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MECHANICAL PROPERTY EVALUATION OF BI-DIRECTIONAL ETHIOPIAN BANANA FIBER EPOXY COMPOSITES

Jegan Raj[1], Thomas Gebre[2], Idiris Mehamud[3], Cheru Zeleka[4]

[1,2,3,4] Department of Mechanical Engineering,

College of Engineering and Technology, Wolkite University, (Ethiopia)

ABSTRACT

In the fast developing world, the concern for environmental pollution and the prevention of non-renewable and non- biodegradable resources have attracted researchers seeking to develop new eco-friendly materials and products based on sustainability principles. Ethiopia as a country whose economic sector depends on agricultural products has great potential to develop and utilize fiber derived from Agricultural waste. Banana and false banana fibers which are important by-products of farmer food processing are discarded as waste in gurage zone. These fibers can be used as reinforcement in composite products. The fibers from the natural sources provide indisputable advantages over synthetic reinforcement materials such as low cost, low density, non-toxicity, comparable strength, and minimum waste disposal problems. In the present experiment banana fiber reinforced epoxy composites are to be fabricated and the mechanical properties of these composites are to be evaluated. The composite samples with different fiber volume fractions are to be prepared by using the hand lay-up process. The samples are to be subjected to mechanical testing such as tensile, flexural and impact loading. Scanning electron microscope (SEM) analysis will be carried out to evaluate fiber breakdown mode, internal structures, and the structure of the fractured surfaces.

Keywords: Banana, Epoxy, Tensile, Flexure, Impact Strength, Scanning Electron Microscopy.

I. INTRODUCTION

A fiber reinforced polymer (FRP) is a composite material consisting of a polymer matrix embedded with high-strength fibers, such as glass, aramid and carbon. Generally, polymers can be classified into two classes; thermoplastics and thermosetting.

Thermoplastic materials currently dominate, as matrices for bio-fibers; the most commonly used thermoplastics for this purpose are polypropylene (PP), polyethylene, and poly-vinyl-chloride (PVC); while phenolic, epoxy and polyester resins are the most commonly used thermosetting matrices.

Focus on the development of natural fibers like jute, coir, sisal, pineapple, ramie, bamboo, banana etc., is to explore its application in low load condition. Composites, the wonder material with light-weight, high strength-to weight ratio and stiffness properties have come a long way in replacing the conventional materials like metals, woods etc. The replacement of steel with composites can save a 60-80 percentage of component weight and 20-50 weight percentages with the aluminum components. The polymer based composite materials use is increasing because of their light weight and good mechanical responses [Ramesh *et al.,* 2012].

The material scientists all over the world focused their attention on natural composites reinforced with banana, jute, coir, sisal, pineapple, ramie, bamboo primarily to cut down the cost of raw materials is to explore its application in low load condition.

The composites can be prepared with desired properties by orienting the fibers according to the application. The composite are comparatively cheaper to manufacture and there are various manufacturing processes available for the composites. The surface finish of the composite is comparatively much higher and it can be manufactured in different techniques. The use of composites has given more flexibility to design engineers to develop new design and for modifications in the existing design. Since the composites are easier to handle and synthesize. The fabrication of composite by using short jute fiber of length 2 - 3 mm with polypropylene as resin was carried out. The composites were prepared considering fiber by weight 20% and resin by weight 80% using compression molding. The mechanical properties were evaluated such as flexural strength, tensile strength, impact strength, and tensile modulus, elongation at break, flexural modulus and hardness of the composites [Khan *et al.,* 2012].

Natural fibers exhibit superior mechanical properties such as flexibility, stiffness and modulus compared to glass fibers [Goulart, 2011]. In the recent days natural fibers such as sisal and jute fibers are replacing the glass and carbon fibers owing to their easy availability and cost [Silva *et al.,* 2010].

The mechanical and water absorption properties of banana/sisal reinforced hybrid composites for taking the length of the fiber and weight percentage as main constituent. They have reported the hybridization of sisal fiber with banana/epoxy composites up to 50% by weight increasing the mechanical properties and decreasing the water absorption properties [Venkateswaran *et al.,* 2011].

