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Experimental Investigations on the Mechanical Properties of Alternate Helmet Materials Made by Epoxy Hybrid Composites Reinforced with Areca and Glass Fibers for Enhanced Performance

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Abstract: This work focused on the development and characterization of hybrid glass/areca fiber reinforced epoxy composite for alternate helmet materials. The total numbers of fiber layers are fixed and by varying the weight percentage of matrix and different fiber layers. Five different composites were manufactured using hand lay-up technique and investigated the mechanical characterization of the developed hybrid composites. Finally the mechanical properties are compared with commonly used plastic material to ensure the possibility to replace the plastic material with the developed hybrid composite material for industrial applications such as helmet for workers in industries. Glass Fiber Reinforced Polymers are mixed with natural fibers to increase Engineering and Technology applications. Using a hybrid composite that contains two or more types of different fibers, the advantages of one type of fiber could complement what are lacking in the other. As a consequence, a balance in performance and cost could be achieved through proper material selection, design, fabrication etc.

Keywords: Hybrid composite, Glass Fiber Reinforced Polymers, Areca fiber, Natural fibers.

I. INTRODUCTION

A composite material is a combination of two or more chemically different materials with a distinct interface between them. The constituent materials maintain their separate identities in the composite, yet of the constituents. One of the constituents forms a continuous phase and is called the matrix. Then their combination produces properties and characteristics that are superior to other major constituents is reinforcement in the form of fibers that is in general added to the matrix to enhance matrix properties. In most of the cases, reinforcement is harder, stronger and stiffer than the matrix. Reinforcements are strong materials with a particular morphology that is incorporated into the matrix to improve a composite's physical properties. Sanjay et al.[1] studied the natural fiber composites application for engineering and commercial purpose. The authors compared the mechanical properties of natural fibers with synthetic fibers and showed the various applications of natural fiber-based composites and their hybrid composites. Surendra et al. [2] fabricated the sisal fiber reinforced polymer composite and sisal/jute/okra fiber reinforced polymer hybrid composite. The authors concluded that the mechanical properties of sisal/jute/okra fiber reinforced polymer hybrid composites were better than the sisal fiber reinforced polymer composite. Murali et al. [3] fabricated the sisal/banana/jute particle reinforced epoxy composite for industrial safety helmet using hand lay-up technique. The authors concluded that sisal/banana/jute particle fiber reinforced epoxy composite can be used as an alternate material of ABS plastics for industrial helmet. Arthanarieswaram et al. [4] analyzed the effect of glass fiber hybridization with randomly oriented natural fibers. The authors concluded that glass fiber improved the tensile strength and impact strength of natural fiber composite. Gopinath et al. [5] analyzed the mechanical properties of jute/epoxy reinforced epoxy composites and jute/polyester reinforced epoxy composites. The composite was synthesized at 18:82 fibers resin weight percentages. The authors concluded that jute reinforced epoxy composites shown superior mechanical properties than jute-polyester reinforced epoxy composites. Ram et al. [6] reviewed the properties of natural fiber composites to replace the existing safety helmet material. The authors showed that natural fiber hybrid composites can replace the existing industrial safety helmet materials which are eco-friendly and light in weight.In the high tensile strength applications, chemically treatedareca fiber reinforced natural rubber composite [7] and forhigh dimensional stability applications, low-density property of raw betalnut husk fiber has found the application in light weight applications [8,9].
This work focused on the development and characterization of hybrid glass/areca fiber reinforced epoxy composite for alternate helmet materials

II. METHODS AND MATERIALS

In the present study E-glass fiber and Areca fibers are used as reinforcements in woven format and epoxy resin LY556, hardener HY951 are used as matrix. Hybrid composite specimens were prepared in five different compositions as per the calculations given. Hand lay-up method was used in the fabrication. Followed by testing and the expected results were obtained.

III. PROCESSING

Hand lay-up technique has been used for the fabrication of composites specimens.

A. Specimen composition

In this study mechanical properties of five different compositions of areca/E-glass fiber reinforced epoxy hybrid composites are done. The different compositions are made to compare which composition exhibit better properties. The composition details are listed in table 1

Table 1 composition details

	Epoxy (%)	AF (%)	GF (%)
Specimen 1	55	--	45
Specimen 2	62	32	6
Specimen 3	70	10	20
Specimen 4	68	20	12
Specimen 5	77	23	--

To fabricate hybrid composites with different compositions, Weight percentage calculations plays an important role. Steps and calculations involved in the above mentioned procedure is done for each composition and Table 2 gives an overview of the calculations done.

