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Processing and Mechanical Behavior of Banana Fibre Reinforced Epoxy based Composite with Alumina and silicon Carbide

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ABSTRACT

Polymer composites have outstanding qualities such as high strength, flexibility, stiffness, and lightweight. Currently, research is being performed to develop innovative polymer composites that may be used in many operational situations and contain a variety of fibre and filler combinations. Banana fibre has low density compared to glass fibre and it is a lingo-cellulosic fibre having relatively good mechanical properties compared to glass fibre. Because of their outstanding qualities, banana fibre reinforced polymer composites are now widely used in various industries. The primary goal of this study is to determine the effect of the wt.% of banana fibre, the wt.% of SiC, and the wt.% of Al_2O_3 in banana fibre reinforcement composites on the mechanical and physical properties of banana fibre reinforcement composites. Tensile strength and flexural strength of unfilled banana fibre epoxy composite increased with the increase in wt. of banana fibre from 0 wt.% to 12 wt.%. Further, an increase in wt.% banana fibre drop in mechanical property was observed. It has been concluded from the study that the variation in percentage weight of filler material with fixed amount (12 wt.%) of banana fibre affects the mechanical properties of filled banana reinforcement composites. Optimum mechanical properties were obtained for BHEC5 (72 wt.% Epoxy + Hardener, 12 wt.% banana fibre and 16 wt.% Al_2O_3).

Keywords: Polymer composites, banana fibre, epoxy, SiC, Al_2O_3, tensile strength, and flexural strength

I. INTRODUCTION

Nowadays, worldwide, researchers are going on to motivate, study and develop a new natural fibre reinforced polymer (NFRP) composite. Researchers are focusing on environmental awareness and the economic value of the different types of polymer composites. Recently, researchers are also focusing on geometrically rising crude oil costs get more significant global waste problems and more operation/processes prices. So that researchers are going on the concepts of sustainability and a reassessment of renewable resources **kawade and Narve (2017)**. Researchers tempted NFRP composites as a research point because NFRP composites have several advantages over synthetic fibre reinforced composites such as an option for low cost, low density, locally available, ease of manufacturing, non-toxicity, good mechanical properties, good insulation property, good renewable, biodegradable, entirely or partially recyclable and environmentally friendly **Singh et al. (2013); Chandole (2012)**.

Rout and Satapathy (2012) created the epoxy-GF/rice husk hybrid composite materials by adding rice husk at four weight percentages (0, 5, 10, and 15) and examined their mechanical properties. It has been discovered that by reinforcing the rice husk, the mechanical properties of the hybrid composites may be significantly improved. When rice husk is added to composite materials, the tensile and flexural strengths are reduced. **Idicula et al. (2010)** observed mechanical behavior of the banana, sisal and hybrid reinforced polyester composites. These aides deciding the layering examples and fibre piece and focus those are the elements of tensile properties of the composites. **Neher et al. (2020)** analysed the mechanical and physical characteristics of continuous aligned banana fibre orientation epoxy composite and continuous bi-directional banana fibre orientation epoxy composite. Authors noticed that epoxy composite with continuous aligned fibre orientation had better tensile strength and hardness as compared to epoxy composites with continuous bi-directional fibre orientation. **Singh et al. (2011)** examined banana fibre composite malleable properties because of the difference in the rate of the weight of silica powder. It indicated that expanding the modulus of flexibility and effect quality of composite by the expansion of silica. **Hussain et al. (1996)** investigated the mechanical characteristics of unidirectional carbon fibre reinforced epoxy composite and unidirectional carbon fibre reinforced epoxy composite with Al_2O_3 filler. Results revealed that hybridization of carbon fibre reinforced composite with nano and micro-sized Al_2O_3 give optimal mechanical properties. **Basavarajappa et al. (2010)** studied the influence of SiC as filler material on the three-body abrasive wear behavior of glass-epoxy composites was explored by taking into account the applied load, sliding speed, and abrading distance as abrasive wear variables. According to experimental results, wear increased with increasing applied load, sliding speed, and rubbing distance for both unfilled glass-epoxy composite and SiC filled glass-epoxy composite. **Patnaik et al. (2010)** studied the impact of filler materials such as silicon carbide (SiC), alumina (Al_2O_3), and pine bark dust (PBD) on the three-body abrasive wear behavior of epoxy-based composites. Al_2O_3 and PBD filled random glass fibre-epoxy resin composites were shown to have superior wear resistance properties than SiC filled random glass fibre-epoxy resin composites, according to the findings of this study. **Raju et al. (2012)** studied the effect of silicon dioxide as a filler material on the two-body abrasive wear behavior of a silicon dioxide filled glass fabric reinforced epoxy composite by measuring its mechanical properties. The mechanical properties and wear resistance of silicon dioxide filled glass fabric reinforced epoxy composite were found to be superior to those of unfilled glass fabric reinforced epoxy composite. **O.Asi (2008)** examined the mechanical characteristics of a glass-fibre reinforced epoxy composite filled with varying quantities of Al_2O_3 particles in a glass fibre reinforced epoxy composite. An experimental analysis reveals that increasing Al_2O_3 particle content in epoxy composites causes the ultimate strength of glass fibre reinforced epoxy composites to degrade while increasing Al_2O_3 particle content causes the flexural strength first to increase and then decline. **Petersan et al. (2015)** experimented to check mechanical properties on fire resistant glass fibre reinforced polymer by using alumina tri hydrate as filler at various percentages. Adding Alumina tri hydrate decreases strength and increases brittleness of fibre reinforced polymer. Increasing filler content shows significant effect of stiffness and strength. This research work has analyzed and compared unfilled and SiC and Al_2O_3 filled banana fibre reinforced polymer composite under the tensile strength and flexural strength.