Now-a-days, natural fibers reinforced composites exhibit the superior mechanical properties than synthetic fiber reinforced polymer composites due to its inherent properties. The mechanical properties such as tensile strength, flexural and impact strengths of natural and synthetic fibers reinforced polymer composites with different fiber volume were evaluated. The result indicated that, there is the significant improvement in mechanical properties and the process of hybridization reduces the risks related to the environmental concern [Ramesh *et al.,* 2013].

Sapuan *et al.*[2006] fabricated the composites by using banana fiber is a waste product of banana cultivation and which is easily available in tropical countries like Malaysia and south India. This fiber has many advantages and holding high mechanical strength when compared to the synthetic fibers. They have prepared three samples with different geometries and evaluated the maximum stress value and young's modulus along two directions and found the maximum deflection under the maximum load conditions.

Ramesh *et al.* [2013] carried out an experiment to evaluate the tensile and flexural properties of hybrid composites and the results are compared. Form the experiment, they found that the incorporation of natural fibers such as sisal/jute with glass fiber improve the tensile and flexural strength and these composites play a vital role in the field of engineering and technology. They suggested that these hybrid composites can be used for medium strength applications.

At present the banana fiber is a waste product of banana cultivation, therefore without any additional cost these fibers can be obtained for industrial purposes [Joseph et al., 2002].

After the composite development to meet the challenges of aerospace sector, researchers have focused to cater to needs of domestic and industrial applications. The abundant availability of natural fibers such as jute, coir, sisal, pineapple, ramie, bamboo, banana etc., has given an impetus to the development of natural fiber composites. This development is done considering the deforestation (depletion of forest resources) with an objective of returns for the cultivation of natural fibers. Composite boards have been used in development of panel and flush doors to satisfy the low cost housing needs. Other product development such as panel roofing sheets with sisal fibers and glass added to jute fiber produces large increase in mechanical properties of composites. Since natural fiber composite being cost effective materials finds it application in building, construction industry (panels, false ceilings, partition boards etc.), packaging, automobile & railway coach interiors and storage devices[Dieter *et al.,* 2003; Haydar *et al.,* 2009].

II. EXPERIMENT

2.1. Materials and Method

As initial work before experiment investigation; banana fiber in a single ribbon form is extracted in four cycles from three places, Emdiber, Agana and Wolkite in southern part of Ethiopia .The method used to extract fiber is traditional, by using metal and human hand to rub the bananas stem in order to remove the cellulose component from the fiber parts. The polymer composites are fabricated by hand lay-up technique.

2.2.Mechanical Properties of Composites

2.2.1.Tensile test

The mechanical behavior of the composites prepared with the fabricated samples was tested in the Universal Tensile testing machine with testing load range of maximum 5 Ton with gear rotation speed of 1.25,1.5,2.5 mm/min. The experiments were conducted at normal room temperature .The test specimens were cut as per ASTM standards using water jet machining. The tensile strength was determined as per ASTM D638 with standard gauge length of 50mm, with a cross head seed of 1.25 mm/min.

2.2.2. Impact test

Impact strength of the composite specimens was carried out in Izod impact testing machine according to ASTM A370 standard. The specimen size was 65.5*12.7*3 mm with depth under notch of 2.5mm .The Charpy impact test, is a standardized high strain rate test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's toughness and acts as a tool to study temperature-dependent, ductile-brittle transition.

2.2.3. Flexural test

The flexural test measures the force required to bend a beam under three point loading situations. The three point bending test was performed in accordance with ASTM D790 standards .The samples were cut into 50.8*12.7*3 mm respectively. The data is often used to select elements for parts that will support loads without inflection. Flexural modulus is used as an indication of a material's stiffness when inflection. Since the physical properties of many elements can vary depending on ambient temperature, it is appropriate to test materials at temperatures that simulate the intended end user environment.

