Experimental Investigation of Glass Fibre Reinforced Metal mesh - PCB Hybrid Composite

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Abstract This study investigated the mechanical properties of fibre reinforced Printed circuit board using epoxy resin. The macroscopic interfacing of recognizable size with combination of more than unity of distinct materials which makes the composites utilized for their basic properties, In addition to the basic properties these composite structures are best used for their upgraded electrical, thermal and environmental properties. Present day composite materials are generally upgraded to improve the necessary properties of diverse applications. So, composite materials is a combination of different materials that binds together in the form continuous matrix constituent which makes it stringer and stiffer. Thus the composite material obtained is having superior properties than the single constituent. The load is shared between the different materials of the composite. The properties of the composite are optimized for their functional properties. It could be created from various blends of constituent that fits the necessary basic application. The composites created for auxiliary applications are further enhanced by materials which increase the required properties. Glass fibers are produced from blending of quarry products at 1600 C (Gl) fibre filaments diameter are ranging from 5-24μm. The idea of hybrid frameworks is utilized for its notable basic properties in engineering design. It is the motivation for reusing the E- waste in hybrid composite materials. Studies on E- waste reusing protects the environment .In this study PCB is the material uses along with woven glass fibre is fabricated and tested for its mechanical properties.

Keywords: Glass fibre, Reinforced metal, PCB, Composite

I. Introduction

The composite material is a combination of two and more chemically different with a distinct interface between them. [1] Fibers exhibit a greater tensile property along its axis like a fibre in a rope. When resin are reinforcing with fibers such as glass, carbon and aramid some
exceptional and desired properties are obtained. The fibers of the composite are safe guarded from impact load and from environmental degradation. The applied load was shared between the individual strand of the composite by the resin matrix. Thermoplastic composites with PEEK and polycarbonate (PC) matrices are finding use as spring elements for car suspension systems [2]. The strength to weight ratio, improved stiffness, easy of moulding complex shapes and high resistance to environment makes the composite superior than metal for many industrial and commercial applications. Composites play a vital role in aerospace, land transportation and consumer goods due to their high specific strength and stiffness leading to reduction in the mass of moving objects. An investigation was conducted by Isaac M Daniel et.al [3] on failure modes and criteria for their occurrence in composite columns and beams. They found that the initiation of the various failure modes depends on the material properties, geometric dimensions and type of loading. Banerji and Nirmal [4] reported an increase in flexural strength of unidirectional carbon Fibre/ Poly (methyl methacrylate), composite laminates having polyethylene Fibers plies at the lower face. The exceptional property of low density makes the composite as a selectable material for engineers for various applications. Li and Xian [5] showed that the incorporation of a moderate amount of carbon Fibers into ultra-high-modulus polyethylene (UHMPE) Fibers reinforced composites greatly improved the compressive strength, flexural modulus while the addition of a small amount of UHMPE fibers into a carbon Fibre reinforced composite remarkably enhanced the ductility with only a small decrease in compressive strength. The large family of epoxy resins available at present, Epoxies are generally better than other resins in terms of mechanical properties and resistance to environment, so it is most commonly used in the manufacture of aircraft components. Epoxy having a better adhesive property used as a laminating resin having a greater resistance to degradation when it is exposed to water for longer period which make these resins to be selected in higher number than other materials for boat body building. Hence water-degraded polyester resins are replaced with Epoxy resins [6-7]. Composites based upon thermoplastic polymeric matrices potentially offer several advantages compared with those based upon thermosetting Resins. The mechanical composites was investigated and the failure modes were examined. The flexural strength and modulus of hybrid composites were measured in order to investigate the effect of stacking sequence [8-10]. The main aim of this work is to perform an experimental study on a low velocity impact behavior on PCB - glass fiber hybrid composite. The specific objective is to fabricate plain and printed circuit board (PCB) E-waste and multilayered glass fiber reinforced hybrid composite laminates. To investigate the mechanical properties by test in UTM machine and to study the low energy impact behavior by conducting drop weight test with various energy levels of impact.