II. METHODS AND MATERIAL

2.1 Material Selection

Epoxy resin (LY 556), hardener (HY951), banana fibre, mold sheet, a heavy-duty silicone spray, alumina (200 mesh) and silicon carbide (200 mesh).

2.1.1 Matrix Materials

As corrosion resistance properties, mechanical properties, low shrinkage and chemical properties are way superior in the polymeric epoxy resin during curing, this is widely used in the formation of many polymer composites. So, for the fabrication of polymer composites, LY556 resin and HY 951 was chosen as the matrix material and hardener, respectively.

2.1.2 Fibre Material

Fibre is the reinforcing phase of composite material in general. Banana fibre is used as a natural fibre in an epoxy matrix to create some hybrid composites. As a result, nonwoven banana fibre was used to make composites for this study.

2.1.3 Filler Material

Silicon carbide and aluminum oxide are extremely favorable materials in fabricating composites as filler materials as they have high strength at elevated temperature, low thermal expansion, high thermal conductivity and chemical reaction reactive properties.

2.2 Fabrication of Composites

The production of the composite slabs is accomplished by using a traditional hand-lay-up approach followed by a gentle compression molding procedure. Firstly, we have prepared the wooden blocks ten in numbers. After that, thin plastic sheets (mold releasing sheets) are fixed at the bottom of the mold plate to get good surface finish of the product. Then after release gel silicon spray is sprayed on the surface of thin plastic sheets to avoid the sticking of polymer to the surface of thin plastic sheets. After this banana fibre is being chopped in a small size and weighted according to the ratio. These pieces of fibre then mixed with the epoxy resin and the hardener in a particular ratio. This procedure is done without silicon carbide and aluminum oxide till now. After properly mixing banana fibre and hardener in epoxy resin we poured this mixture on the already made wooden block. After that, releasing gel is sprayed on the inner surface of the plastic sheet. Then, this sheet is placed on the top layer of fibre and polymer. A roller is moved with a mild pressure on the plastic sheet to remove any air trapped as this mixture and leave of 24 hours. Then new composites with a different weight proportion of SiC and Al2O3 particulates composite have been fabricated, as shown in Table 1

TABLE: 1
FABRICATION OF COMPOSITES REINFORCED WITH VARYING WT.% OF REINFORCEMENTS AND FILLERS

Composite Designation	Composition			
	Matrix Epoxy -Resin (wt.%)	Reinforcement Banana Fibre (wt.%)	Filler material	
			SiC (wt.%)	Al_2O_3 (wt.%)
BEC1	96	4	0	0
BEC2	92	8	0	0
BEC3	88	12	0	0
BEC4	84	16	0	0
BHEC1	80	12	8	0
BHEC2	72	12	16	0
BHEC3	64	12	24	0
BHEC4	80	12	0	8

BHEC5	72	12	0	16
BHEC6	64	12	0	24

After fabrication of the composites for physical and mechanical characterization, suitable-sized specimens were cut with a cutter as per ASTM standards for respective tests.

