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Experimental Study on Fabrication and Comparison of Mechanical Properties of Plain Weave Copper Mesh Embedded Hybrid Composite with E-Glass Fiber Reinforced Epoxy GFRP Composite

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Abstract—This paper presents the experimental study on GFRP (Glass-Fiber Reinforced Plastic) composite which is fiberglass reinforced with epoxy matrix and find its mechanical properties that can be compared with other hybrid composite which include plain weave copper strips mesh in between the layers of fiberglass in GFRP composite. The main objective is to find out whether the copper metal mesh bonds with epoxy or not and also finding any improvements in Mechanical & Physical Properties. Both type of composites are made using hand layup technique i.e., placing of chopped fiberglass sheet and then epoxy resin layer by layer, after filling of epoxy and fiberglass at 20% fiber loading which is measured by digital scale, then a pressure is also applied on this sandwich. After 24 hours it is ready to be demolded and after 48 hrs. samples was cuts as per ASTM standards then testing was done on both GFRP and Hybrid composites to find their Mechanical & Physical Properties. Results shows improvement as we introduce plain weave copper strips mesh in between the GFRP laminate to make it hybrid.

Keywords: E-Glass Fiber, Plain weave copper strips mesh, Epoxy Resin, Mechanical Properties, Composites, GFRP.

1. Introduction

Polymeric building materials are applied in different applications such as automotive, sports equipment, marine, electrical, industrial, construction, building, home items, etc. [1] among many others. A composite laminate is made out of a precise mixture of fiber and matrix. Unique features of composite are that it has some high strength. In weight-bearing constructions, such as aerospace structures, high-speed boats, and trains, the compound is employed as an alternative to metal items. E-Glass Fiber is a composite material that consists of glass fibers in an epoxy matrix. The glass fibers as purchased are a standard 450 GSM chopped standard mat. There are several types of epoxy available. The characteristics of fiberglass materials depend on the volume of the two materials and the properties of the fiber-glass material and each component of epoxy. Orientation of Fibers also influenced the final strength of composites [2].

In this study, the manufacturing and behavioral processes of fiberglass-reinforced composites are forced by a unique parameter such as addition of plain weave copper strips mesh strips. GFRP (Glass-Fiber Reinforced Plastics) composite represents E-Glass Fiber reinforced with epoxy resin LY556 at 20% fiber loading, and Hybrid composite represents E-Glass fiber reinforced with epoxy resin LY556 which also inclusion of plain weave copper strips mesh at 20% fiber loading.

2. Material and Method

2.1 Research Objectives

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The main objectives of the current composite study are:

• To fabricate a hybrid composite that includes plain weave copper strips mesh embedded in between the layers of fiberglass in a GFRP composite.

• To analyze mechanical as well as physical properties of hybrid composite and compare with GFRP composite.

2.2 Excremental Detail

Materials used in this research:

E-Glass Fiber (CSM 450 GSM)

Epoxy Resin Araldite LY556

Hardener Aradur HY951

Flat Copper Sheet 35 Gauge (0.213 mm thickness)

Composite is prepared by hand lay-up [3] technique. Preparation of composite the whole process is in various steps which are as follows: Firstly, the surface of the mould is cleaned with Acetone, which removes any dirt which is present on the surface of mould. Then a thin coat of Wax is applied and leave it for 30 minutes, wax is also used while we use PVA (Poly Vinyl Alcohol) which is water soluble [4] as a release agent this is because for continuous use of PVA leads to damage mould. When wax layer is dries then a thin layer of PVA is applied and leave it to dry at room temperature for 45 minutes. After this a second layer of PVA is also applies this layer is thick as compare to previous layer and also drying time for this layer is also 45 minutes at room temperature. After Successively applied PVA on the mould then the amount of epoxy resin and fiber glass is measured as we use fiberglass as 20% weight percentage [5]. The whole measuring is done on electronic weight scale with 0.1 gm accuracy. For the preparation of plain weave copper strips mesh strips mesh, the copper sheet is first cut into the strips having a length of 350 mm and width of 4 ± 0.2mm with a constant thickness of 0.213 mm and then it is woven with a gap of 4mm as shown in Figure 1. The gap is necessary because when we use plain metal sheet it won't properly stick with epoxy therefore, in between them gap is necessary.