2. Material Selection

In this project the following materials are selected for making the laminates,
For Reinforcement: Glass Fibre Reinforced with plastic is used. Figure 1 shows the different types of glass fibers used in metal matrix composite. It is made of (Bi – Directional type)
Epoxy glass
(i) Matrix: Epoxy type matrix
(ii) Resin: Epoxy resin - LY556
(iii) Hardner:code - HY951
(iv) PCB E- waste
2.1 Resin
In general the flexural strength of the laminate composite beam can be improved considerably by the addition of fibers with a certain volume fraction of each layer. [8] Strands of fibre alone can just display malleable properties along the fiber's length, similarly as filaments in a rope. It is the point at which the resin frameworks are joined with fortifying strands, for example, glass, carbon and aramid exhibit extraordinary properties as individual materials. The resin matrix spreads the load applied to the composite between every one of the individual filaments and further more shields the strands from the degradation caused by the environment. High qualities and stiffness's, easy of manufacturing complex shapes, high resistance to degradation all combined with low densities, make the resultant composite better than metals for some applications.

2.2 Epoxy Resins
The enormous groups of epoxy resins are available; some of them represent the highest performance of them. Epoxies commonly out-perform most other resin types as far as mechanical properties and protection from natural scraping of material, which prompts their practically restrictive use in air ship segments. As an overlaying pitch their expanded glue properties and protection from water degradation make these resin perfect for use in applications, for example, vessel building. Here epoxies are broadly utilized as an essential development material for many industrial applications. Epoxy resin of LY556 is selected according to its bonding strength, curing time and cost of production a hybrid structure.

3. Hybrid Composites
Composite containing two or more types of fibre of apparent improvement of properties is the effect of hybrid. Unidirectional high carbon steel wires to improve the impact properties of epoxy resin reinforced with unidirectional carbon Fibre reinforced [7]. The selection of the components of composite is based on the types of hybridization, construction requirement and property enhancement. The selection of material for a hybrid composite is the tedious task as it must meet the requirement. The chemical, mechanical and physical stability of the fibre / matrix system are the prime importance of selection of composite constituents. There are a few sorts of hybrid composites delegated. Figure: 2 shows the Schematic view of hybrid Composite.
3.1 Interchange composite
Interchange composite or two by-tow, in which the at least two constituent kinds of fiber are blended in a standard or arbitrary way.

3.2 Sandwich Composite
Sandwich mixtures, otherwise called center shell composite, which contains one material is sandwiched between two layers of another.

3.3 Interplay
Interplay or laminated composite which contains one layer being laminated on the other in a fashioned manner to form as a stack of material.

3.4 Blended Hybrid
Intimately blended hybrid, where the constituent filaments are made to blend in a non-fashionable manner so that the fibers are mixed randomly with uneven distribution. For example, those strengthened with ribs, pultruded wires, slim cloak of fiber or mixes of the above mentioned or combinations of the above.

Figure 2 Schematic view of Hybrid Composite

4. Printed Circuit Board (PCB)
The main function of a printed circuit board (PCB) is to support electric and electronic components supports mechanically using conductive tracks and pads. The features are etched from one or more copper sheets in the form of layer are laminated. The stack of layers is the base of PCB having non-conductive substrate. Components are electrically connected and mechanically fastened in the PCB. Multiple copper layers of copper plates along with a hardener resin forms a printed circuit board. A two-layer PCB has copper layer on both sides; multi-layer boards of sandwich type are having additional layers of copper between the insulating materials. Conductors are connected on different layers. Holes on the copper plates acts as electrical tunnels through the insulating substrate. Through-hole system of component placing on PCB is also efficient. The worn out PCB is made plain by removing the attachments. The waste PCB board is used to support the steel mesh thereby strengthen the hybrid laminate.
5. Fabrication

One of major problems in achieving this reliability is the occurrence of voids in the final part [8]. The laminate is fabricated by professional hand laying technique. Before starting the fabrication process the glass fibre is cut in specific dimensions as per ASTM standards. The standards provide dimensions as 30cm x 30cm. For cross piled woven fibre were cut in a required angle of either 0°, 30° or 90°. Similarly the thermosetting plastic, epoxy and hardener were mixed in a ratio of 10:1. Setup was made to ensure that each layer has the same ratio of mixing and the same volume ratio of the reinforcement and epoxy resin is used. Now the epoxy mixture with hardener was applied over a glass sheet before placing the first layer of glass fibre. The glass fibre was evenly placed parallel to that of the applied epoxy and it was made to wet with the applied epoxy. A hand rolling roller was rolled over the glass fibre to eject out the air bubbles and to guarantee contact between the epoxy and the glass fibre. On affirming the pores and air bubbles were discharged from each layer. The second layer was placed and applied with epoxy and the procedure is repeated. After completion of layers the epoxy is applied and glass sheet is placed on top to close the Epoxy resin. Now the pores and air bubbles located are removed by carefully uniform movement of a plane scale over the glass sheet. After removing the pores and air bubbles, an appropriate compression pressure is applied laminate for curing and setting of the thermosetting plastic resin. After curing the laminate for 24hrs the glass sheet is peeled out and the corners with Epoxy over flow are removed. Two samples are made and tested. Figure: 3 shows the specimen is being prepared and Figure: 4 is the specimen after curing. Two samples are made with Sample (i) is made with 2 layers of Fibre glass with a metal mesh cured with Epoxy resin. Sample (ii) is made with PCB is having 2 layers of glass fibre with metal mesh on either side cured with Epoxy resin. Table 1 shows the dimension and mass of the composite plain laminate. The mass of the hybrid composite is greater than the plain laminate because of the addition of PCB board Table 2 shows the mass and weight of Hybrid composite.
Table: 1 Dimension and mass of plain laminate