TABLE: 2

SPECIMENS AS PER ASTM STANDARDS FOR MECHANICAL TESTING

S. No.	Mechanical Test	Samples as per ASTM standards
1.	Tensile Test	
2.	Flexural Test	

III.RESULTS AND DISCUSSION [Page Style]

3.1 Mechanical Testing of Developed Composites

3.1.1 Tensile Test

The tensile test of the developed epoxy composites was performed using a universal testing machine (UTM Instron 1195) under ambient circumstances. According to the ASTM standard, the shape and size of specimens for the tensile test has designation (D3039-76).

TABLE: 3

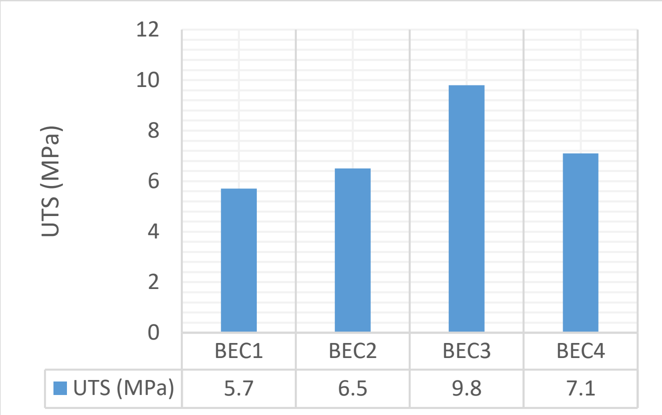
TENSILE STRENGTH OF UNFILLED COMPOSITES

Composite Designation	Banana Fibre (wt.%)	Tensile Strength (MPa)		
		1	2	Mean
BEC1	4	5.8	5.6	5.7
BEC2	8	6.7	6.3	6.5
BEC3	12	10.1	9.5	9.8
BEC4	16	7.0	7.2	7.1

The tensile load applied at a crosshead speed of 0.5 mm/min. For all the fabricated composites, two identical specimens have been tested. The average of the tensile strength value has been taken as tensile strength for that composite, as shown in table 3. It can be shown in figure 1 that the tensile strength of developed epoxy composites increases as the amount of fibre loaded increases. For low weight % of fibre loading (BEC1), tensile strength is low due to the less fibre interface area. Further increase in % weight of fibre leads to an increase in fibre interface area, therefore increasing tensile strength (BEC3). Beyond the specific limit, further increase in fibre loading decreases tensile strength due to incomplete adhesion at the entire surface because of fibre-fibre interaction and improper wetting of fibre (BEC4). When comparing all of the unfilled banana fibre reinforcement composites manufactured, the composite with 12 percent fibre loading (BEC3) has shown the highest tensile strength.

FIGURE: 1

COMPARISON OF TENSILE STRENGTH USING DIFFERENT WT. % OF BANANA FIBRE



3.1.2 Flexural Test

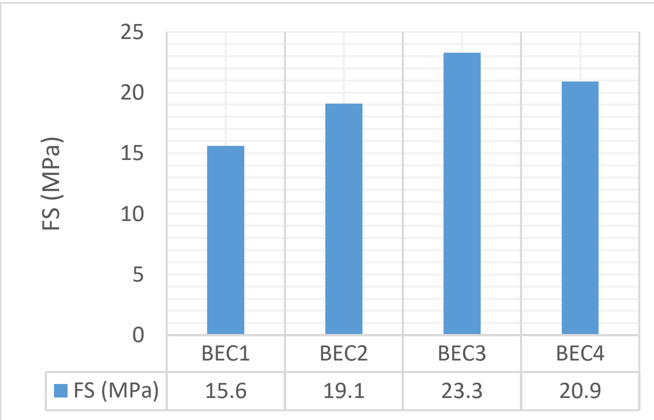
The flexural test of the composite was carried out with the help of a universal testing equipment (UTM Instron 1195). The shape and size of specimens for flexural test has been fabricated according to the ASTM standard with designation (D2344-84).

The flexural load was applied at a crosshead speed of 0.5 mm/min. For all the fabricated composites, two identical specimens have been tested. The average of the flexural strength value has been taken as flexural strength for that composite as shown in table 4. Figure 2 shows the bar chart for flexural strength of unfilled banana fibre composites.

