RESEARCH ARTICLE OPEN ACCESS

Review On Design and Development of Banana Fiber Composites for Bio-degradable applications

Shivaling I Mukanavar
Research scholar
Srinivas University, Mangalore

Shreeprakash B
Department of Mechanical Engineering,
Srinivas University, Mangaluru

ABSTRACT
Natural fibres are versatile components that can take the place of composite materials made with glass fibre. Natural fibres are reinforced into a matrix to create natural fibre-based hybrid composites because of its various advantages, such as low cost, light weight, good stiffness, and low wear rate. In addition to having high mechanical qualities, such as being non-abrasive and bio-degradable, biocomposites are also favorable to the environment. To determine if employing a hybrid banana-coir-epoxy composite is feasible for tribological purposes, the current study looks at this.In the current study, a hybrid composite made of banana and coir was created by manually combining biofibers with epoxy resin. Epoxy resin has been employed for binding purposes, and solidum hydroxide (NaOH) alkali treatment has been used for improved adherence. To analyze banana coir epoxy-based hybrid composites' tensile strength characteristics and particular wear rate, pin on disc equipment is used. The test technique and necessary calibration were carried out in accordance with ASTM standards. Banana-coir epoxy composite made of five separate sets of banana and coir fibres has been created in the current study by volume fraction.The best banana-coir epoxy hybrid composite for tribological purposes is determined by this study. The findings show that BBBB (0% coir, 40% banana, and 60% epoxy) has the maximum mechanical strength whereas BBCC (20% coir, 20% banana, and 60% epoxy) offers the lowest specific wear rate.

Keywords: Banana, NaOH, Biocomposites, fiber, ASTM, CCCC, BBBB, BBCC, BBBC

I. INTRODUCTION

Composites may be made from a variety of multi-component materials. Because they blend material features in interesting ways, composites are fascinating. Composite materials are created when two or more elements come together. In many instances, a rigid, strong, or structural component is immersed in softer, more compliant elements to form the matrix or continuous phase. A material comprising at least one polymer element is referred to as a polymer composite. Biofibers, also known as natural fibres, are made of cellulose, hemicellulose, cellulose, sugar, starch, lignin, moisture, oils, and proteins. The push toward bio-based polymers and materials is being driven by advantages to the environment and the economy.Plant-based fibres include seed, bast, fruit, stem, and leaf. The composite can be reinforced with oil, wheat, jute, kenaf, wood, flax, bananas (also known as musa), and other bio fibres. Composites made from plants are more environmentally friendly, light, corrosion-resistant, inexpensive, low density, suitable, high modulus, and biodegradable. Biofiber reinforced composites have the potential to be a novel and valuable material. Natural fibres are extremely stiff and robust, but since they are fibrous, it is difficult to use them in load-bearing applications. Fiber provides structural stability and stiffness to fibre reinforced composites, acting as reinforcement. Epoxy simultaneously creates sufficient structural components while acting as an anchor to keep the fibre in place.

The wear and tear of the functioning components must be considered while designing mechanical components. The functioning components have been in relative motion while performing their tasks, which leads to wear and tear. Although they can be reduced, these variables still exist [1,2]. The tribological behavior of polymer composites with reinforcement was reviewed by **Parikh and Go** [3]. They discovered that wear and friction are two elements that contribute to energy loss and reduce material performance. They also note that reinforced polymer composite materials, which exhibit improved tribological performance, can be used in place of clean polymer. Research on fibre reinforced polymer composites was conducted by **Aldousiri et al.**

They claim that the composite may be utilized in a variety of structural and tribological applications in place of conventional metals and alloys. **Zsidai et al[5]** work on fiber-reinforced composites was completed. They observed that the composites were impacted by the fibre length, volume percentage, and internal adhesion between both the matrix material and fibres.

Furthermore, they claim that by adding extra fibres to the matrix materials, it is possible to achieve the desired composite strength, stiffness, and tribological properties. To connect the mechanical characteristics of reinforced composite polymers to the length of the fibre, several tests have been conducted. They found that technical characteristics including stiffness, strength, and impact properties are significantly influenced by the fiber's length. Collaboration studies on the wear and frictional behaviors of composite materials are very important. Mining, earth moving stuff wear, and bearing wear have all been studied by Tiwari et al. They found that abrasive wear is the type of wear that occurs most frequently in the applications. Fiber-reinforced polymers have been developed by Friedrich et al. They concluded that the definition of composite depends on the interfacial connection between the matrix and reinforcement.