Table 2 Weight corresponding to the composition

	Epoxy (g)	AF (g)	GF (g)	Total weight (g)
Specimen 1	966.966	--	791.15	1758.12
Specimen 2	976.717	94.521	504.112	1575.35
Specimen 3	986.125	140.875	281.75	1408.75
Specimen 4	876.316	257.7	154.644	1288.70
Specimen 5	864.96	258.365	--	1123.32

B. Hand layup method

Hand lay-up technique is the simplest method of composite processing. The infrastructural requirement for this method is also minimal. The processing steps are quite simple. First of all, a release gel is sprayed on the mold surface to avoid the sticking of polymer to the surface. Thin plastic sheets are used at the top and bottom of the mold plate to get good surface finish of the product. Reinforcement in the form of woven mats or chopped strand mats is cut as per the mold size and placed at the surface of mold after Perspex sheet. Then thermosetting polymer in liquid form is mixed thoroughly in suitable proportion with a prescribed hardener (curing agent) and poured onto the surface of mat already placed in the mold. The polymer is uniformly spread with the help of brush. Second layer of mat is then placed on the polymer surface and a roller is moved with a mild pressure on the mat-polymer layer to remove any air trapped as well as the excess polymer present. The process is repeated for each layer of polymer and mat, till the required layers are stacked. After placing the plastic sheet, release gel is sprayed on the inner surface of the top mold plate which is then kept on the stacked layers and the pressure is applied. After curing either at room temperature or at some specific temperature, mold is opened and the developed composite part is taken out and further processed. The time of curing depends on type of polymer used for composite processing. For example, for epoxy based system, normal curing time at room temperature is 24-48 hours.Fig 1 shows hybrid composites fabricated by Hand layup method of different compositions of areca fiber, glass fiber, and epoxy

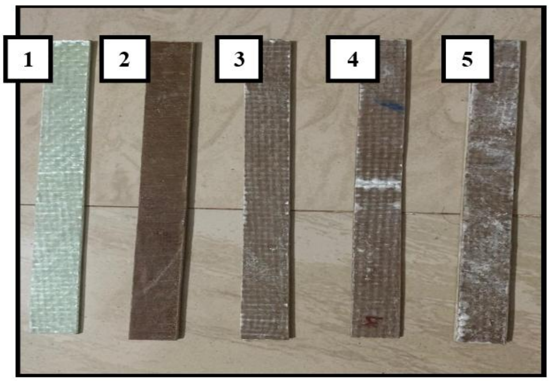

Fig 1 Test specimens fabricated by Hand layup method

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IV. MECHANICAL CHARACTERIZATION

A. Hardness test

Shore d hardness testing of the composites is carried out as per ASTM D2240 standard. An indentation hardness test using calibrated machines to force a square –based pyramidal indenter having specified face angles, under a pre-determined load, into the surface of the material under test.

B. Impact test

Notched Izod testing of composites is going to carried out as per ASTM A 370 standard. The pendulum impact testing machine ascertains the notch impact strength of the material by shattering the notched specimen with a pendulum hammer. The energy consumed is measured on dial-indicator which is used to calculate impact strength.

C. Tensile test

Tensile testing, is also known as tension testing, is a fundamental materials science test in which a sample is subjected to a controlled tension until failure. Test is carried out by Universal Testing Machine as per ASTM D 3037 standard.

D. Flexural strength

The test method for conducting the test usually involves a specified test fixture on a universal testing machine. As per ASTM D 3739 the sample is placed on two supporting pins a set distance apart and a third loading pin is lowered from above at a constant rate until sample failure.

E. Water absorption

Water absorption is expressed as increase in weight percent. Immersion of a specimen in distilled water during 24 hours at 23°C as per ASTM D 570 standard. $A\% = 100 * \frac{M_{w-}M_d}{M_d}$, Where, Mw = Mass of sample at wet condition and Md = Mass of sample at dry condition.