|   | Description                                      | Value    |
|---|-------------------------------------------------|----------|
| 1 | Thickness of the laminate                       | 5.0mm    |
| 2 | Size of the laminate                             | 300X300 mm |
| 3 | Weight of the single layer 300 X 300 mm glass Fibre | 36 g     |
| 4 | Weight of single layer 30 x 30 mm SS mesh        | 64 g     |
| 5 | Amount of epoxy used                             | 500 g    |
| 6 | Amount of hardner used                           | 50 g     |
| 7 | Weight of the laminate                           | 1.67 kg  |
| 8 | Density of composite material (ρ)                | 2.11 g/cc |

Table: 2 Dimension and Mass of Hybrid Laminate

|   | Description                                      | Value    |
|---|-------------------------------------------------|----------|
| 1 | Thickness of the laminate                       | 4.5mm    |
| 2 | Size of the laminate                             | 300X300 mm |
| 3 | Thickness of Wire mesh                          | 0.8 mm   |
| 4 | Weight of the single layer 300 X 300 mm glass Fibre | 36 g     |
| 5 | Weight of single layer 30 x 30 mm SS mesh        | 64 g     |
| 6 | No.of glass fibre layers                         | 4        |
| 7 | Weight of PCB                                   | 72 g     |
| 8 | Amount of epoxy used                             | 500 g    |
| 9 | Amount of hardner used                           | 50 g     |
| 10| Weight of the laminate                          | 1.244 kg |
| 11| Density of composite material (ρ)                | 2.17 g/cc |

6. Testing Of Specimen

The samples are tested for its Structural strength by finding its impact strength. To calculate the structural strength the plain and hybrid laminate are cut precisely without any flaws or with sharp corners. The plain hybrid specimen is first fixed in the vice and load is released by releasing the lever of Impact load calculation machine. The amount of structural strength of the plain laminate is observed as calculated. The same procedure is used to calculate the structural strength of hybrid laminate. Figure 5 shows the testing setup of Impact load using charpy Impact load setup. To find the tensile strength of specimen, the plain and hybrid are tested in Universal testing machine. The specimen is prepared by cut into the dimension as per the standard and then it is fixed in between the top and bottom plate. The specimen is tightly locked by the rotating lock handle. Load is applied by moving apart the top and base plate. The corresponding stress is noted as per the applied load. The tensile stress of both plain and hybrid composite is observed. Figure 6 shows the testing of specimen in UTM to find its tensile strength. The hardness of the specimen is tested in Rockwell hardness
machine. The specimen of plain laminate is fixed rigidly and load is applied by releasing the handle. Hard steel truncated cone intender is used as the composite structure is hard in nature because of the cured resin. The same procedure is followed to test the hardness of hybrid laminate. The properties of structural strength, tensile strength and hardness number are tested as its plays a vital role in the selection of composite structure for various Industrial applications. Table 3 shows the test results of plain and Hybrid composites for its Impact strength, Tensile stress and hardness number. It was observed that after the initial damage takes place, the response of the lamina was described and observed to be brittle or degrading modes with the collapse of the entire laminate.[10]

![Figure 5 Impact testing set up](image1)

![Figure 6 Universal testing setup](image2)

**Table 3** Test result of Plain and Hybrid composite

| Samples  | Impact strength N/mm² | Tensile stress N/mm² | Hardness Number |
|----------|-----------------------|----------------------|-----------------|
| Sample (i) | 0.20 N/mm²        | 3.77 N/mm²        | 28.95           |
| Sample (ii) | 0.48 N/mm²               | 3.91 N/mm²               | 32.84           |