Furthermore, they discovered that when damage to longer fibres is concentrated as wear with abrasive particles, continuous fibre reinforcement outperforms discontinuous fibre reinforcement in minimizing abrasive wear in composites. The remaining fibres support the composites' resilience to wear. Glass-reinforced composites were the subject of experiments by Bahadur and **Polineni** [16] with various fibre lengths. They claimed that high impact angles had no effect on fibre length erosion. They also observe that compared to steel surfaces, the composite has a higher wear rate, a lower frictional coefficient, and greater mechanical strength.

Due to the detrimental environmental effects of glass fibre, **Pihtili**[15] explored with testing the mechanical characteristics of composites made from natural fibers. They note that natural fibres are biodegradable and exhibit strong mechanical characteristics when used as reinforcement. Glass-epoxy composite system experiments were conducted by Kishore et al. [8]. They emphasize that natural fiber-based composites are not as strong and rigid as synthetic fiber-based composites, which limits their structural uses. The tribological use of natural fiber-based compounds as an alternative for glass fibre reinforced composites has received only a limited amount of research up until recently. Numerous studies have revealed that Biocomposites lack mechanical performance and stiffness, although these properties might be improved with good structural engineering and better natural fibre topologies.In India, banana is widely available and is made from the bark of the banana tree, whereas coir comes from the coconut tree. There are several factors that affect the fibre density and mechanical qualities of bananas. On a natural fibre composite made of banana and flax, Srinivasan et al. [14] conducted experiments. They discovered that banana has outstanding mechanical qualities for a lingocellulosicfibre. They also claim to have excellent strength, on par with common materials like glass fibre. Polymer hybrid composite materials were reviewed by Perov and Khoroshilova [15]. They observe that mechanically sound materials combined with ecologically benign components create a hybrid composite material with applications in every imaginable field. The mechanical characteristics of a composite made of banana fibre were assessed by Muralikrishna et al. [13].

They discovered that fibre loading enhances the mechanical properties of the composite, but they also assert that banana fibre may be used in place of glass. Ku et al. evaluated the mechanical properties of composites reinforced with kenaf, sisal, coir, and jute. They concluded that the tensile characteristics of the coir-based composite had been enhanced by increases in fibre volume percent. According to Boopalan et al., treated banana fibre hybrid composites have greater ultimate tensile values than jute fibre hybrid composites. As natural fibrecomposites, banana [14], **sisal** [14], coir [15], **jute** [15], and bamboo [14] have all been investigated. Coir fibre and rice husk were tested by **Yogish et al.** [13] to see if they may enhance the mechanical properties of an epoxy resin-based polymer composite.The thick central layer of the coconut fruit (Cocos Nucifera) contains a fibrous material called coir (mesocarp). About 25% of the husk's composition is fine particles, while 75% is fibre. Banana fiber-based composite was evaluated by **Sivaranjana** and **Arumugaprabu** [12]. They discovered that a variety of parameters affect the hardness as well as other mechanical qualities. They discovered that adding polyester improves the harness's characteristics. The impact of alkalization on banana fiber-based composite was assessed by **Vardhinhi et al.** [12]. They discovered that it absorbs less water and has more robust mechanical qualities. The physical features of banana and coir fibres have been studied by **Chavhan and Wankhade** [11], who also listed several useful engineering applications. Table 2 contains a list of several engineering uses for composites.

Area	Applications
Electronics and Electrical Appliances	Packaging, switches, Casting, pipes,etc.
Aerospace Industries	Propellers and helicopter fan blades, Wings, Tails, etc.
Civil Industry	wall, roof tiles, floor, partition boards,panels, window and door frames, false ceilings, etc.
Transportations	Gears, railway coach interior, Automobile, etc.
Daily Used Substances	helmets, suitcases, baseball bats, ice skating boards, bicycle frames, lampshades, etc.
Furniture	Table, bath units, Chair, hanger, shower, handle, door panel, etc
Storage Tank	Grain storage silos, biogas containers, dryers, Post-boxes, etc.
Marine and Military Applications	Various applications

Table 1 : An important application of hybrid composites

Evaluation of the impact of hydrophilic content of natural fibres on composite was done by Shanmugam and **Thiruchitrambalam** [15]. They discovered that the fundamental property of natural fibres is what results in poor adhesion between the fibres and matrix, lowering the engineering properties of the composite. These restrictions can be lessened by applying chemical treatments to fibres, such as heat, alkali, potassium permanganate, etc. The impact of NaOH treatment on different lengths of banana fibre was examined by **Prasad et al.** [14]. They discovered that the composite had better mechanical characteristics and could absorb less water. On a banana coir-based composite, **Kumar et al.** [15] experimented with determining the impact of layering patterns and chemical treatment. They discovered a beneficial influence on improved mechanical performance as well as higher energy absorption capacity, or damping indication.A test was carried out by **Adhikari and Gowda** [12] to determine the impact of the volume fraction of fibre on a hybrid composite made of banana and jute. They note that for banana jute hybrid polyester composites, flexural, tensile, and impact strength rise steadily with increasing fibre volume percentage.