TABLE: 4
FLEXURAL STRENGTH OF UNFILLED COMPOSITES

Composite Designation	Banana Fibre (wt.%)	Flexural Strength (MPa)		
		1	2	Mean
BEC1	4	15.8	15.4	15.6
BEC2	8	19.3	18.9	19.1
BEC3	12	23.6	23.0	23.3
BEC4	16	21.0	20.8	20.9

FIGURE: 2
COMPARISON OF FLEXURAL STRENGTH USING DIFFERENT WT. % OF BANANA FIBRE



From figure 2, it can be seen that the value of flexural strength of fabricated composites first improves with an increase in fibre loading up to weight percent 12 (i.e., BEC1 to BEC3), after which the value decreases. The homogeneous distribution of fibres in composites rises with an increase in the percentage of fibres in the composite, which helps to prevent early sliding of the polymer phase. The stress transfer occurs near the fibres. The homogenous distribution of fibres in the composites causes fracture initiation and propagation to appear in multiple directions rather than in a single direction, increasing flexural strength by increasing flexural stiffness. Beyond the specific limit, further increase in fibre loading (BEC4) decreases flexural strength due to incomplete adhesion at the entire surface because of fibre-fibre interaction and improper wetting of fibre. The maximum flexural strength has been achieved with 12 wt.% loading of fibre.

3.2 Mechanical Behavior of Filled Particulate Banana Fibre Polymer Composites

This section describes the mechanical testing and analysis of results obtains after mechanical testing.

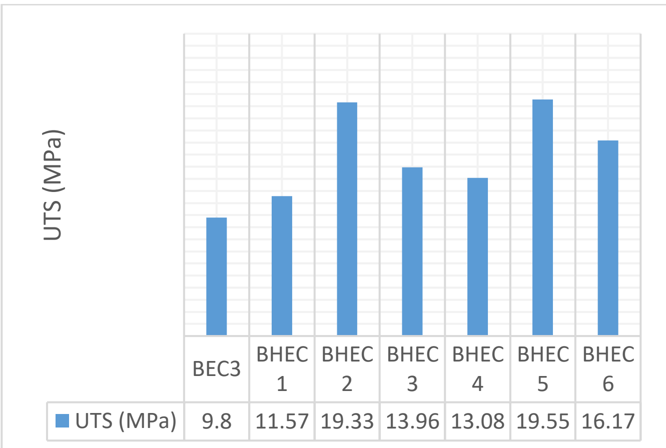
3.2.1 Tensile Strength

For all the fabricated composites, two identical specimens have been tested on UTM. The average of the value of ultimate tensile strength has been taken as ultimate tensile strength for that composite as shown in table 5. Figure 3 indicates the tensile strength of fabricated composites.

TABLE: 5
COMPARISON OF TENSILE STRENGTH USING DIFFERENT WT. % OF SIC AND Al_2O_3

Composite Designation	Ultimate Tensile Strength (UTS) (MPa)		
	UTS1	UTS2	UTS Mean
BEC3	10.10	9.50	9.80
BHEC1	11.69	11.45	11.57
BHEC2	20.32	18.34	19.33
BHEC3	13.67	14.24	13.96
BHEC4	13.51	12.64	13.08
BHEC5	19.23	19.86	19.55
BHEC6	16.42	15.92	16.17

FIGURE: 3
COMPARISON OF TENSILE STRENGTH USING DIFFERENT WT. % OF SiC AND Al_2O_3



It has been exposed from the figure 3 that the value of tensile strength of composites initially increases with increase either SiC or Al_2O_3 filler up to 16% wt. This is because filler particles act as a barrier in transferring stress from one point to another. Also, filler particulates increase the area for the bonding between the three different constituents of composites. Further addition of filler particulates from 16 wt.% in the composites reduces the tensile strength. It is due to an increase in more surface area and less matrix material for bonding. Due to insufficient bonding between three different constituents, the loads may not effectively be transferred from one end to another. Hence, there is a reduction in the tensile strength of the composite. The maximum tensile strength (19.55 MPa) was achieved with 16 wt.% filling of filler material (BHEC5).

