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Mechanical characterization of drumstick fiber reinforced epoxy composite

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ABSTRACT
The focus of this paper is using drumstick fiber and epoxy resin to manufacture a composite material offering high strength to weight ratio as compared to most conventional materials. As drumstick is very available in winter in our country, it can be a new source of fiber to replace the expensive and non-renewable synthetic fibers, so products can be produced cost effectively. The research is mainly focused on the manufacturing of the drumstick fiber reinforced epoxy composite and investigates the mechanical properties such as the tensile, flexural and impact strength of the manufactured composite. The tensile and flexural strength of the manufactured composite are on average 11.77 MPa and 41.032 MPa respectively. The tensile strength is quite close to the tensile strength of plastic. However, the flexural strength is much lower. Thus, it can be used as a replacement of plastic where flexural stress can be ignored. Also the fibers can be chemically modified to enhance the properties.

Key Words: Composite material, drumstick fiber, epoxy resin, tensile strength, flexural strength.

1. Introduction

A composite is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure, differentiating composites from mixtures and solid solutions.
For a very long time, people have been fabricating composites. From the history, it is found that people from Israel, China and Egypt were familiar with the fabrication of composites [1, 2].
Composites are generally classified by the type of reinforcement materials they use. This reinforcement is embedded into a matrix that holds it altogether. Thus, the composite provides high strength and stiffness as well as a high strength to weight ratio. In general, the most common types of composites are metal composite, fiber reinforced polymer composite (FRPC), bio-degradable composite etc.
The basic formation of FRPCs includes the use of synthetic fibers such as carbon, glass, aramid, Kevlar etc. Aside from high strength and high stiffness, these composites have long fatigue life and adaptability to the intended function of the structure.
In the recent years, much attention has been paid to the research of natural fiber reinforced polymer composites. Natural fiber is considered as one of the environmentally friendly materials, which have good properties compared to synthetic fiber [3]. In natural fiber reinforced composites, fibers are extracted from natural sources such as trees, leaves, pulp, animals etc. instead of using synthetic fibers. Composites with natural fibers have many advantages such as lower density, better thermal insulation and reduced skin irritation. Another beneficial side of using natural fiber is their biodegradability. Fibers such as glass, aramid, basalt, polycrylonitrile etc. are not biodegradable. Most of these are petroleum base products. In one hand, they are depleting rapidly, on the other hand, they are damaging the environment. Therefore, to reduce environmental damage, to alleviate the green house effects, to decrease the use of fossil fuels, the use of natural fibers has caught the eyes of researchers.
Basically, the fiber phase of a composite is used for the load carrying purpose because the fibers generally have high strength. So, literally it is clear that the fiber provides the basic tensile strength of a composite. On the other hand, the matrix phase holds the reinforcement phase and the loads are uniformly distributed through it. Also the matrix phase provides protections to the reinforcements from external effects. So, the fiber phase of the composite holds a heavy importance to enhance the mechanical properties. In most cases, the natural fibers used are Jute, Sisal, Kenaf, Flax, Banana etc. However, there are also some natural fibers which do not provide much strength to the composite. To overcome this, hybridization of the fibers is done.
Drumstick is got from Moringa Oleifera tree, which is generally used as a vegetable. It is an uncommon material which is full of fibers inside and is 1 to 1.5 feet tall. The fibers can easily be extracted and are strong enough to be used as a reinforcement material in composite.

2. Experimental Procedure

2.1 Materials

Drumstick fiber and epoxy resin (LY 556) with hardener (HY 951) at room temperature was selected for the fabrication of the composite. Drumstick fiber is an uncommon type of fiber so, it was extracted from the raw drumstick following a long procedure.

2.2 Fiber Extraction

The fiber was extracted by smashing and keeping the raw drumsticks under filthy water for 15 days. This caused the lignin bonds to rot and only the fibers were left. After that, the fibers were kept under bright sunlight and tilted so that rest of the lignin falls off. After drying the fibers,

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they were sewed in a plate-like shape to perform as the reinforcement material.