The synthesis and characterization of banana-coir epoxy composite have been carried out for broad applications, according to earlier works on banana-coir epoxy hybrid composite materials. Less information is known, nevertheless, on the production and characterization of banana-coir epoxy composites used in frictional materials. To find the ideal Banana-coir epoxy hybrid composite to utilize as frictional materials, the current work tries to examine this. To conduct the experiment, a hybrid composite made of banana, coir, and epoxy has been used for tribological purposes. The goal of the current study is to identify the banana coir epoxy fibres with the lowest specific wear rate, the appropriate Somerfield number, and the required mechanical strength and acoustical stability.

II. MATERIALS AND METHODS

The components and procedures employed in this experimental inquiry have been covered in-depth in this section.

2.1: Materials

The epoxy resin kit and alkali were given by a nearby store (NaOH). Banana fibre is manually removed from banana tree bark and coir bought from nearby suppliers. Epoxy and hardener were combined in a 1:1 weight ratio.

2.2: Chemical Treatment of Banana and Coir

Before creating composite samples, fibres were chemically treated with a NaOH solution to increase fibre adhesion. The coir and banana fibres were properly dried in the sun to eliminate moisture after being immersed in a 0.05N NaOH solution for eight hours. The roughness of the fibre in textiles was increased by chemical treatment. When fibres are treated with alkaline, wax, and greasy substances are removed, making the surface harder.

Fibers	Moisture (wt. %)	Cellulose (wt. %)	Hemi Cellulose (wt. %)	Lignin (wt. %)
Banana	12 - 14	64 - 66	20	6
Coir	10 - 12	34 - 37	14	46

Table 2 - Chemical properties of banana and coir

2.3: Mold Preparation

The mild steel mould box has dimensions of 200 mm x 200 mm x 50 mm. The Hand Layup Process was used to create the composite samples. The fibres are covered by the moulding box, which compresses them and prevents leaking while doing so. The moulding box was prepared in accordance with ASTM requirements.

2.4: Fabrication of Composite

Epoxy was used at first as the basis material, together with banana and coir fibres. The length of both fibres is 10 mm. The molding box was cleaned with regular water, and after washing, it instantly dried for 30 minutes in the sun. For simple sample removal, the wax was single coated throughout the molding box. The needed mixture of banana, coir fibre, and epoxy has been manually laid up into the prepared mould box. The hardener was then poured after the moulding box had been continuously exposed to 200 Newton stresses until the appropriate composite layer thickness was reached.Figure 1 shows the specifics of how composite samples were made.

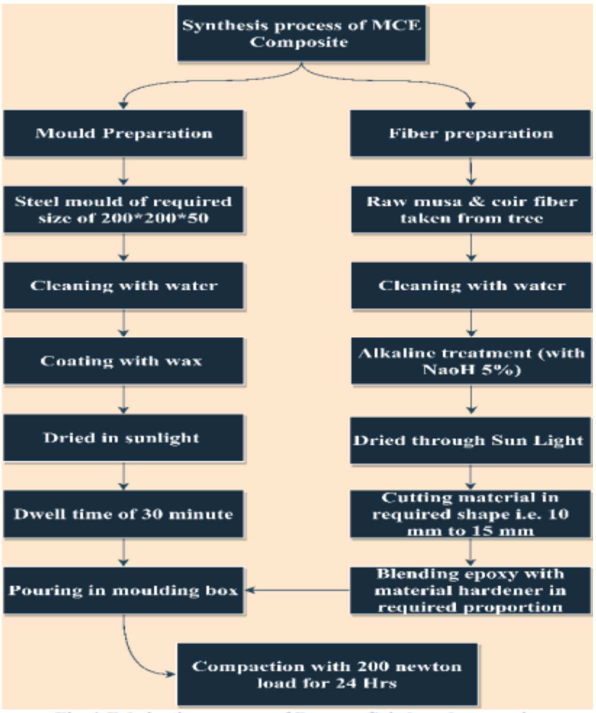


Figure No. 1 - Fabrication process of Banana-Coir based composite

After curing, composite samples were removed from the mould and cut to size in accordance with ASTM standards to examine mechanical performance. Table 4 displays the volume percent compositions of the composite samples, and Figures 2(a) and 2(b) display the manufactured composite samples.