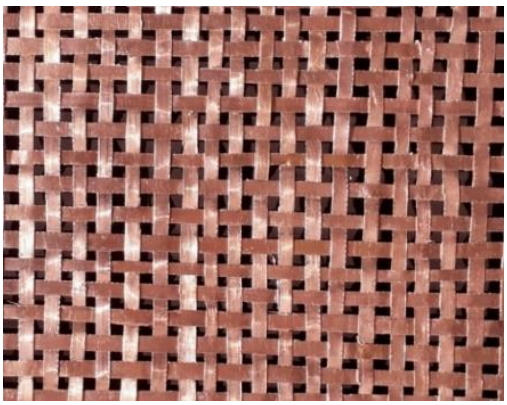
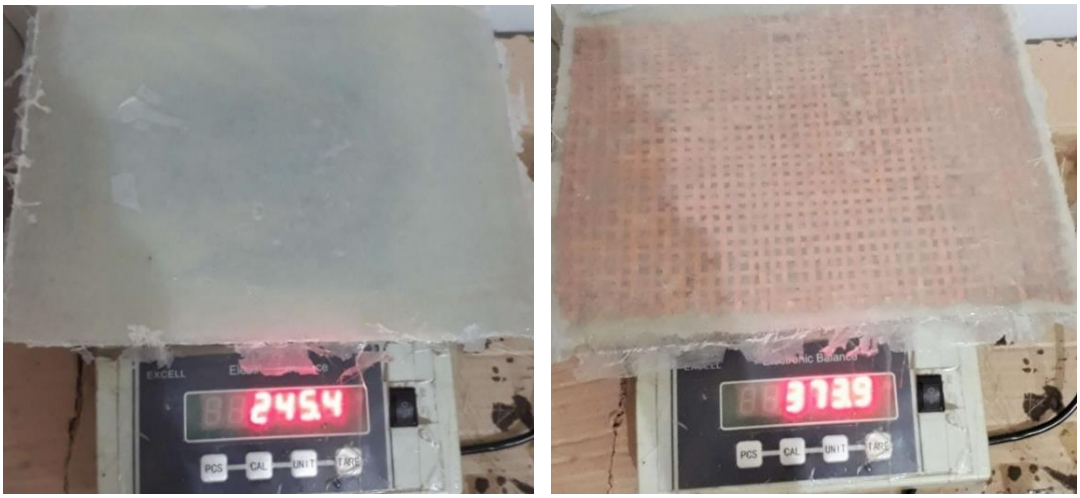


Figure. 1 Plain weave copper strips mesh Strips

When the mould is ready then it is filled with very small amount of epoxy resin and spreaded all over the mould and heats up with heat gun to remove air bubbles as air bubble is generally introduce while mixing epoxy resin and hardener, After that fiber glass is place which is previously cut in desired dimension 280x230mm according to fits in mould then epoxy resin is spreaded again and heat is also

used again his process continues until all amount of resin and fiber glass is fused then a washer roller is used for applying pressure and also removing any kind of air bubbles and gaps. By applying pressure through the roller makes uniform distribution of epoxy all over the mould. Then the mould is cover by another flat piece of Bakelite which also includes a thick layer of PVA and makes a sandwich then this is cured at room temperature for 24 hours under the pressure of approx. 40-50 kg.



(a) GFRP Composite **(b) Hybrid Composite**

Figure 2. Composites

Similarly, the other hybrid composite is prepared as we introduce plain weave copper strips mesh strips mesh in between the layers of fiber glass which is equally centered in the layers of fiber glass. The representation of both the composites is shown in Figure 2.

Mechanical testing

After successfully making the composite laminate sheets of both types of composite then it's time to cut out the samples on which tests have to be done. Samples were cut as per the desired dimensions according to ASTM standards followed. A series of various tests performed while determining the mechanical properties and physical properties of any material. Samples with their testing standards is shown in Table 1. The following test were performed.

i. Tensile Strength
ii. Flexural Strength
iii. Izod Impact Strength
iv. Density
v. Shore D Hardness

Table 1. Nomenclature & Brief Details of Prepared Samples

Sample Code	Composite Type	Test Name	Sample Standard	Sample Dimensions (mm)	Sample Weight (gm)
C1,1	GFRP	Tensile	ASTM D3039	250x25x3	24.8
C2,1	Hybrid	Tensile	ASTM D3039	250x25x3	36.3
C1,2	GFRP	Flexural	ASTM D790	125x12.7x3.2	6.1
C2,2	Hybrid	Flexural	ASTM D790	125x12.7x3.2	8.9
C1,3	GFRP	Izod Impact	ASTM D256	64x12.7x3.2	3.5

C2,3	Hybrid	Izod Impact	ASTM D256	64x12.7x3.2	4.8
CII	GFRP	Density	ASTM D792	10x10x3.2	0.4013
CI	Hybrid	Density	ASTM D792	10x10x3.2	0.5554
CII	GFRP	Shore D Hardness	ASTM D2240	10x10x3.2	0.4
CI	Hybrid	Shore D Hardness	ASTM D2240	10x10x3.2	0.5

Tensile test

The tensile tests of both GFRP and hybrid composites were performed in a Tensile Testing Machine in accordance with ASTM D3039 [6] standard to evaluate the tensile strength of the combinations. The length, width and thickness of both type of specimens were 250, 25 and 3 mm, respectively. One sample was tested in each sample group.

