Preparation and Characterization of Banana Fiber Reinforced Epoxy Matrix Composite

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Abstract— This paper describes how we can use the polymeric materials with synthetic fiber such as glass, carbon provide advantages of high stiffness and strength to weight ratio and their use is very well justified in varieties of application. Despite these advantages, the wide spread use of synthetic fiber reinforced polymer composite is declining because of their higher cost and adverse environmental impact. On the other hand the use of natural fiber to develop environment friendly green materials are attracting researches worldwide due to their advantages like biodegradability, high weight, low cost and high specific strength compared to synthetic fiber. In these categories, banana fiber is also a natural fiber. It is mainly used as a fruit and good for healthy growth of human body. just like any other conventional raw material in banana production also waste are generated during production. These waste to some extent are used for manufacturing less delicate products such as partition board , false ceiling, doors and window panels. In order to find value added application of this waste, the present work deals with preparation and characterization of epoxy composite with addition of banana fiber and aluminium oxide.

Keywords: Epoxy, banana fiber, aluminium oxide

I. INTRODUCTION

A. Background:

Fibre-reinforced polymer (FRP) is a composite material made of a polymer matrix reinforced with fibres. The fibres such as glass, carbon, aramid, natural fiber and polymers such as epoxy, vinyl ester, polyester thermosetting plastic and polyethylene, polypropylene thermoplastics are in use. FRPs are commonly used in the aerospace, automotive, marine, and construction industries. Composite materials are engineered or naturally occurring materials made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct within the finished structure [1].

II. METHODOLOGY

A. Preparation of The Composite:

The composite is fabricated by hand lay-up technique. This is an open mould shaping method in which resin and reinforcement are mixed. Then mixture is manually applied to an open mould to build the FRP composite structure. For composites fabrication a wooden mould of size (250 mm × 250 mm × 5 mm) has prepared. The fiber is dipped in the epoxy resin and aligned in the mould where the resin is also poured. The upper side is pressed using a roller under room temperature until the matrix is set properly. The setup is left to cure for 24 hours at room temperature. Now the prepared composite was cut for testing conform to the dimensions of the specimen as per ASTM standards. This process has been used for fabrication of composites of different composition as shown in table 1.

S.No	Designation	Resin	Particulates	Fiber
		Epoxy (vol.%)	Aluminum Oxide (vol.%)	Banana fiber (vol.%)
1	S_1	95	2	3
2	S_2	93	2	5
3	S_3	90	2	8
4	S4	88	2	10

Table 1: Designation and detailed composition of the composites.

B. Tensile Test:

Fig. 1 shows the specimens prepared for tensile test. The testing is done using UTM to measure the force required to break a polymer composite specimen and the extent to which the specimen stretches or elongates to that breaking point.

Fig. 1: Tensile test specimens

C. Flexural Test:

Flexural strength is defined as a materials ability to resist deformation under load. Flexural strength and stiffness are the combined effects of a materials basic tensile, compressive and shear properties. That is, when a flexural loading is applied to a specimen, all three of the materials basic stress states are induced. Material failure, then, is dictated by which of the three basic stresses is the first to reach its limiting value that is, its strength. Despite the obvious complexities implied by the above, flexural testing is common, the test specimen is easy to prepare, the fixture can be simple and the test itself is easy to perform. ASTM-D638-a is used for short-beam strength of polymer matrix composite materials. Figure 4.8 shows Universal Testing Machine made by Instron Corporation Series IX Automated Materials Testing System which is used with cross head speed 5 mm/min.