3.2.2 Flexural Strength

For all the fabricated composites, two identical specimens have been tested. The average of the flexural strength value has been taken as flexural strength for that composite, as shown in table 6. Figure 4 shows the bar chart of flexural strength of fabricated composites.

TABLE: 6

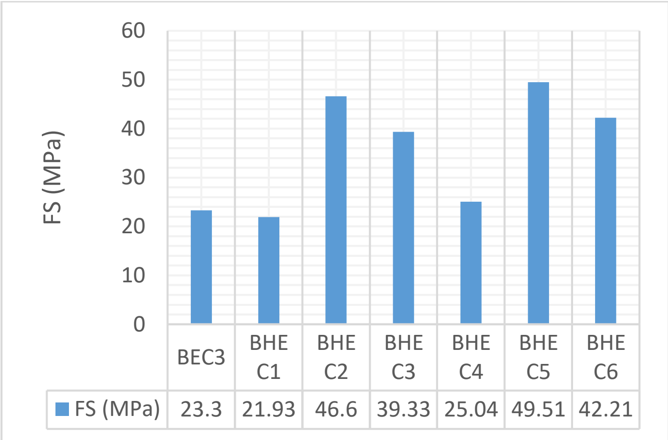
COMPARISON OF FLEXURAL STRENGTH USING DIFFERENT WT. % OF SiC AND Al_2O_3

Composite Designation	Flexural Strength (FS) (MPa)		
	FS1	FS2	FS Mean
BEC3	23.60	23.00	23.30
BHEC1	22.38	21.48	21.93
BHEC2	46.53	46.67	46.60
BHEC3	39.72	38.93	39.33
BHEC4	24.34	25.73	25.04
BHEC5	49.23	49.78	49.51
BHEC6	42.54	41.87	42.21

It has been observed from the figure 4 that the value of flexural strength of fabricated composites initially increases with increase either in wt.% of SiC or wt.% of Al_2O_3 up to 16 wt.% It is due to an increase in bonding surface area between fibre, filler epoxy matrix. The figure also revealed that further addition of filler material above 16 wt.% decreases the flexural strength of fabricated composites. It is due to incomplete adhesion at the entire surface because of improper wetting of fibre, hence improper interfacial bonding between the alumina particles, fibre and epoxy matrix. The maximum flexural strength has been obtained for BHEC5 with 16 wt.% loading of Al_2O_3 particulates.

FIGURE: 4

COMPARISON OF FLEXURAL STRENGTH USING DIFFERENT WT. % OF SiC AND Al_2O_3



From the analysis of figure 3 and 4 it was revealed that SiC or Al_2O_3 filled banana reinforcement composites exhibited superior mechanical properties than unfilled banana reinforcement composites. On the other hand, it was also shown that impact strength, flexural strength, tensile strength initially increases with increased wt.% of filler particles from 0 % weight to 16 % weight. Further, rise in filler particles from 16 wt.% to 24 wt.% decreases the impact strength, flexural strength, tensile strength of banana fibre composites. The maximum impact strength, flexural strength, tensile strength is achieved with 16% wt. of Al_2O_3 filler (BHEC5). The hardness of the SiC or Al_2O_3 filled banana fibre reinforcement composites continuously increases with an increase in filler from 0% wt. to 24 % wt. in the composites. The maximum hardness is achieved with 24% wt. of Al_2O_3 filler (BHEC6).

IV. CONCLUSION

The present work is focused on investigating the effect of fibre loading and % wt. of filler content on mechanical and Physical behavior of banana fibre reinforced epoxy composites. The following conclusions were obtained from the current study:

- The variation in percentage weight of banana fibre affects the mechanical properties (tensile strength and flexural strength) of unfilled banana reinforcement composites.
- The flexural strength, and tensile strength increase with fibre loading from 4 wt. % to 12 wt. %. Further increase in banana fibre loading beyond 12 wt.% leads to decreased in flexural strength and tensile strength.
- The BEC3 shows the maximum flexural strength, and tensile strength of fabricated unfilled banana reinforcement composites.
- Initially flexural strength and tensile strength increase with increase in % wt. of filler material from 0 % weight to 16 % weight. Further increase in filler particles from 16 % wt. to 24 % wt. decreases the flexural strength, and tensile strength of banana fibre composites.
- The maximum flexural strength and tensile strength is achieved with 16% wt. of Al2O3 filler (BHEC5).

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