Flexural test

The three-point flexural tests of both GFRP and hybrid composites are in accordance with ASTM D790 [7] standard to evaluate the flexural strength of the composites. The length, width and thickness of the specimens were 125, 12.7 and 3mm. Length of Span for the flexural test samples was 98 mm in both composites.

Impact test

Izod impact tests were conducted on both GFRP and hybrid composites according to ASTM D256 [8] standard. The length, width and thickness of the specimens were 64, 12.7 and 3 mm. The test specimen was placed over the vertical cantilever beam, and it's broken by way of a single pendulum performing in the center of the samples.

Density

The density of both GFRP and hybrid composites was determined theoretically by the ratio of mass divided by volume as per ASTM D792 [9]. Mass of these samples was measured on a digital scale with accuracy of 0.0001gm and volume is measure by multiplying length, width and thickness by the help of digital Vernier Caliper. The approx. length, width and thickness of the specimen were 10, 10 and 3 mm.

Hardness

The hardness was evaluated of both GFRP and hybrid composites were performed in a durometer type Shore D accordance with ASTM D2240 [10]. The length, width and thickness of the specimens were 10, 10 and 3 mm.

3. Result and Discussion

3.1 Effect on the tensile strength of composites

The tensile strength of hybrid composite is 69MPa attained while tensile strength of GFRP composite with 20% fiber loading is 59.3MPa. Which shows improvement of approx. 10MPa.

3.2 Effect on the flexural strength of composites

The effect of adding plain weave copper strips mesh strips mesh influencing as flexural strength of composite. The flexural strength of GFRP composite is 124.4MPa and hybrid composite is 160.5MPa.

3.3 Effect on the impact strength of composites

The effect of addition of plain weave copper strips mesh strips mesh influencing as impact strength of composite. The hybrid composite impact strength is 54.28% higher than GFRP composite. Hybrid composite have the impact strength of 93.613 (Kg.cm/cm) and GFRP composite have 60.677 (Kg.cm/cm).

3.4 Density of composites

For addition of plain weave copper strips mesh strips mesh into the GFRP composite, it increases up to 1.95 g/cc from 1.24g/cc at 20% reinforcement in GFRP composite. The increasing density of composite is directly dealing with fiber loading in the composite. The hybrid composite gives the higher value of density value when compared to be other GFRP composites, which is 57.258% higher as compare to GFRP composite.

3.5 Effect of hardness on composites

The test was evaluated by shore D hardness tester of the specimen through an indentation. In hybrid composite the indentation due to better bonding strength of the specimen. The hardness values of hybrid composite attained is 74 when compared to GFRP composite at 20% fiber loading is 65.

Table 2. Results

Sample Code	Composite Type	Test Name	Result Value	Unit
C1,1	GFRP	Tensile	59.3	(N/mm^2)
C2,1	Hybrid	Tensile	69.0	(N/mm^2)
C1,2	GFRP	Flexural	124.4	(N/mm^2)
C2,2	Hybrid	Flexural	160.5	(N/mm^2)
C1,3	GFRP	Izod Impact	60.677	$\left(\frac{\text{Kg. cm}}{\text{cm}}\right)$
C2,3	Hybrid	Izod Impact	93.613	$\left(\frac{\text{Kg. cm}}{\text{cm}}\right)$
CII	GFRP	Density	1.2409	(gm/cm^3)
CI	Hybrid	Density	1.9508	(gm/cm^3)
CII	GFRP	Shore D Hardness	65	Shore D
CI	Hybrid	Shore D Hardness	74	Shore D

4. Conclusion

Based on experimental results, this study has led to the following conclusions: Plain weave copper strips mesh can be successively added to GFRP composite and suitably bond with epoxy resin. Mechanical and physical properties which were evaluated successively show increment. There was an increment in tensile strength by 16.357 % in the hybrid composite as compared

to GFRP composite, the flexural strength of the hybrid composite was increased by 29.019 %, where impact strength of the hybrid composite was increased by 54.28 %, the density of hybrid composite was increased by 57.208 % and hardness of hybrid composite shows the least improvement among all which is 13.846 %.

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