | 12 | 12 |

The above table (3) shows the result obtained from the impact test indicating the increase in the absorbed energy of the specimen from laminates 1 to 3 due to increase in carbon fiber ratio in the laminates

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V. CONCLUSION

The carbon/glass fiber reinforced hybrid composite have been fabricated and tested experimentally to find the mechanical properties like tensile strength, Flexural strength and impact strength as per the ASTM standards. The results are plotted and evaluated to understand the improvement in the mechanical properties due to the changes made in the carbon/ glass fiber ratio in three different laminates. As you can see the tensile strength, flexural strength and the impact strength increases as the ratio of the carbon fiber reinforcement is increased in the matrix. The strength of the laminate also depends on the bonding between the fibers and matrix, individual properties of the fibers, presence of voids, adopting ideal fabricating process etc.

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