V. RESULTS AND DISCUSSIONS

A. Hardness test

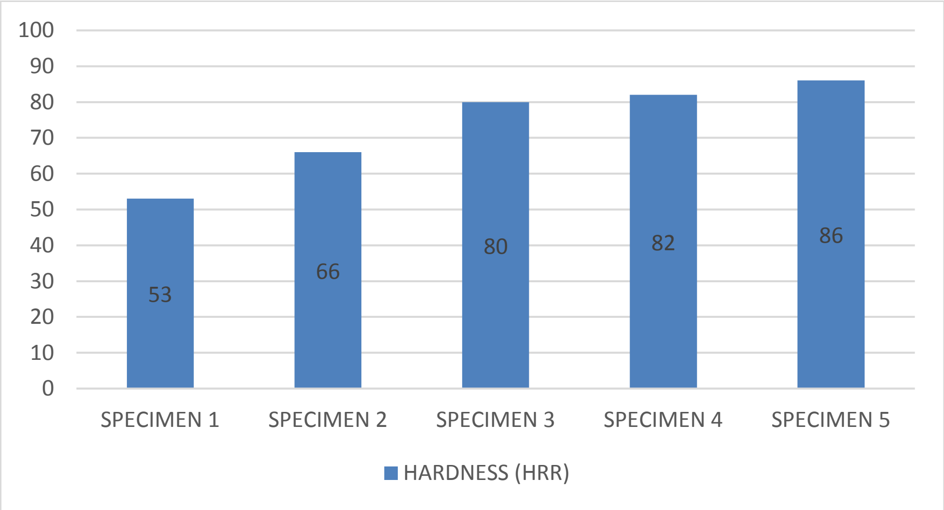

Fig 2 Hardness of Developed Composite Samples

The hardness of hybrid composites developed is increases while more amount of areca fiber added in glass/epoxy composite it is clear from the Fig 2. The minimum value for hardness is for glass/epoxy composite (53 HRR). And the max value obtained is 86 HRR for areca/epoxy composite. Areca/glass/epoxy hybrid composite shows higher results than the glass fiber was used alone as reinforcement in the matrix. That means the integration of areca fiber with glass fiber for reinforcement will improve the hardness of the material.

B. Impact test

Figure 3 shows the impact resistance of the tested composites. The maximum impact force value for the Epoxy 70 % + E glass fiber 20 % + Areca fiber 10 % composite sample is 48 J/m and the minimum value for the Epoxy 77 % + Areca fiber 23 % composite sample is 25 J/m. The result shows that the impact strength of glass / epoxy composite (40 J / m) is higher than the areca/ epoxy composite (25.5 J/m).

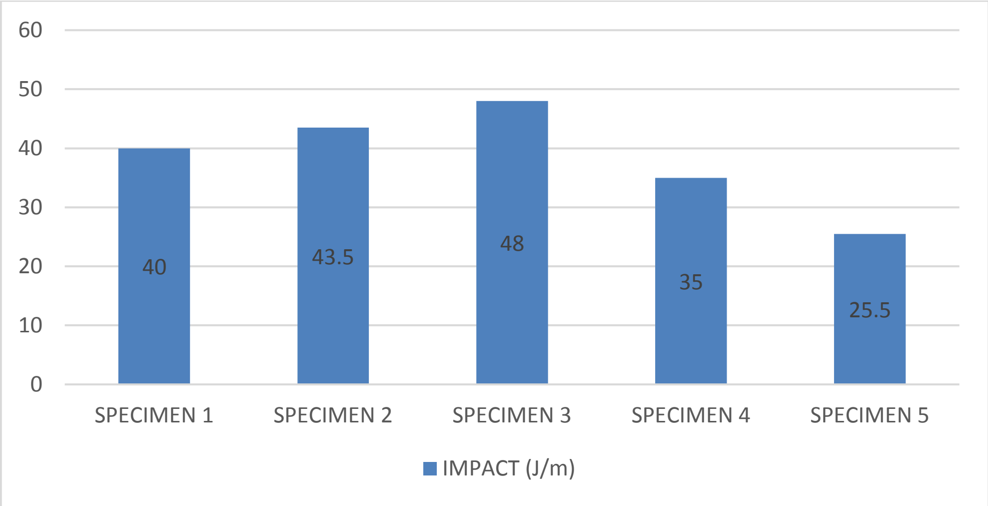

Fig 3 Impact Strength of Developed Composite Samples

By the integration of areca fibers with glass fibers improves the impact strength of glass / epoxy composite. Further increasing the weight percentage of areca fibers results in decreased impact strength of areca / glass / epoxy hybrid composite as shown in Figure 3. this may be due to the increasing weight percentage of areca fibers in glass/epoxy composite may involve improper wetting of areca fibers with epoxy matrix which weakens the interface and hence reduction in impact strength of hybrid composite.

