Experimental Evaluation of Mechanical Properties of Banana Fiber Reinforced Polymer Composites

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Abstract—Natural fiber reinforced polymer composites are nowadays being used in various engineering applications to increase the strength, 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. This is mainly due to their applicability, benefits that they offer like low density, low cost, renewability, biodegradability and environmentally harmless and also comparable mechanical properties with synthetic fiber composites. Banana fiber is a coarse and strong natural fiber being increasingly used in composite materials as reinforcement in the application areas of aerospace, automotive, furniture and construction as well as plastics and paper products. In this project banana fiber reinforced polymer composite was fabricated by using an epoxy resin combination of hand lay-up method. The Specimen was cut from the fabricated laminate according to ASTM standard for different experiments, i.e., tensile test, flexural text, and impact test. The result indicates that percentage increase of the weight of banana fiber results in improvement in the mechanical properties of the composite material.

Index Terms— Banana Fiber, Polymer Composites, Natural fiber , epoxy resin, mechanical properties

1. INTRODUCTION

In recent years, polymeric based composite materials are being used in many applications such as aerospace, automotive, sporting goods, marine, electrical, industrial, construction, household appliances, etc. Polymeric composites have high strength and stiffness, light weight, and high corrosion resistance. Natural fibers are available in abundance in nature and can be used to reinforce polymers to obtain light and strong materials. Banana fiber, among the natural fiber, is extracted from a banana plant which is abundantly grown in Ethiopia. However, there are some efforts in researching to take advantage of the production of such materials, the information given to the consumption of banana fiber in reinforcing polymers is limited in the literature. The analysis of tensile, flexural, and impact properties of these composites reveals that composites with good strength could be successfully developed using banana fiber as the reinforcing agent. The source of banana fiber is the waste, banana trunk or stems which are abundant in many places of the world. Nature continues to provide mankind generously with all kinds of rich resources in plentiful abundance, such as natural fibers from a vast number of plants. Since, the last decade, a great deal of emphasis has been focused on the development and application of natural fiber reinforced composite materials in many industries. Needless to say, due to relatively high cost of synthetic fibers such as glass, plastic, carbon and Kevlar used in fiber reinforced composite, and the health hazards of asbestos fibers, it became necessary to explore natural fiber, like banana fibers.

The natural fiber presents important advantages such as low density, appropriate stiffness, and mechanical properties with high disposability and renewability. Moreover, these banana fibers are recyclable and biodegradable. Banana fiber, a lingocellulosic fiber, obtained from the pseudo-stem of banana plant (Musa sepientum), is a best fiber with relatively good mechanical properties. In tropical countries like Ethiopia, fibrous plants are available in abundance and some of them like bananas are agricultural crops. At present the banana fiber is a waste product of banana

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cultivation, therefore without any additional cost these fibers can be obtained for industrial purposes [1].

After the composite development to meet the challenges of the aerospace sector after meeting the challenges of the aerospace sector through the development of composites, researchers have focused to cater to the needs of domestic and industrial applications. Composite boards have been used in development of panel and flush doors to satisfy the low cost housing needs. Other product developments such as panel roofing sheets with sisal fibers and glass added to jute fiber, produce large increases in mechanical properties of composites. Since natural fiber composite being cost effective material, finds its application in building, construction industry (panels, false ceilings, partition boards, etc.), packaging, automobile & railway coach interiors and storage devices [2].

Natural fibers exhibit superior mechanical properties such as flexibility, stiffness and modulus compared to glass fibers [3]. And because of that, nowadays, natural fibers such as sisal and jute fibers are replacing the glass and carbon fibers owing to their easy availability and cost [4]. Other researchers [5] fabricated the composites by using banana fiber, which is a waste product of banana cultivation and simply 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.