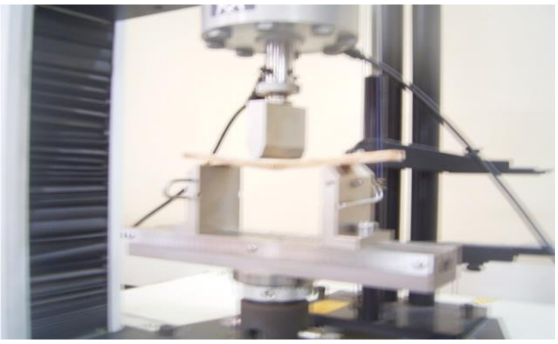
Fig. 2: Flexural test arrangement

D. Impact Test:

Impact is a single point test that measures a materials resistance to impact from a swinging pendulum. Impact is defined as the kinetic energy needed to initiate fracture and continue the fracture until the specimen is broken. The Fig.3 shows the impact testing observation during the experimental work


Fig. 3: Impact testing of the specimen

III. RESULT

This chapter presents the mechanical properties of the banana fiber/epoxy with filler material AL2O3 composites prepared for this present investigation. The Details of processing of these composites and the tests conducted on them have been described in the before chapter. The results of various characterization tests are reported here. These include evaluation of tensile strength, flexural strength and impact strength, Hardness (Shore D) and Surface morphology that has been studied and discussed.

A. Tensile Test:

Tensile testing of specimen prepared according to ASTM - D638-a sample was carried out, using electronic tensile testing machine with cross head speed of 5mm/min and a gauge length of 120 mm. Observations of tensile properties were presented in Table 1

Designation (samples)	Composition	Tensile strength (MPa)	Tensile modulus (GPa)
S_1	Epoxy + 2 vol.% Aluminium Oxide+3 vol. % Banana fiber	15.288	2.285
S_2	Epoxy + 2 vol.% Aluminium Oxide+5 vol. % Banana fiber	16.522	2.189
S_3	Epoxy + 2 vol.% Aluminium Oxide+8 vol. % Banana fiber	15.671	2.118
S_4	Epoxy + 2 vol.% Aluminium Oxide+10 vol. % Banana fiber	12.169	1.802

Table 2: Tensile strength and tensile modulus of samples

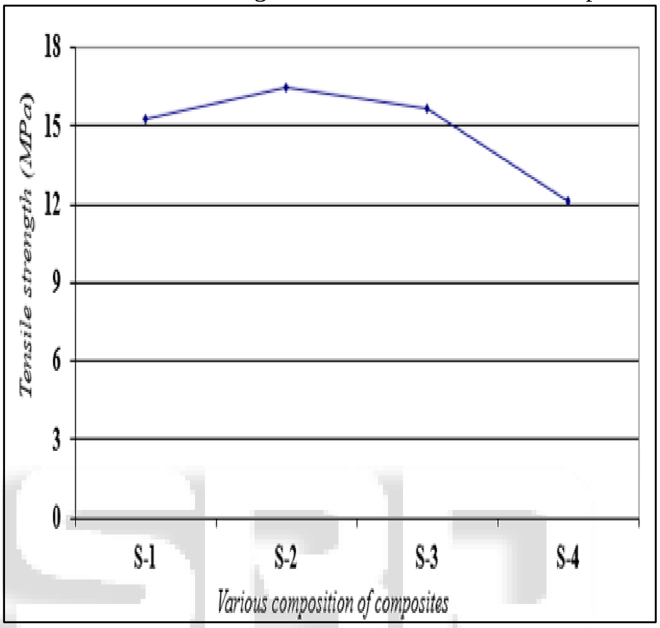

Fig. 4: Variation of Tensile strength for different composition of banana fiber epoxy composites

The tensile modulus and elongation at break of the composites were calculated from the stress strain curve. Four specimens were tested for each set of samples and mean values were reported.

As expected, From Fig - 4 shows that there is gradual increase in tensile strength from 15.288 MPa to16.522 MPa with increase in the banana fiber contents from 3 vol. % to 5 vol.%. However, the influence of banana fiber addition has been significant up to 5 vol. %. This type of behaviour of composites reinforced with banana fiber and filled with aluminium oxide powder filler is due to better interface adhesion with epoxy matrix.