C. Tensile test

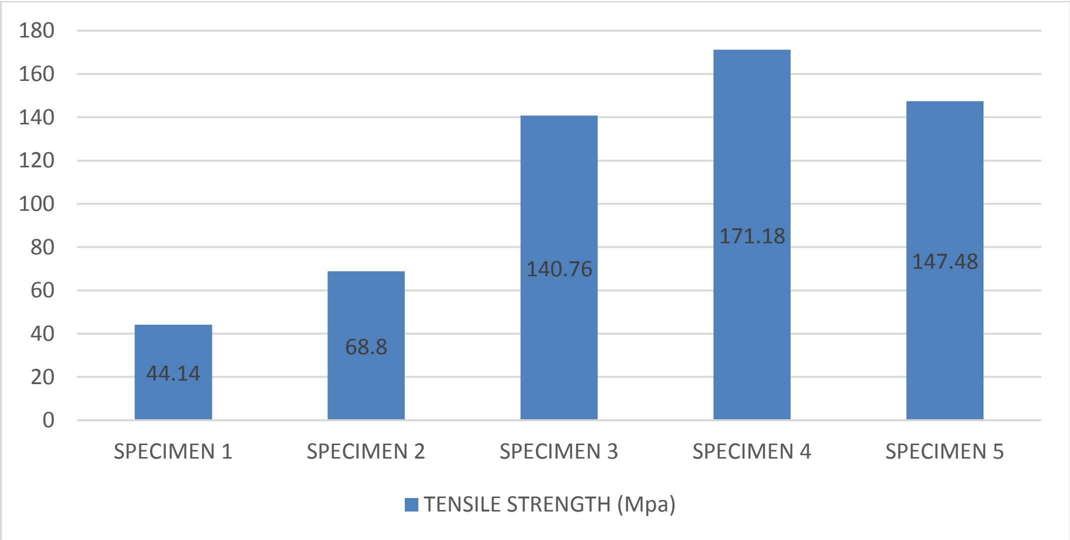

Fig 4 Tensile Strength of Developed Composite Samples

The values for tensile strength for different combination of developed composites are is given in figure 4. It is clear that the addition of areca fiber increases the tensile strength. And after a limit it decreases. The maximum value of tensile strength is 171.18 MPa for Epoxy 68% + E glass fiber 12% + Areca fiber 20% combination after reaching this value further apply of areca fiber decrease the tensile strength. The minimum value obtained is 44.14 MPa for Epoxy 55%+E glass fiber 45% composition. Incorporation of areca fiber with glass fiber in matrix shows improved results than the usage of glass fiber alone as reinforcement.

D. Flexural strength

The values of flexural strength of the developed composites shown in figure 5 and. The maximum value of flexural strength is 42.5 MPa for the Epoxy 68% + E glass fiber 12% + Areca fiber 20% hybrid composite and the minimum value of the flexural strength is 29 MPa for the glass/ epoxy composite. It is observed that the value of flexural strength increase with decrease in weight percentage of glass fiber and increases with increase in weight percentage of areca fiber. The maximum flexural strength when the weight fraction of glass/areca is 12/20. After that increase in weight percentage of areca fiber decreases the strength. This may happen because of the improper impregnation of areca fiber into the matrix which leads the debonding of fibers.