2. EXPERMIENTATION

2.1 Materials and Methods

2.1.1 Raw Material Used

The main constituents of raw materials used in this experiment for fabrication were banana fibers, epoxy resin (LY5560), the hardener methyl ethyl ketone peroxide (MEKP) and acetone thinner. The banana fibers are collected in the form of residues from Wachiga Esho District, Wolaita Zone, which is located in the southern part of Ethiopia. Banana fiber is extracted from Banana plant through a traditional method by using metal scraps and a wood panel. The metal scrapper rubes against the wood panel on which banana stem is placed. Through a continuous rubbing of the scrapper on the panel will produce banana fiber and cellulose component separately. The epoxy resin (LY5560) and the hardener methyl ethyl ketone peroxide (MEKPO) are purchased from a local dealer, SClab and Ranchem Company, Addis Ababa Ethiopia. The physical properties of the banana fibers are presented in Table.1.

Figure 1: A woman scrapping the banana fiber placed on the wood panel

Figure 2: Raw banana fiber.

Table 1: Physical properties of banana fiber [6]

Properties	Range

Cellulose (%)	63-64
Hemicellulose (%)	19
Lumen Size (%)	5
Moisture Content (%)	10-11
Density (g/cm3)	1.0-1.5
Elongation at a break (%)	4.5-6.5
Young's modulus (GPA)	20
Microfibrillar angle (deg.)	11
Lignin (%)	5

2.2 Fabrication of Material

The composites are fabricated by hand lay-up technique. The required mixture of LY5560 resin and hardener was made by mixing them in (10:1) ratio in a beaker while stirring the mixture by a rod, taking into care that no air should be entrapped inside the solution. The mixture was poured into the prepared moulds, keeping in assessing the requirements of various testing conditions and characterization standards.

2.2.1 Mould Preparation

Wooden mould having dimensions of 50 x 50cm were prepared and used for casting of polymer matrix composite slabs. The mould comprises of two plates on top and bottom, and a third rectangular mould cavity inside. The inner cavity dimensions of the mould are 150mm x 150mm x 10mm. After that by placing the three pieces together, holes were drilled & tightened by nuts & bolts.

2.2.2 Casting of slabs

Six sets of samples were prepared; the first set is a 10% banana fiber with 90% epoxy resin, the second set is with 20% banana fiber with 80% epoxy resin, the third set is 30% Banana fiber with 70% of epoxy resin, the fourth set is 40% Banana fiber with 60% of epoxy resin, the fifth set is 50% Banana fiber with 50% of epoxy resin, and finally the sixth set is 60% Banana fiber with 40% of epoxy resin. All of the specimens are on 0/90 degree orientation and the banana fibers in a linearly increasing percentage indicate the optimum condition of the experiment.

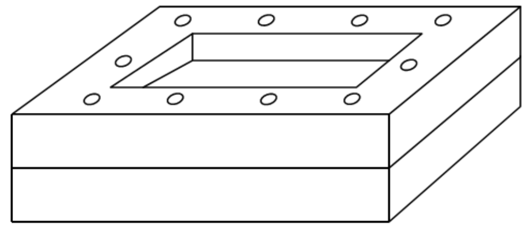

Figure 3: Mold Assembly

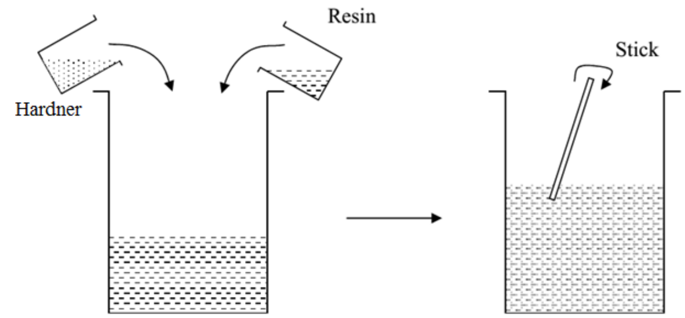

Figure 4: Mixing of Resin and Hardener

Place banana fibers on 90 degree orientation on the mold cavity prepared. Then pour the mixture of resin and hardener over the place banana fibers. A releasing agent is used on the mould to release mallex sheets to facilitate easy removal of the composite from the mould after curing. Then place mallex sheet over the resin mixture and fiber. 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. The entrapped air bubbles were removed carefully with a sliding roller. Now the prepared composites were cut for testing, conforming to the dimensions of the specimen as per ASTM standards. After curing the slab was taken out of the mould and cleaned for the testing procedures.

