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Research Article

Study on Mechanical Behavior of Banana Fiber Reinforced Epoxy Composites

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ABSTRACT

Natural fiber composites are nowadays being used in various engineering applications to increase the strength and to optimize the weight and the cost of the product. Various natural fibers such as coir, sisal, jute, coir, and banana are used as reinforcement materials. In this paper, both treated and untreated banana fibers are taken for the development of the hybrid composite material. The untreated banana fiber is treated by sodium hydroxide to increase the wettability. The untreated banana fiber and sodium hydroxide treated banana fiber are used as reinforcing material for both epoxy resin matrix and vinyl ester resin matrix. Coconut shell powder is used along with both untreated and treated banana fibers as a reinforcing material. In this process, the banana fiber is treated with 5% of sodium hydroxide for 1 h and the specimen is fabricated by hand lay-up process. The mold used for fabricating the hybrid composite material is made up of aluminum with a debonding agent applied on the inner side. The banana fiber content is kept constant to 30% of weight fraction of entire composite material. The variation in mechanical properties is studied and analyzed. Here, the tensile strength has calculated by universal testing machine, impact strength has calculated by pendulum impact tester, and flexural strength has calculated by universal testing machine with flexural test arrangement of the specimen. Then, the treated and untreated specimens are analyzed and compared through scanning electron microscope to study about its adhesion between fiber and resin matrix and surface morphology.

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INTRODUCTION

The world is as of now concentrating on alternate material source that is environment agreeable and biodegradable in nature. Due to the expanding natural concerns, biocomposite produced out of regular fiber and polymeric resin is one of the late advancements in business. The use of composite materials field is increasing gradually in engineering. Fiber reinforced polymer composites have numerous preferences due to minimal effort of creation and better quality contrast than perfect polymer tars. Satyanarayana *et al.*[1] studied that natural fibers have numerous points of interest contrasted with glass fiber as natural fibers have low thickness; they are biodegradable and recyclable. Banana reinforced polymer composite has a high impact of fiber loading and length of fiber on the properties of composites.[1] Kulkarni *et al.*[2-5] studies show that banana fiber can obtain from fruit and stem of the plant and is abundantly cultivated. Many researchers have done investigations on different types of natural fibers such as cotton, bamboo, wheat, and barley to study the mechanical properties of composite materials. Merlini *et al.*[6,7] have studied the effect of surface treatment on the chemical properties of banana fiber and reported that treated banana fiber gives higher shear interfacial stress and tensile strength when compared with the untreated fiber. Venkateshwaran *et al.*[8-10] studied the mechanical properties of tensile and flexural strength of banana/epoxy composite material. Thiruchitrambalam *et al.*[11] have investigated the influence of fiber content and length on short banana fiber reinforced polyester composite material. They also studied the physical and mechanical behavior of banana fiber reinforced polymer composite and noticed that kraft mashed banana fiber material has better flexural strength. The banana and glass fiber biocomposites may be used to fabricate outdoor and indoor applications where high strength is not necessary and it can be considered as the replacement to wood materials and protect the forest resources. In this present work, to improve the mechanical properties, the banana fibers of different lengths are treated with different weight % epoxy resin. The banana fibers are used as reinforcement in epoxy resin.

MATERIALS AND METHODS

Chemical treatment

Banana fiber was collected from local banana plant source, Bengaluru, India. The extracted banana fibers were subsequently sun-dried for 8 h and then dried in the oven for 24 h at 105°C to remove free water present in the fiber. The dried fiber was cut into lengths of 5, 10, and 15 mm. Then, the dried fibers were treated with different weight % epoxy resin for 24 h. The fibers are then washed thoroughly with distilled water. Fibers are then dried in oven for 2 h at 100°C to remove the moisture present in it.

Matrix

Epoxy resin and hardener are procured from Ciba Geigy India Ltd. As per the ASTM standards, the matrix is formed with nine different combinations untreated and treated fiber reinforced epoxy resin composite.