III.RESULT AND DISCUSSION

The use of banana fiber nowadays has become popular, especially in Asian country like India, Indonesia, and Malaysia, to replace metals, alloys, and glass-fiber; as well as due to its advanced benefits like recycling, biodegradability and eco-friendliness. Many researchers have tested the different properties of banana fiber and its composite, but Ethiopian banana which is very similar to false banana stem but different in some cases is not under consideration, since it’s not popular in most countries. Since this banana is popular in Ethiopia this research presents the evaluation of mechanical properties of this plant in the form of epoxy composite. Specimen is for tested for tensile, impact and flexural strength with corresponding testing method. The table below shows the result of experiment for each mechanical property evaluated from different specimen investigated according to experiment procedure. The result indicates that bidirectional banana fiber has very good mechanical property which is increased in relation to epoxy content. Experiment results of the banana composite samples are given in Table. 1.

Table 1.Tensile, Flexural and Impact properties of different composites samples

Fraction by weight %	Tensile strength(MPa)	flexural strength(MPa)	Impact strength(Joules)
5% Banana + 95% resin	67.5	390.442	6.7
10% Banana + 90% resin	60.3	338.375	4.4
15% Banana + 85% resin	56.6	272.287	3.1
20% Banana + 80% resin	50.4	263.127	2.4

3.1. Tensile properties

The banana fiber composites prepared with the fabricated samples was tested in the Universal Tensile testing machine under room temprature with all volume fractions. The graph below shows the relation of loading capacity or tensile strength to the ratio of composite. At early stages with higher percentage of epxoy, the tensile strength increases linearly with the ratio. This shows the properties of banana fiber minimized based on composite component. Fig.1 presents the results of tensile strength of different ratios of fiber and resin.

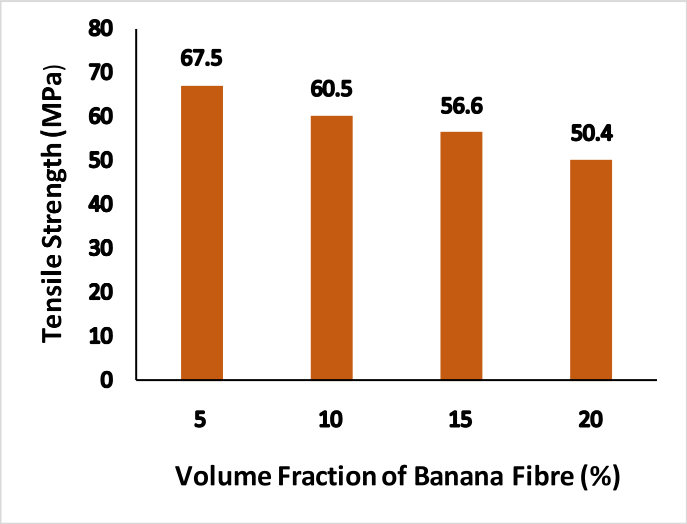

Fig. 1. Tensile strenght versus weight ratio

3.2.Flexural properties

The line graph below shows the relation of flexural propeties with weight fraction based on results tested by three point loading situations. The capacity of the composite to resist breaking under load is high. Similarly at early stages, flexural streghth increased linearly up to the ratio,and then increased rapidly. Fig.2 presents the results of flexural strength.

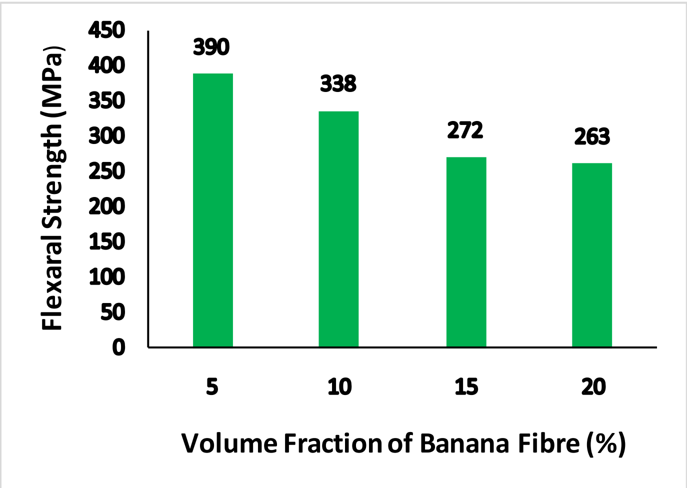

Fig. 2. Flexural strength versus weight ratio

3.3.Impact properties

To Identify the sudden load carrrying capacity which depends on energy loss or absorbtion of materials the impact test was conducted. Similarly at early stage with smaller percentage of fiber , impact streghth increased linearly up to the ratio, increased to 10% ,and then increased rapidly. Fig.3 shows that, banana fiber composite has higher impact strenght when compared to most other natural fibers.