2.2.3 Sample Preparation

After curing, the specimens of suitable dimension are cut using a diamond cutter for mechanical tests as per the ASTM standard. The fabricated composite slab is as shown in Figure 5.

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Figure 5: Fabricated Composite Laminate

2.3 Mechanical Property Testing

The mechanical behavior (tensile strength, impact strength, and flexural strength) of the composites was tested on the Universal Tensile testing machine (UTM). The testing, load range of maximum 5 Ton with different gear rotations speed of 1.25,1.5 and 2.5mm/min were applied.

2.3.1 Tensile Strength

It is the ability to resist breaking under tensile stress and is one of the most important and widely measured properties of materials used in structural applications. Figure 6, 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. The tensile strength was determined as per ASTM D638 to standard gauge length of 50mm, with a cross head seed of 1.25 mm/min.

2.3.2 Flexural Strength

Flexural strength, also known as modulus of rupture, bend strength, or fracture strength a mechanical parameter for brittle material, is defined as a material's ability to resist deformation under load. It is a 3-point bend test, which generally promotes failure by inter-laminar shear. 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.

Figure 6: Tensile Test Specimens

The data are 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.

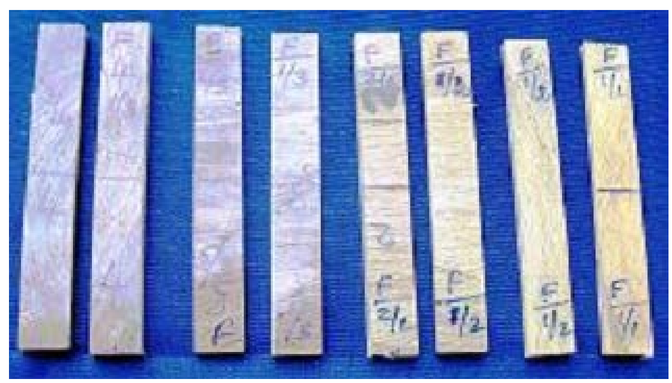

Figure 7: Flexural Test Specimen

2.3.3 Impact Test

Impact is a single point test that measures a materials resistance to impact from a swinging pendulum. Impact strength of the composite specimens was carried out on Izod impact testing machine according to ASTM A370 standard.

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Figure 8: Flexural Test Arrangement

The impact is defined as the kinetic energy needed to initiate fracture and continue the fracture until the specimen is broken. 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. The Figure 9 shows the impact testing, observation during the experimental work.

Figure 9: Impact Testing Arrangement

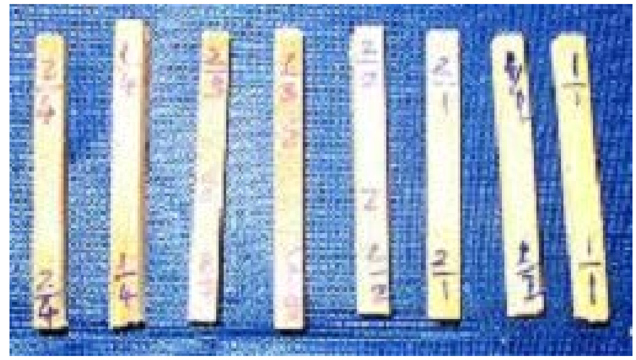

Figure 10: Impact Test Specimen

2.3.4 Microstructural Test

SEM analysis of the post mechanical tests was carried out to observe banana fiber and epoxy resin composites. Images were taken to identify the effect of fiber content on its structural orientation. The SEM micrographs are to be used to observe the internal cracks, fractured surfaces and internal structure of the tested samples of the composite materials. In most of fiber composites the micro object has fiber, matrix, air voids and fiber agglomeration [7, 8]. The SEM micrograph of the sample is subjected to tensile loading, flexural loading and Impact loading.