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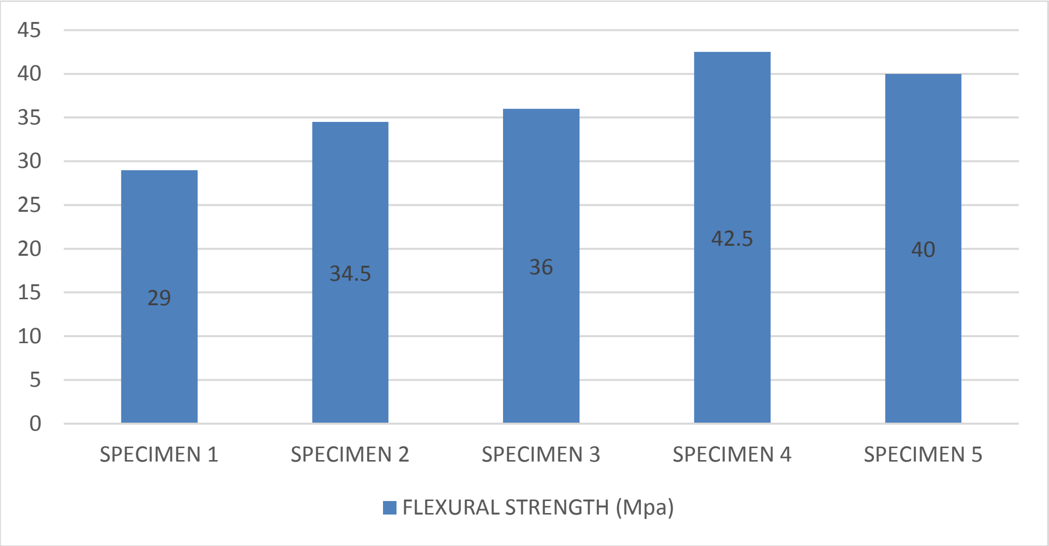

Fig 5 Flexural strength of developed composite samples

E. Water absorption

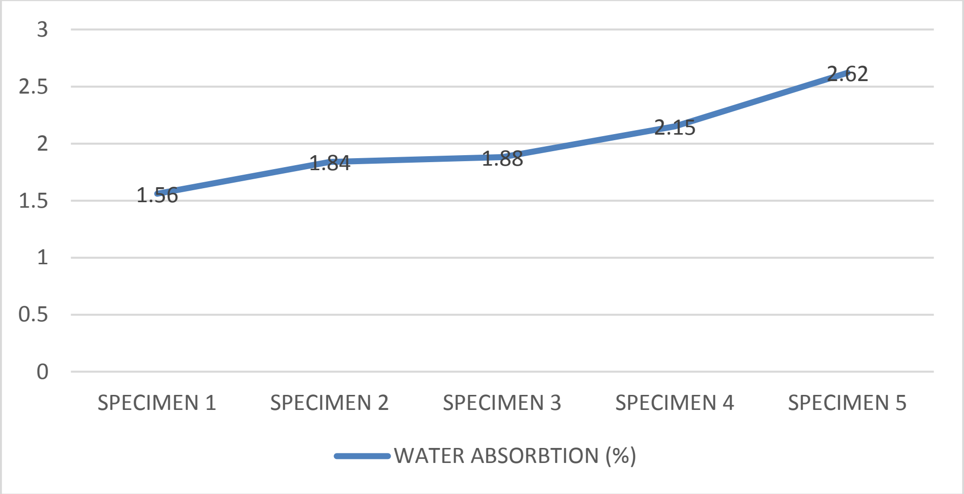

Fig 6 Water absorption of developed composite samples

In the case of water absorption it can be observed that increase in areca fiber in the matrix increase the rate of water absorption. The minimum value of water absorption is 1.56 % for glass/epoxy composite and the maximum value of water absorption is 2.6 % for areca/epoxy composite. The final hybrid composite selected for comparing mechanical properties with commonly used ABS plastics is hybrid composite having composition Epoxy 70% + E glass fiber 20% + Areca fiber 10% . So the intermediate value taken as water absorption is 1.88%.

Table 3 Comparison of mechanical properties of ABS plastic with developed hybrid composite

Mechanical properties	ABS	Areca/glass/epoxy hybrid composite
Impact strength (J/m)	50	48
Tensile strength (MPa)	46	140.76
Flexural strength (MPa)	72	36
Hardness(HRR)	50	80
Water absorption (%)	1.8	1.88

VI. CONCLUSION

- In the present study Hybrid Glass/Areca fiber/epoxy composite in different compositions are fabricated.
- By using natural fiber as reinforcement the mechanical performance is met in an eco-friendly manner.
- The incorporation of areca fiber with glass fiber showed better result than glass fiber used alone as reinforcement.

- Mechanical properties of ABS plastics are compared with Epoxy 70% + E glass fiber 20% + Areca fiber 10% hybrid composite which shows the highest impact strength.
- All the properties other than flexural strength showed better results when compared with ABS plastics(commonly used plastic in helmet manufacturing)

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