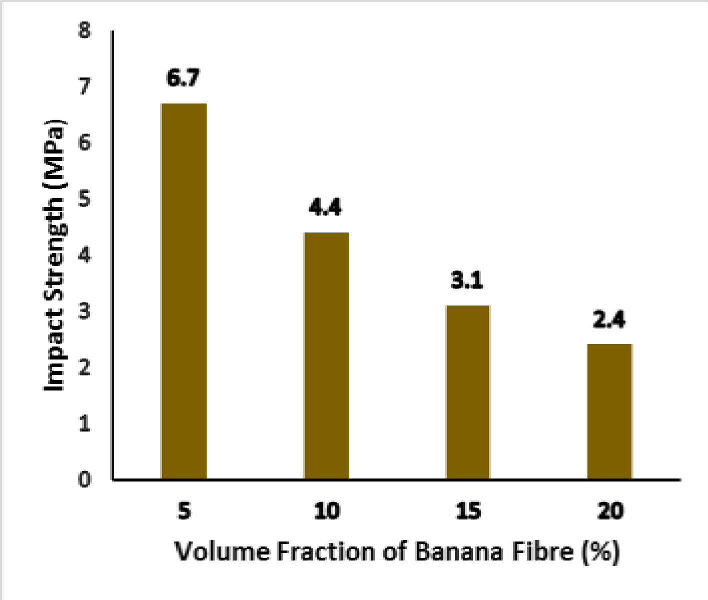

Fig. 3. Impact strenght versus weight ratio

3.4. Scanning electron mcrocope (SEM) analysis

The structure of the fractured surfaces due to the mechanical loading was observed through SEM analysis. The SEM micrographs were used to observe the internal cracks, fractured surfaces and internal structure of the tested samples of the composite materials. The SEM micrograph of the sample subjected to tensile loading, flexural loading and Impact loading are shown in the figures below.