3 Results and Discussion

In this section, the results of various mechanical characterization tests are reported.
These include evaluation of tensile strength, flexural strength, impact strength and microstructural characteristics that have been studied and discussed in the earlier sections. The table below (Table 2) shows the result of the experiment for each mechanical property evaluated from different specimens investigated according to the experimental procedure listed above.

Table 2: Tensile, Flexural and Impact properties of composite samples

Percentage of Weight %		Tensile Strength (MPa)	Flexural Strength (MPa)	Impact Strength (Joules)
Banana	Epoxy			
10	90	43.6	230.7	6.9
20	80	56.7	344.6	6.1
30	70	69.5	458.7	4.8
40	60	75.6	570.6	4.4
50	50	94.7	713.2	3.1
60	40	85.3	585.4	2.4

The samples were tested in their corresponding testing machines and the tensile, flexural and impact properties were determined. Each type of sample is tested three times and the average values were found. The sample graphs generated with respect to load for banana fiber is presented below. The result indicates the mechanical properties of banana fiber reinforced polymer increases in relation to the weight percentage of banana fiber.

3.1 Tensile Testing Result

The banana fiber reinforced composite specimen were prepared with different volume fractions and tested on the universal testing machine (UTM). The typical load versus displacement graph generated directly from the machine for tensile test is presented in Figure 12. From the figure it can be observed that, the load is gradually increasing up to the maximum load carrying capacity of the material and decrease progressively. From the figure it has been clearly indicated that the 50% banana fiber and 50% epoxy resin polymer composites are performing better than the other composite combinations tested.

Figure 11: Tensile Test Specimen after Fracture

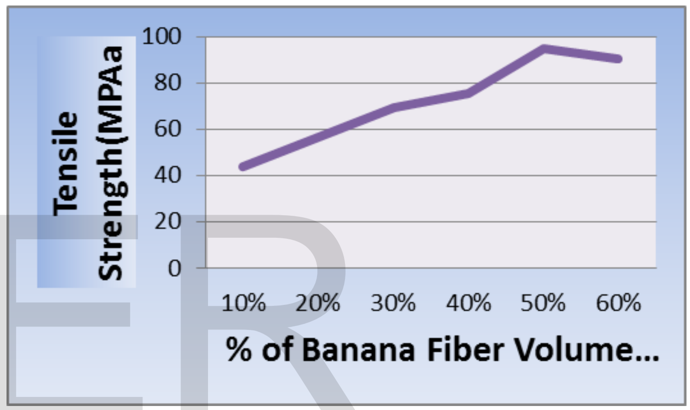

Figure 12: Tensile Strength Weight Ratio

3.2 Flexural Testing Result

The line graph below shows the relationship of flexural properties 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 strength increased linearly up to the ratio, and then increased rapidly. Figure 14 presents the results of flexural strength.