PREPARATION OF THE COMPOSITE

By hand lay-up technique, the composite is fabricated. The molds have been prepared with dimensions of 180 mm × 180 mm × 40 mm^3. The banana fiber of different length has been mixed with matrix mixture with their respective values by simple mechanical stirring and mixtures were slowly poured into molds. The releasing agent has been used on the mold sheet which gives easy to composite removal from molds after curing the composites. A sliding roller has been used to remove the trapped air from the uncured composite and mold has been closed at temperature 30°C for 34 h duration. The constant load of 50 kg is applied on the mold, in which the mixture of the banana, epoxy resin, and hardener has been poured. After curing, the specimens were taken out from molds and the composite material is cut in suitable dimensions with the help of zig saw for mechanical tests as per the ASTM standards.

Designation	Composition
C1	Fiber length (5 mm) (10 wt%) + Epoxy (90 wt%)
C2	Fiber length (5 mm) (15 wt%) + Epoxy (85 wt%)
C3	Fiber length (5 mm) (20 wt%) + Epoxy (80 wt%)
C4	Fiber length (10 mm) (10 wt%) + Epoxy (90 wt%)
C5	Fiber length (10 mm) (15 wt%) + Epoxy (85wt%)
C6	Fiber length (10 mm) (20 wt%) + Epoxy (80 wt%)

Tensile test

Figure 1 shows the specimen prepared for tensile test. The specimen size was 150 × 15 mm^2 and gauge length was 70 mm. The tensile strength was tested in Instron machine 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. Here, Figure 2 indicates a broken piece during the tensile test.

Flexural test

The capacity of a material to resist deformation under the load applied is known as flexural strength. The specimen dimension for flexural test was 100 mm × 15 mm × 70 mm. Due to inter laminar shear, fiber failure takes place, which is observed in a three point bend test. Using Universal Testing Machine Instron 1195, the test is conducted. The loading arrangement for flexural strength test is shown in Figure 3.

Flexural MR is about 10–20% of compressive strength depending on the size, volume, and type of coarse aggregate used. Anyway, the best correlation for specific materials is obtained by laboratory tests for given materials and mix design. The maximum fiber stress at failure on the tension side of a flexural specimen is considered the flexural strength of the material. Thus, using a homogeneous beam Equation (1), the flexural strength in a three-point flexural test is given by,

$$\sigma_f = \frac{3FL}{2bd^2} \quad (1)$$

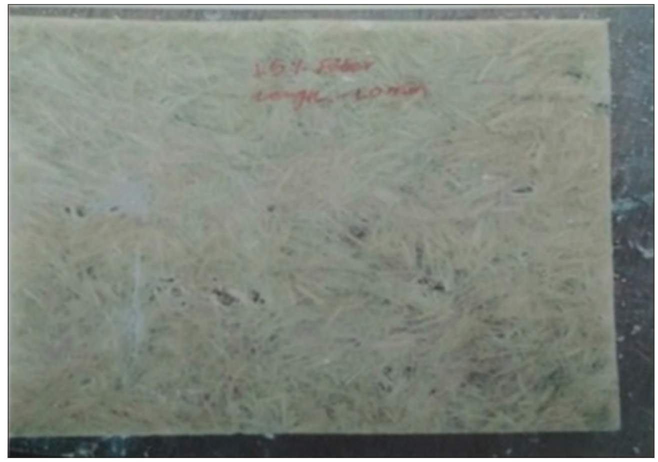

Figure 1: Tensile test specimens

Figure 2: Tensile specimen in Instron Machine

Figure 3: Flexural test arrangement

Where,
P_{max}= Maximum load at failure
b = specimen width
h = Specimen thickness and
L = Spcimen length between the two support points

Impact test

Impact is a single-point test that measures a material 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. Figures 4-6 shows the impact testing observation during the experimental work.

Hardness test

Hardness is the ability to oppose the indentation, which is obtained by measuring the stable depth of the indentation. In the Vickers hardness test, a square base pyramid shaped diamond is used for testing.

Fabricated composite was cut in a dimension of 20 m × 20 mm for hardness test. The hardness test was conducted in Vickers hardness test machine. 0.3 kg of load was applied on the composite and the load was held for 10 s. The experimental setup for hardness test is shown in Figure 5.