Again when banana fiber content increase to 8 vol.% and 10 vol.%, tensile strength decreases to 15.671 MPa and 12.169 MPa respectively. This decrease in tensile strength is due to the weak chemical bonding and poor adhesion among constituents. Because with increase in the banana fiber vol.% , volume percent of epoxy (matrix) decreases, epoxy work as a binder in composites. The tensile strength in the present work is higher compression with the previous literature J.Santhosh, N.Balanarasimman [9] with untreated banana fiber epoxy composites.

B. Flexural Test:

The flexural test was performed by the three-point bending method according to ASTM D-368-a, and cross head speed of 1 mm/min. The flexural properties were presented below in Table.3

From four sample of composites only Four specimens were tested from each sample, and the average was calculated

Designation (samples)	Composition	Flexural strength (MPa)
S_1	Epoxy + 2 vol.% Aluminium Oxide+3 vol. % Banana fiber	45.425
S_2	Epoxy + 2 vol.% Aluminium Oxide+5 vol. % Banana fiber	23.661
S_3	Epoxy + 2 vol.% Aluminium Oxide+8 vol. % Banana fiber	35.516
S_4	Epoxy + 2 vol.% Aluminium Oxide+10 vol. % Banana fiber	31.431

Table 3: Flexural strength of various samples

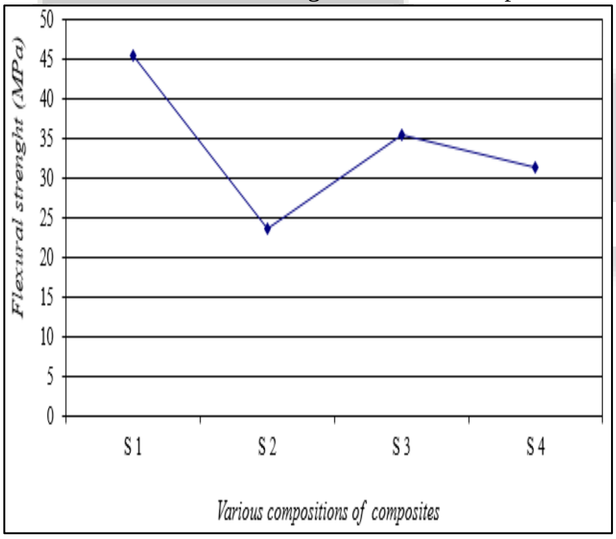

Fig. 5: Variation of Flexural strength for different composition of banana fiber epoxy composites

As expected, from Fig -5 shows flexural strength of samples S1, S2, S3 and S4. In which it is observed that the flexural strength of the composite has increased to 45.425 MPa for sample S1, but it has decreased to 31.43 MPa for sample S4. Investigations have shown that the similar results have been obtained by valente et al. [12] with LDPE/glass/wood flour and PP/glass/wood flour composites and also The flexural strength in the present work is higher compression with the previous literature J.Santhosh, N.Balanarasimman [9] with untreated banana fiber epoxy composites.

The reason behind increase in flexural strength is strong interfacial bonding among the banana fiber, epoxy and dispersed aluminium oxide particles, which act as mechanical interlocking between banana fiber and epoxy. This creates a high friction coefficient.

The decrease in flexural strength is due to a poor interface bonding among the banana fiber, epoxy and dispersed aluminium oxide particles. As the vol. % of banana fiber increases, the vol.% of epoxy (matrix) decreases which makes ineffective the transfer of stress from the matrix to the fibers, thus not allowing a full exploitation of the reinforcement. The poor dispersion of micro sized aluminium oxide particles in the epoxy matrix and possibility of the existence of voids in the samples S2 and S4 due to increase vol. % of banana fiber are another reason for decrease in flexural strength.

C. Impact Test:

The relationship between fiber weight and impact strength is shown inTable-4. The impact property of a material shows its capacity to absorb and dissipate energies under impact or shock loading. The impact energy level of the composites depends upon several factors such as the nature of the constituents, construction and geometry of the composites, fiber arrangement, fiber/matrix adhesion, and test conditions.