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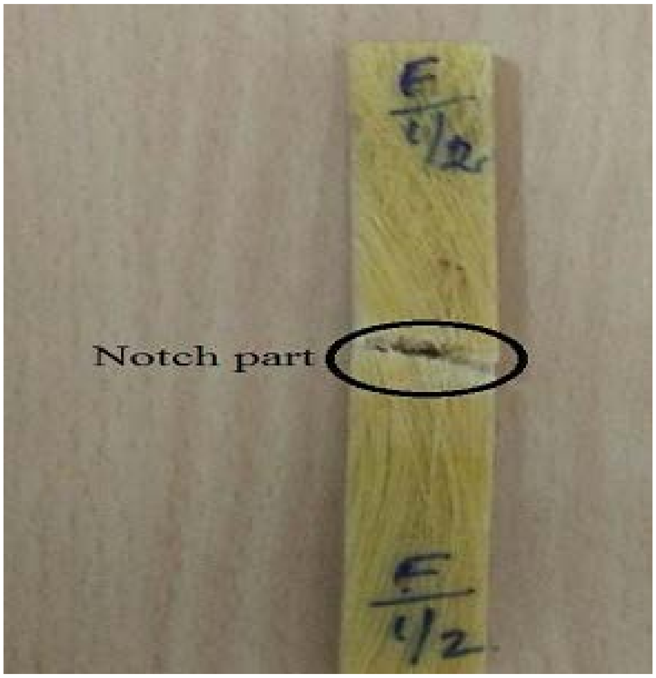


Figure 13: Flexural Test Specimen after Fracture

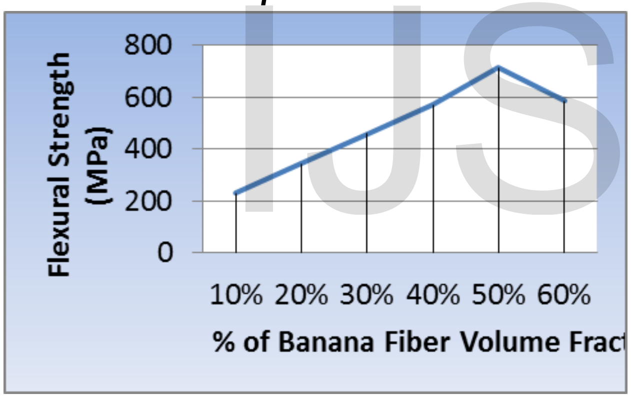


Figure 14: Flexural Strength VS Weight Ratio

3.3 Impact Property Testing

To identify the sudden load carrying capacity, which depends on energy loss or absorption of materials the impact test was conducted. Similarly, at an early stage with a smaller percentage of the banana fiber, the impact strength gets higher and higher and eventually decreases. Figure 15 shows that, banana fiber composite has higher impact strength when compared to most other natural fibers.

Figure 14: Impact Test Specimen after Fracture

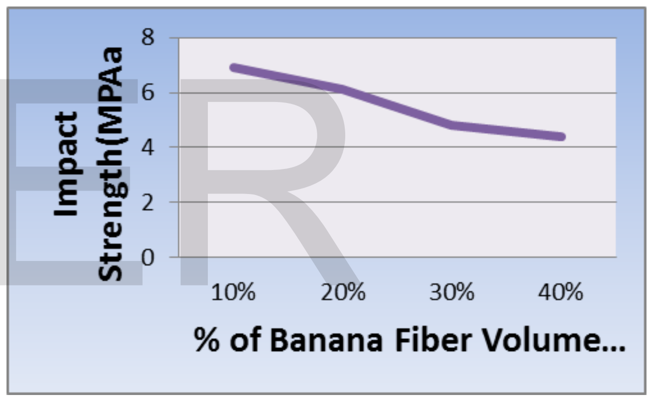
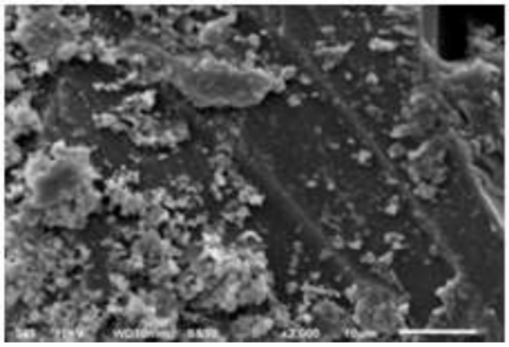