Figure 4: Impact testing of the specimen

Figure 5: Experimental setup for Hardness testing of the specimen

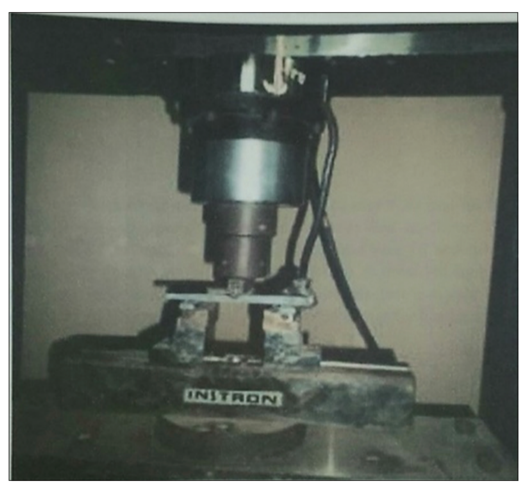

Figure 6: Three point bend test loading arrangement for Impact strength test

RESULTS AND DISCUSSIONS

This chapter deals with the mechanical properties of the treated/untreated banana fiber/epoxy and treated/un-treated banana fiber composites prepared for this present investigation.

Mechanical properties of composites

Mechanical properties of composites such as flexural strength, tensile strength, hardness, and impact strength have been investigated. The mechanical property of the composites mainly depends on fiber content and length.

Influence of fiber parameters on tensile strength

The influence of fiber length and loading on tensile properties of composites is shown in Figure 6. It has been observed that the tensile strength of composites increases with an increase in fiber length and loading.

Influence of Fiber parameters on flexural Strength

Figure 7 shows that, the flexural strength of the fabricated composites increases up to 10 mm of fiber length and then decreases. When fiber loading increases, then flexural strength increases up to fiber loading 15% and then decreases. The maximum flexural strength is observed when fiber length is 10 mm and loading is 15%.

Influence of fiber parameters on impact strength

Figure 8 shows that impact energy increases with an increase in fiber length. It also shows that the impact energy increases with increase in fiber loading. Maximum impact energy is absorbed by the fiber length material of 15 mm and 20% of fiber content.

Influence of fiber parameters on hardness

Figure 8 shows that the hardness value increases with an increase in fiber length and it is maximum at 10 mm fiber

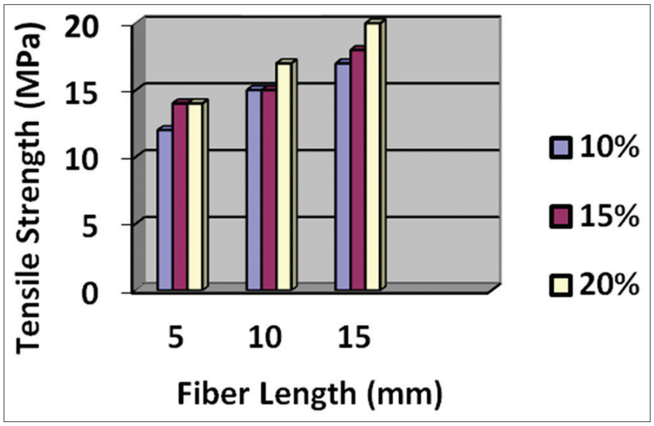

Figure 7: Influence of fiber parameters on tensile strength

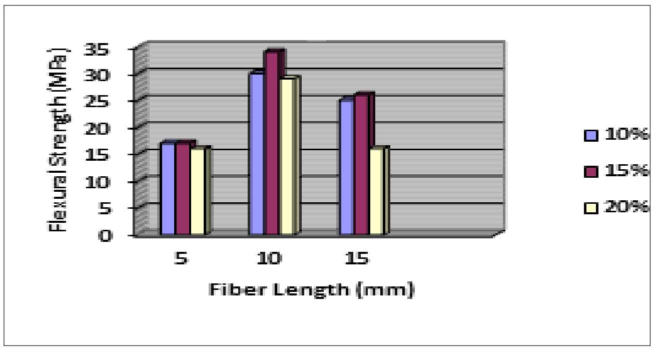

Figure 8: Influence of fiber parameters on flexural strength

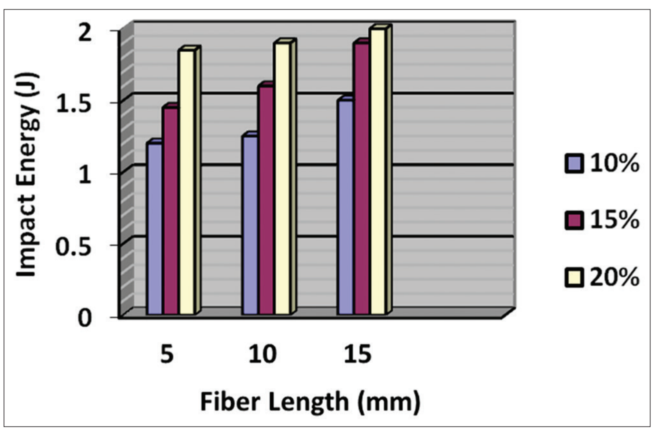

Figure 9: Influence of fiber parameters on Impact strength

length. However, the hardness value increase with increase in fiber loading up to 15 wt% and then the hardness value decreases.