Designation (samples)	Composition	Impact strength (KJ/m^2)
S_1	Epoxy + 2 vol.% Aluminium Oxide+3 vol. % Banana fiber	$2.25 KJ/m^2$
S_2	Epoxy + 2 vol.% Aluminium Oxide+5 vol. % Banana fiber	$2.45 KJ/m^2$
S_3	Epoxy + 2 vol.% Aluminium Oxide+8 vol. % Banana fiber	$2.55 KJ/m^2$
S_4	Epoxy + 2 vol.% Aluminium Oxide+10 vol. % Banana fiber	$3.33 KJ/m^2$

Table 4: Impact strength of various samples

As expected, Fig-6 shows that resistance to impact loading of aluminium oxide composites improves with addition of banana fiber. It is seen that impact strength increases from 2.25 KJ to 2.45 KJ with 3 vol.% and 5 vol.% addition of banana fiber and then it continues increases to 2.55 KJ and 3.33 KJ with addition of 8 and 10 vol.%. of banana fiber respectively. Similar observations have been found by cui and tao [10] for fiber reinforced wood plastic composites. Mareri et al. [11] reported that mobility of polymer chain is constrained by filler content, therefore the content of fiber and particulates is to be decided very carefully before any specific application, keeping the strength in mind.

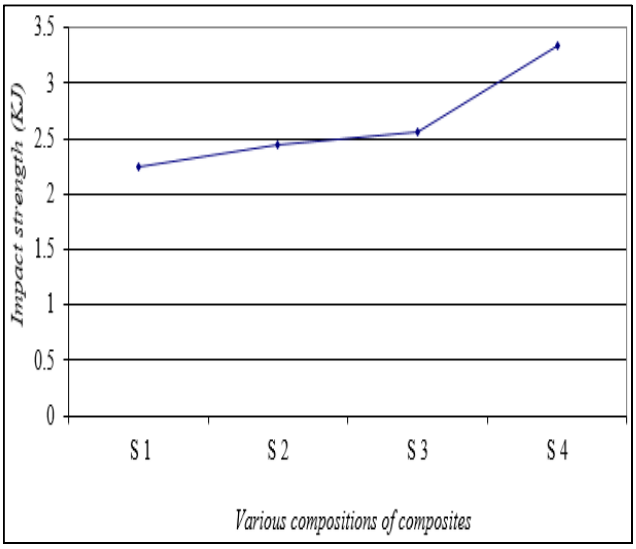

Fig. 6: Variation of Impact strength for different composition of banana fiber epoxy composites

D. Hardness Test:

Hardness may be defined as a material's resistance to permanent indentation. The hardness of plastics is most commonly measured by the Shore hardness test, which measures the resistance of plastics toward indentation and provides an empirical hardness value.

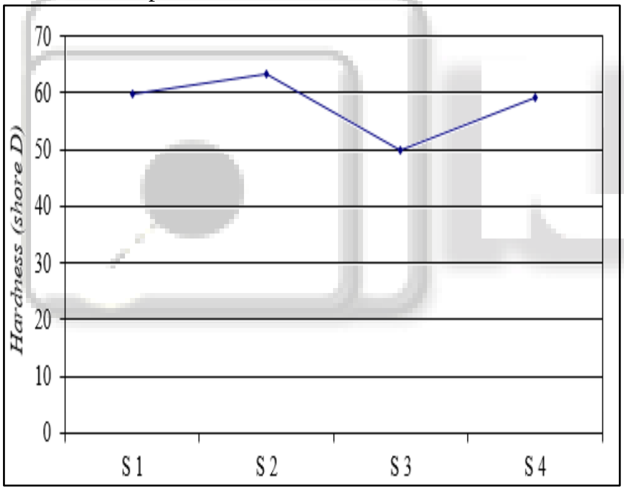

Fig. 7: Variation of Hardness (Shore D) for different composition of banana fiber epoxy composites

As Fig-7 shows increased hardness with increase in vol. % of banana fiber. Hardness is considered to be one of the important factors in composites for determination of wear rate. With the increase in banana fiber content from 3 vol.% to 5 vol.% hardness increases from 59.8 to 63.2. The hardness number in the present work is higher compression with the previous literature J.Santhosh, N.Balanarasimman [9] with untreated banana fiber epoxy composites.