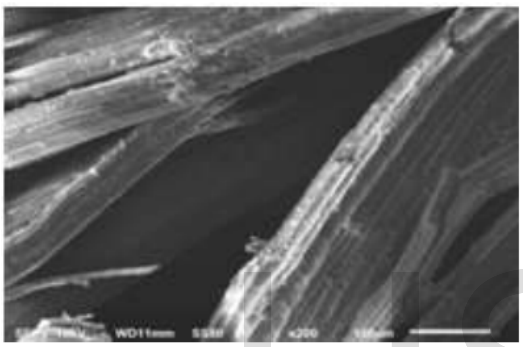
Figure 15: Impact Strength vs Weight Ratio

3.4 Scanning Electron Microscope (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. The reinforcement of the banana fibers and fiber fracture due to tensile loading is clearly visible from the micrograph. The figures presented below are the result. The fiber dispersion is evidently seen in the SEM images provided.

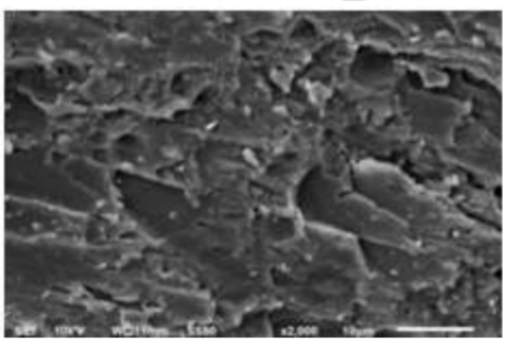


a) Before fracture

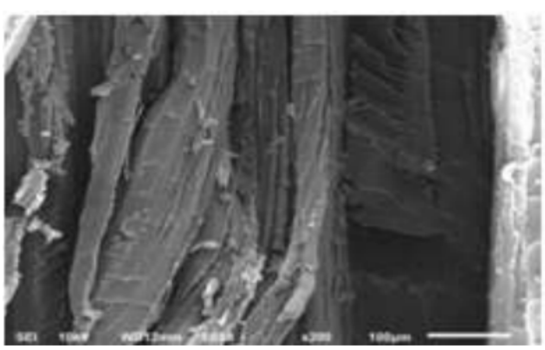


b) After fracture

Figure 16: 10% volume fraction of banana fiber

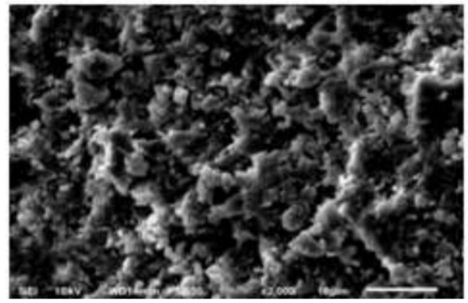


(a)