Observations of tensile properties are presented in Table 1.

SURFACE MORPHOLOGY

Scanning electron microscope (SEM) images of untreated, alkali-treated fiber composite specimens are shown in Figures 9 and 10. Figure 11 shows the SEM of untreated composite after tensile test, and it reveal that the arrangements of fiber are not dense and voids are present in it, so mechanical properties yield poor in this category.

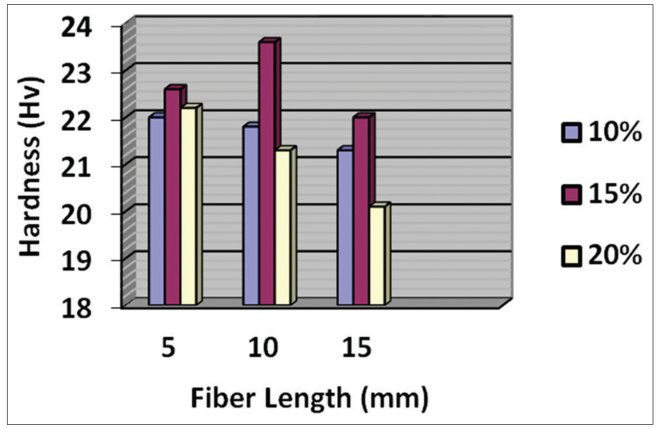

Figure 10: Influence of fiber parameters on Hardness

Figure 11: Untreated scanning electron microscope image (×500) of banana fiber epoxy composite

Figure 12 is the SEM view of alkali-treated banana fiber composite sample after the tensile investigations. This image reveals that treatment has improved the property by adhesion between fiber and matrix which turn improved the mechanical strength. From the image, we can say that the distribution of hybrid resin is dominated the fiber effect. Hence, the results compared to the treated fiber shows a better result in these investigations.

CONCLUSION

In this work, mechanical properties of untreated/alkali-treated banana fiber/epoxy and untreated/alkali-treated banana fiber composites were investigated. The tensile, flexural, impact, and hardness properties of the composites as a function of fiber content are analyzed.

The fabrication of banana fiber epoxy-based composites with different loading of fiber and different lengths of the fiber is possible by hand lay-up process. From the current experiment results, it has been observed that fiber loading and length have major effect on the mechanical properties of composites such as tensile strength, flexural strength, impact strength, and hardness.

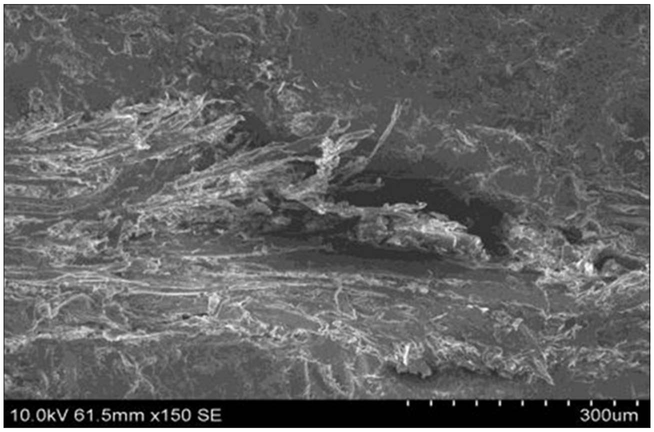

Figure 12: Alkali treated scanning electron microscope image (×300) of banana fiber epoxy composite

It has been observed that the better mechanical properties found for composites reinforced with 10 mm fiber with 15% fiber loading

SCOPE FOR FURTHER STUDIES

This work can be further extended by preparing hybrid composites using different reinforcements in varying proportions and various mechanical properties of these composites can be compared.

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