7. Result and discussion

From the Figure 7 it is observed that the sample (i) composite structure without PCB is having low impact strength than the sample (ii) composite with PCB which makes the hybrid composite to withstand more impact load than the plain composite. This is because of an additional PCB structure in the hybrid composite which can withstand the impact load and not allowing the structure to break easily. The hardened resin and the thin copper wires
embedded in the E waste act as a structural strengthening member to safeguard the structure from failure. From the Figure 8, it's clear that the tensile strength of sample (ii) is more than the plain composite. It is observed that the tensile property of hybrid is increased by adding the PCB board along with the metal matrix composite as it acts as a reinforcement member. Figure 9 show that the hardness number of sample is more than the plain composite. The Hardness number is a deciding factor while selecting a member for Boat hull, Automobile body structure and for other structural members. Most widely used sort of FRP may be a stratified structure, created by stacking and bonding skinny layers of fiber and compound till desired thickness is obtained. By variable fiber orientation among layers, a such as level of desired properties may be achieved within the laminate. Fibre orientation type of laminate and epoxy resin plays a vital role in the life and properties of composite structures. Apart from the structural properties, the samples with various layers and orientation has to be tested for degradation, wear, stiffness which makes these hybrid composite laminates to be used in such as aircraft wing and fuselage sections, automobile and truck body panels, and boat hulls.

![Figure 7 Impact strength of Hybrid composite](image1)

![Figure 8 Tensile stress of hybrid composite](image2)

![Figure 9 Hardness number of Hybrid composite](image3)
8. Conclusion

This paper reported the development of hybrid composite structure with E- waste and to compare the mechanical properties of composite with metal mesh as a plain laminate and the hybrid composite with E- waste. The PCB strengthens the composite structure in terms of strength and rigidity. Further the recycling of E waste is a challenging task which can be considerably reduced by utilizing the waste to build a hybrid composite structure. From the figures it is cleared that the Hybrid laminate is best in all mechanical properties than the plain laminate. An Additional cost is for manufacturing a hybrid structure is avoided as the waste is freely available in abundant quantity. As the PCB is a hardened cured resin of hard structure, it acts as a strengthening rib which avoids the steel mesh to be rolled before curing. The increase in the mass of the laminate by using a PCB board is also an important factor to be considered especially aircraft fuselage structure as it increases the weight of the structure. But comparing the weight to strength ratio the hybrid composite owns to be an alternate member.

9. Reference

[1] Mallick P.K., Composite Engineering Handbook 1997 Marcel Dekker Inc., NY, USA.
[2] Gill, R.M 1973 Carbon Fibers in Composite Materials, Page Bros (Norwich)Ltd, England.
[3] Isaac M. Daniel, Emmanuel E. Gdoutos, Deformation and Failure of Composite Structures, Journal of Thermoplastic Composite Materials 2003; 16 345.
[4] NirmalSaha, Amar Nath Banerjee, 1996, “Flexural behavior of unidirectional polyethylene-carbon fibers-PMMA hybrid composite laminates,” J. App. Poly Sci. vol.60, pp. 139-142.
[5] Y.Li, K.J.Xian, C.L. Choy, MeiGuo, Zuoguang Zhang 1999 Compressive and flexural behavior of ultra-high-modulus polyethylene fiber and carbon fiber hybrid composites,” Comp. Sci. & Tech., vol.59, pp. 13-18.
[6] Robert Matteson and Roger Crane 2003 Flexural testing of steel wire composite beams made with Hardwire unidirectional tape, NASA Technical Report
[7] P.D.Bradley, S.J. Harris, 1977, Strategic reinforcement of hybrid carbon fibers reinforced polymer composites, J. Mater. Sci., pp. 2401-2410.
[8] Dr. Jawad Kadhim Uleiwi, 2007, Experimental Study of Flexural Strength of Laminate Composite Material, Eng. & Technology, Vol.25, Suppl. of No.3, pp 454-466.
[9] Wen-Pin Lin, Hsuan-Teh Hu, 2002, Parametric Study on the Failure of Fiber- Reinforced Composite Laminates under Biaxial Tensile Load, Journal of composite materials, Vol. 36, No. 12/2002, pp 1481-1503.
[10] Rohchoon Park, Jyongisk Jang; 1997 Stacking Sequence effect of aramid-UHMPE hybrid composites by flexural test method, Polymer Testing, vol. 16, pp. 549-562