Fig.1 Raw Drumstick

Fig.2 Extracted Drumstick fiber

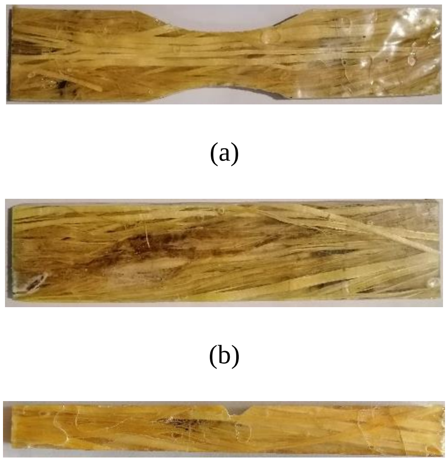
2.3 Composite Fabrication: Hand Lay-up Process

In fabricating the composite, a hand layup process was used [4-5]. The drumstick fiber was used as reinforcement and epoxy resin was used as matrix material. The following procedures were followed during the fabrication:

A mold of stainless steel was at first wrapped with polythene. In this case, the smoother the mold surface, the better will be the quality of composite surface. Thus two plates of stainless steel on the bottom and above created the mold inside which, the composite was to be prepared.

Then the plate-like fibers were cut as per the mold size (12×12 inch.). On the other hand, the epoxy resin and hardener were mixed in 10:1 ratio. Then the mixture was poured on the mold plate and spread out evenly on the plate with a brush. Then one fiber plate was set upon the mold plate and rolled with a roller so that no bubbles could take place inside the laminate. Then again some resin were poured, spread and another fiber plate was put upon the previous one. This procedure was followed till four fiber plates were used. Approximately, 600 gm. of resin and hardener mixture was used for the fabrication of one composite plate.

Finally, the laminate was kept under high pressure for over 24 hours. This provided the laminate proper thickness. As the resin and hardener mixed and worked well in room temperature, no temperature control was required. Then the mold was opened, and the polythene was removed to get the composite plates. Three composite plates were fabricated, and they were cut in different shapes for different tests according to the test standards.



(a)

(b)

(c)

Fig.3 Photographic view of test specimens (a) Tensile test specimen (b) Flexural test specimen (c) impact test specimen.

2.4 Tensile Test

The most common tests for natural fiber reinforced composites (NFRC) are the tensile test, flexural test and impact test. These three types of tests were performed in this study. Tensile test determines the materials behavior under tension load. In the simplest case, a material is elongated to its breaking point to find out the ultimate tensile strength of that material. The basic measuring criteria are the applied force and elongation. Universal Testing Machine (UTM) was used for the tensile test cutting the composites in a dog-boned shape according to the standard ASTM D638 [6]. Dimensions of samples were (150×30×7.5) mm. The test was performed applying tension stress until failure. The strain rate used in the test was 10mm/min. From the test results, the stress-strain curve was plotted. To measure tensile strength, following equation was applied:

$$\sigma_u = \frac{F}{A}$$

Tensile modulus was determined from the slope of the stress-strain diagram.

2.5 Flexural Test

The flex or bending strength of a material is determined by the flexural test or three-point bending test. It is initiated by placing a specimen between two supports and applying a load by the third point. Flexure test is performed in order to measure flexural strength and flexural modulus. The maximum stress either tension or compression, developed at the outer fiber of the composite is its flexural strength. Flexural modulus is calculated from the slope of the stress vs. strain deflection curve. In the test, a strain rate of 5 mm/min was used. For flexural test, uniform rectangular specimens were cut according to the ASTM D7264 standard [7].

To determine the flexural strength, following equations were applied:

$$\sigma_f = \frac{3FL}{2bt^2}$$

Flexural modulus was determined from the slope of stress-strain diagram.