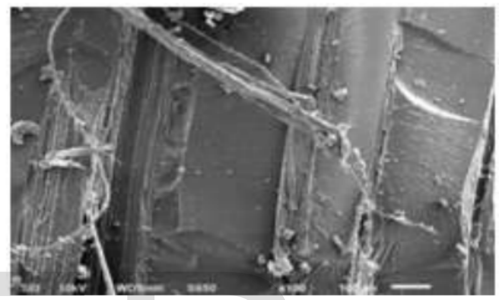


(b) After fracture

Figure 17: 20% volume fraction of banana fiber

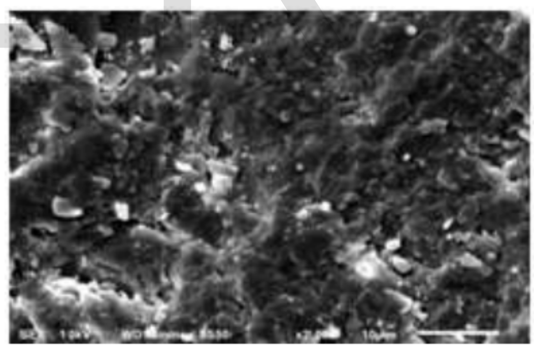


a) Before fracture

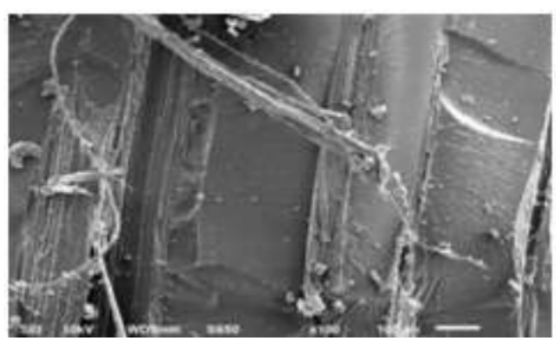


b) After fracture

Figure 18: 30% volume fraction of banana fiber



a) Before fracture



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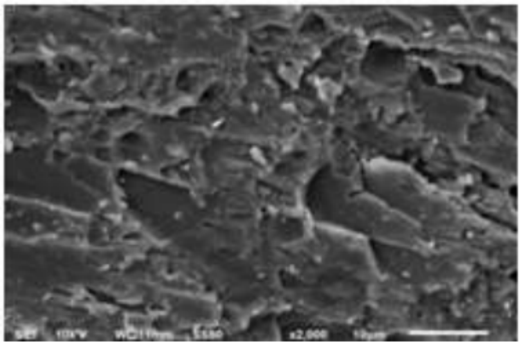
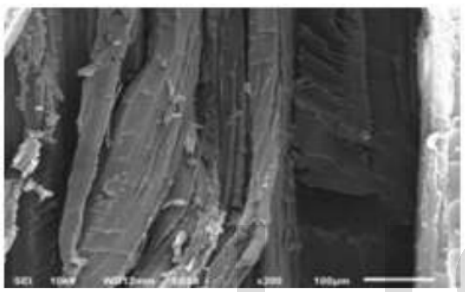
(b) After fracture

Figure 19: 40% volume fraction of banana fiber

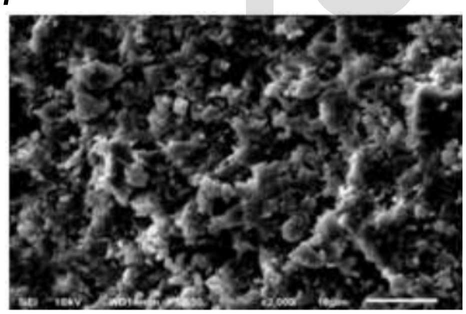


a) Before fracture

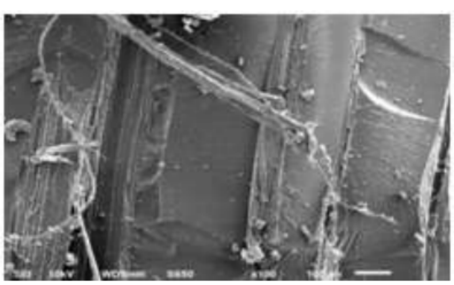


b) After fracture

Figure 20: 50% volume fraction of banana fiber



a) Before fracture



b) After fracture

Figure 21: 60% volume fraction of banana fiber

3. Conclusion

1. Epoxy based banana fiber composites were fabricated by hand lay-up process. There is an improvement in the tensile properties of the 0/90 oriented banana fiber – epoxy resin composites. At 50% of fiber volume fraction, the tensile strength is the maximum. At lower volume fractions of banana fiber, the strength of the composite specimen is reduced when compared to the virgin resin. The impact strength decreases when fiber volume gets increased. Banana fiber having high specific strength and flexural strength makes a lightweight composite material and can be used to make lightweight automobile and aerospace interior parts. The morphological study reveals that fibers pull out are occurring on various percentages of unidirectional fibers.

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