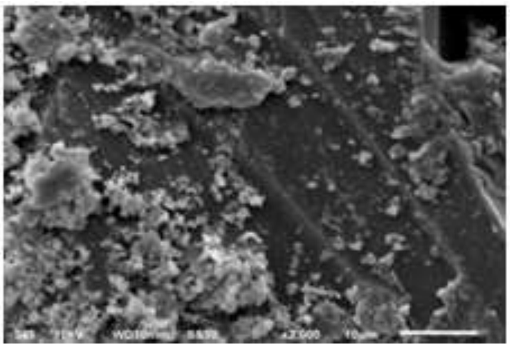

Fig.4. (a) 5% Banana 90/0 before fracture

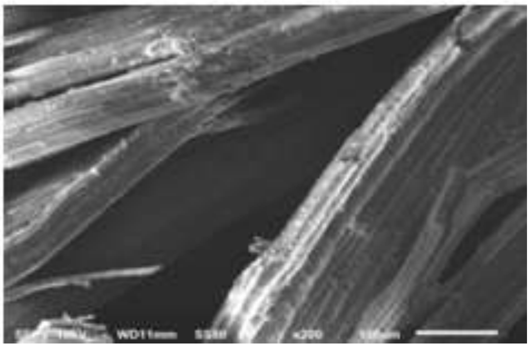

Fig.5. (b) 5% Banana 90/0 after fracture

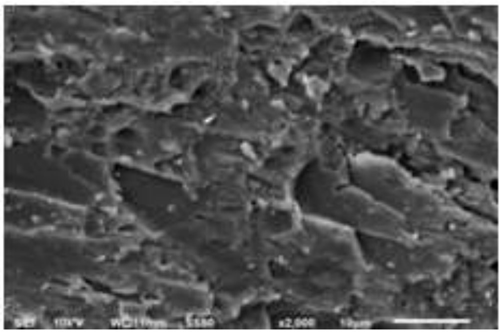

Fig.6. (a) 10% Banana 90/0 before fracture

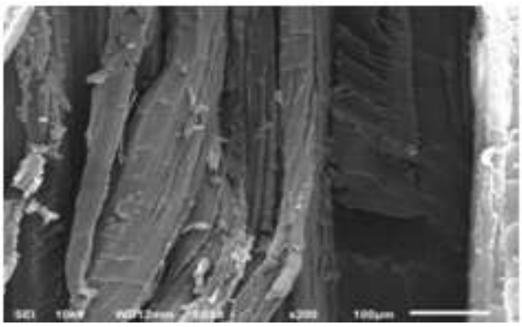

Fig.7. (b) 10% Banana 90/0 after fracture

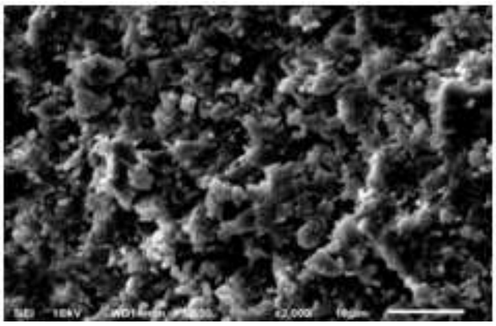

Fig.8. (a) 15% Banana 90/0 before fracture

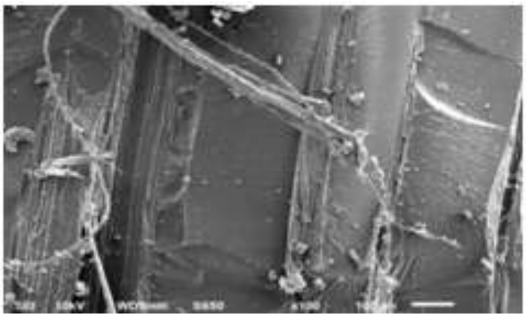

Fig.9. (b) 15% Banana 90/0 after fracture

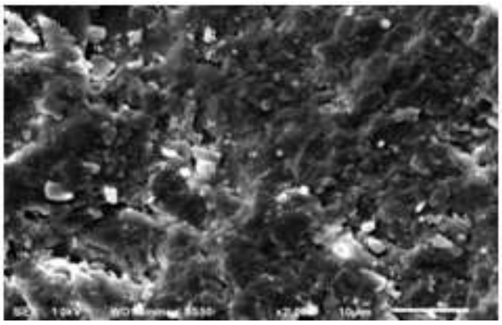

Fig.10. (a) 20% Banana 90/0 before fracture

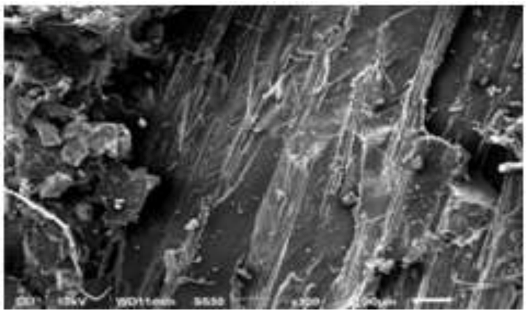

Fig. 11. (b) 20% Banana 90/0 after fracture

IV. CONCLUSION

This work shows that of a banana fiber filled epoxy based composites could be fabricated with hand lay-up techniques successfully. The samples with various percentages were cut as per ASTM standards using water jet machining for conducting physical and mechanical tests such as tensile strength, flexural, impact strength test. The comparison of tensile strength reveals that 05% banana 90^o orientation fiber/ epoxy composite has 67.5 MPa higher tensile strength than 20% banana bidirectional fiber 47.4 MPa, fiber concentration decreases the tensile strength also increases. Impact tests reveal that 05% banana fiber / epoxy and 10% banana bidirectional fiber possess higher impact strength than other fiber samples. The flexural strength of 05% banana fiber/ epoxy exhibits improved flexural strength of 390.442 MPa than other banana fiber permutations. The morphological study reveals that fibers pull out occurred on various percentages of bidirectional fiber, from the figure 5. (a) and 6. (b) Epoxy resins are well bonded than bidirectional fibers which results in weak interfacial bonding on fiber percentage and 5% banana 90% orientation fibers.

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