The tensile and flexural modulus of elasticity were calculated from the experimental data. Also, the slope of the stress-strain diagram is the measurement of the modulus of elasticity.

$$Modulus\ of\ elasticity = \frac{Change\ in\ stress}{Change\ in\ strain}$$

2.6 Impact Test

Impact tests are used to determine a materials ability to withstand impact force as well as the materials toughness. The Izod impact testing procedure was followed and uniform rectangular shaped specimens containing a V-notch at the middle were prepared. The standard followed for impact testing of the composite is ASTM D5628. To determine the energy absorption, following equation was applied:

$$E_i = mg(h_2 - h_1)$$

3. Results and Discussion

In this experiment, three samples were taken for each test. In fig. 4 and fig. 5, stress vs strain and stress vs displacemnt graph of tensile and flexural test respectively are showed. In case of tensile testing, sample 1 and 2 shows almost the same property where sample three has some deviations. In flexural testing, sample 1 and 3 has close values but sample 2 shows huge deviation. However, all the curves abide by the Hook's law which is strain is proportional to the applied stress within the elastic limit of a material. The deviations may have been caused due to the non-uniformness of fibers inside the composite.

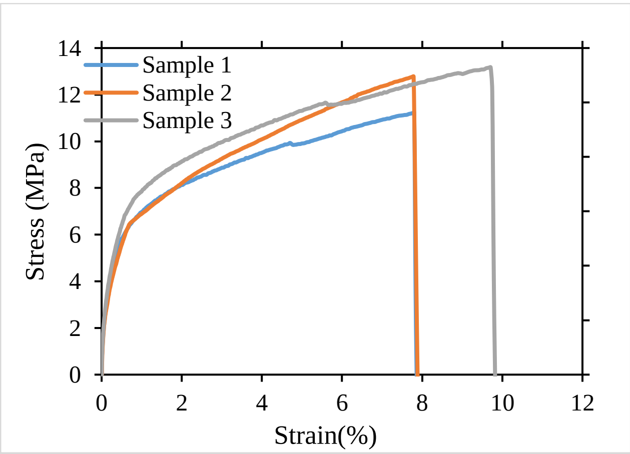


Fig.4 Stress vs strain graph of tensile test

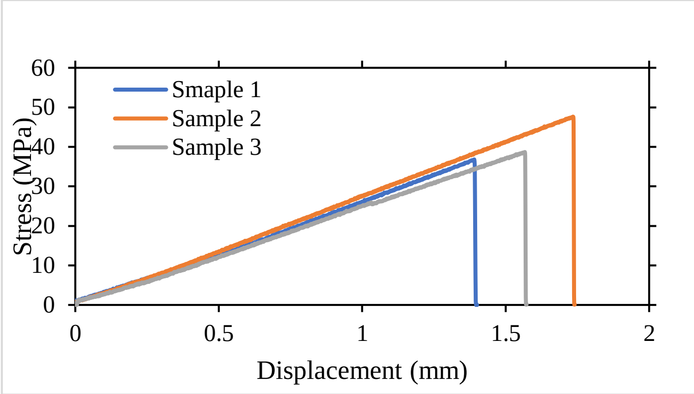


Fig.5 Stress vs displacement graph of flexural test

Table 1 Experimental results of tensile, flexural and impact test.

Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (KJ/m^2)
11.77 ± 0.875	41.03 ± 5.784	8.33 ± 0.404

Table 2 Experimental results for tensile and flexural modulus of elasticity.

Type of test	Modulus of elasticity(MPa)
Tensile	1211.1 ± 206.88
Flexural	25.66 ± 1.44

To understand the properties of the manufactured composite, a comparison with a common material or composite is required. In the following table and figures, the average tensile, flexural and impact strengths of the manufactured composite is compared to the properties of a coir fiber reinforced epoxy composite [8-9].

Table 3 comparison of tensile, flexural and impact strength.