E. Surface Morphology:

The SEM observations explain the results presented in the Figure 8 for banana fiber reinforced epoxy composites by the Instrument JSM-6390 with the range of 2 µm,5 µm, 10 µm,50 µm.The Optical micrographs of fracture surfaces of different composition are shown in figure 4. Figure 8 (a) shows a homogeneous dispersion of the reinforcement. This has been achieved by hand layup fabrication process and it also exhibits a relatively rough fracture surface with presence of voids (in a circle). In figure 8 (b), the presence of epoxy and Al2O3 mixture adhering to the banana fiber surface suggests about the strong interfacial adhesion in composites.

In figure 8 (c), the surface of the sample is rough, indicating that the adhesion among the constituents is poor. A weak interfacial bonding result in easy separation of fiber from the resin and particulates mixture and the crack prefers to propagate along the weak interfaces. Figure 4 (d) shows some localized agglomerations of Al2O3 at higher volume fraction of Al2O3.

The micrograph obtained in the present work is in good agreement with the previous literature J.Santhosh, N.Balanarasimman [9].

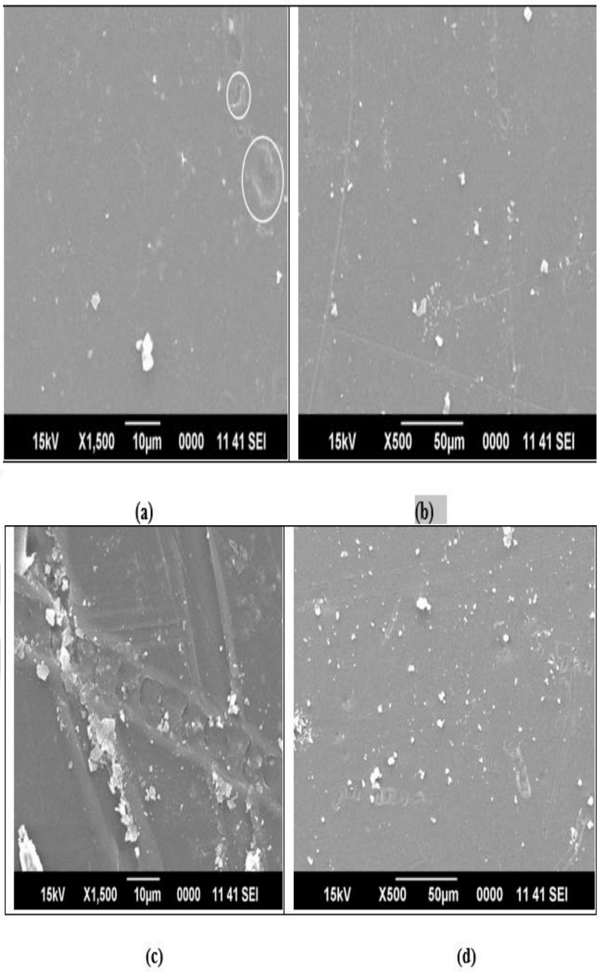

Fig. 8: Surface morphology of different composition of banana fiber epoxy composites.

IV. CONCLUSION

In this work, Mechanical properties of banana fiber/epoxy, composites were investigated. It has been observed from the literatures [1 -6, 6-12] were compared the resulting mechanical properties. The tensile, flexural and impact properties of the composites as a function of fiber content were analyzed. The work demonstrates that hybridization of aluminium oxide particulate with banana fibers is successfully achieved by hand lay-up method (a fabrication technique). The micrographs of the composites demonstrate that a uniform dispersion of banana fiber and AL2O3 particulates has been achieved. The results shows that the value of tensile strength, Impact strength and flexural strength as well Hardness value of the composites are improved when compared with the previous literature J.Santhosh, N.Balanarasimman [9].

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