Fiber	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (KJ/m^2)
Drum-stick	11.77 ± 0.875	41.03 ± 5.784	8.33 ± 0.404
Coir	17.86±2.32	31.08±6.01	11.49±0.99

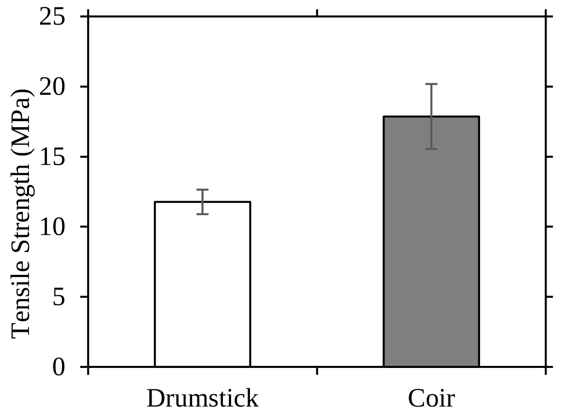


Fig.5 Comparison of tensile strength.

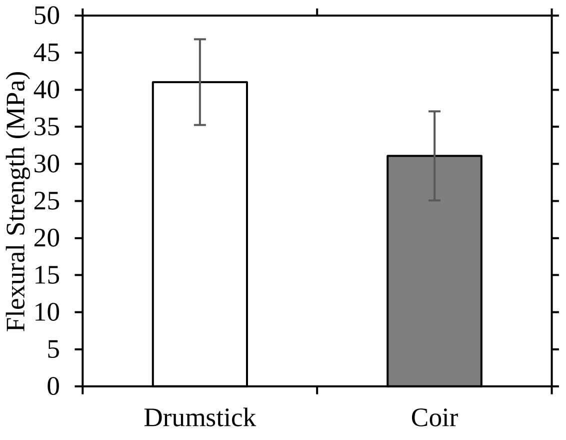


Fig.6 Comparison of flexural strength.

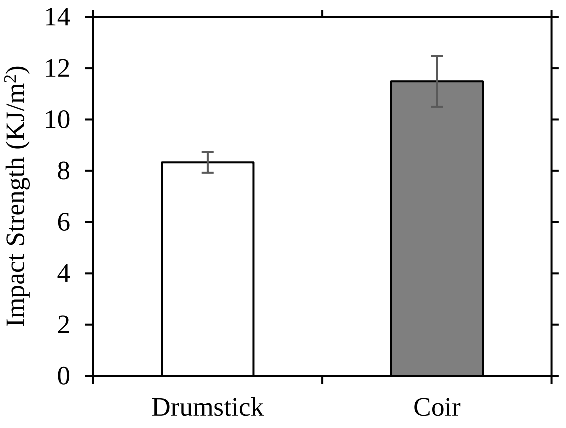


Fig.7 Comparison of impact strength.

The coir fibers were raw fibers and its composite had lower tensile, flexural and impact strength; still higher than the drumstick fiber reinforced epoxy composite. Although the flexural stress was higher in case of drumstick, the results are not overall satisfactory.

From the above comparisons, it is clear that the tensile and flexural properties measured for the manufactured composite were not appealing. The composite has very low tensile, flexural and impact strength compared to other composites or materials. So, the composite is not applicable for any practical process. However, the fibers used in this test were raw drumstick fibers. So, the properties of the composites maybe enhanced by chemical modification. Also, the fibers can be used with some other fibers to form hybrid composites.

4. Conclusion:

Because of the uniqueness of the fiber, and as only a few works have been performed on the drumstick fiber, the composite was manufactured and its properties were analyzed. The study leads to the following conclusion:

A composite consisting of four layers of drumstick fiber was prepared. It was cut in different shapes according to the standards for tensile, flexural and impact testing. However, the results were not satisfactory. But, being a very uncommon fiber, there is still huge scope remaining to work on it.

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