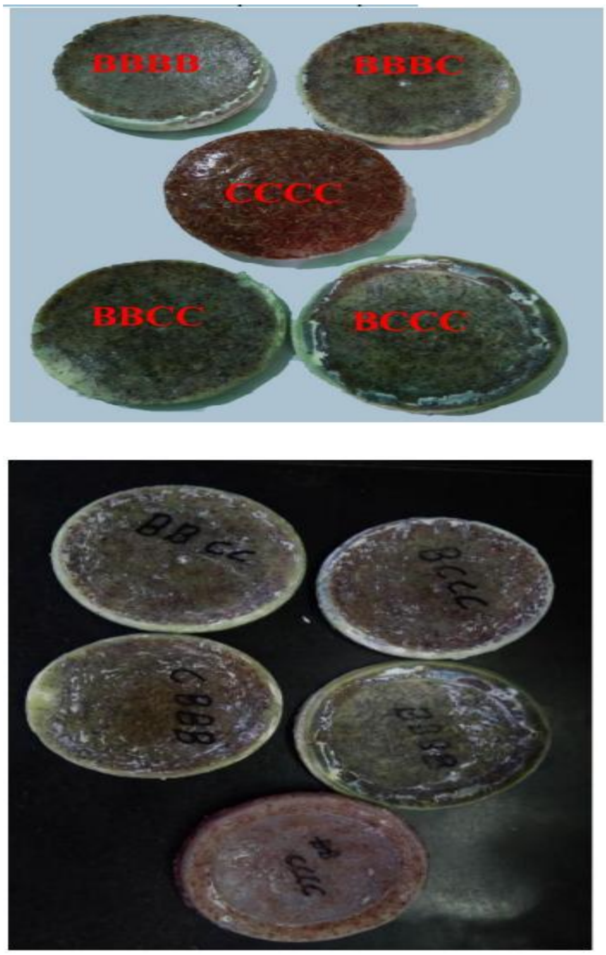


Figure 2 - Fabricated composite samples Front and Back End for Wear Test

Figure No.3 – Sample for Tensile Tests.

Sr No.	Designation	Composition (% Volume)
1.	CCCC	Coir (40%) +Banana fiber (0%) + epoxy (60%)
2.	CCCB	Coir (30%) + Banana fiber

		(10%) +epoxy (60%)
3.	CCBB	Coir (20%) + Banana fiber (20%) +epoxy (60%)
4.	CBBB	Coir (10%) + Banana fiber (30%) +epoxy (60%)
5.	BBBB	Coir (0%) + Banana fiber (40%) +epoxy (60%)

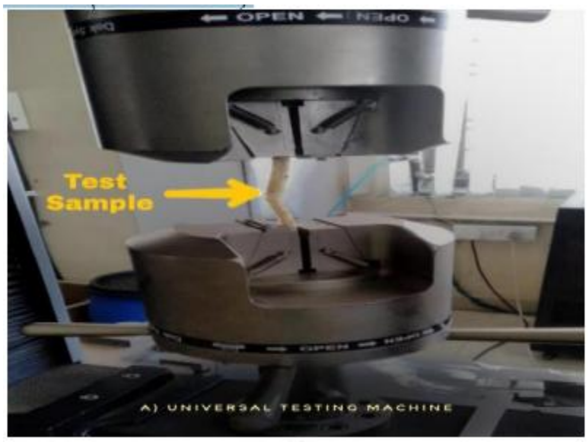
Table No. 3:Composition of specimens

2.5: Wear Test

In the study, a pin-on-disc wear machine was employed. As seen in Figure 3, the testing is performed using Pin on Disk apparatus in accordance with ASTM D3702. (b). The machine may carry the sample in the holder thanks to a special attachment. Weigh the samples both before and after the wear test. The variables are sliding distance, speed, and load [6]. The sliding rate is thought to be 200 revolutions per minute. 10, 15, 20, and 25 Newton were the loads. The two spots are kept a thousand meters apart. The testing criteria are comparable to all other elements.

2.6: Tensile Test

A tensile test, sometimes referred to as a tension test, is the most fundamental mechanical test that can be performed on any material. Tensile tests are straightforward, reasonably priced, and entirely standardized. The composite samples were constructed to ASTM D638 specifications. The composite specimens had dimensions of 127 mm in length, 12.7 mm in breadth, and 5 mm in thickness. The tensile test was conducted using a universal testing equipment, as shown in Figure 3(a) (UTM machine).



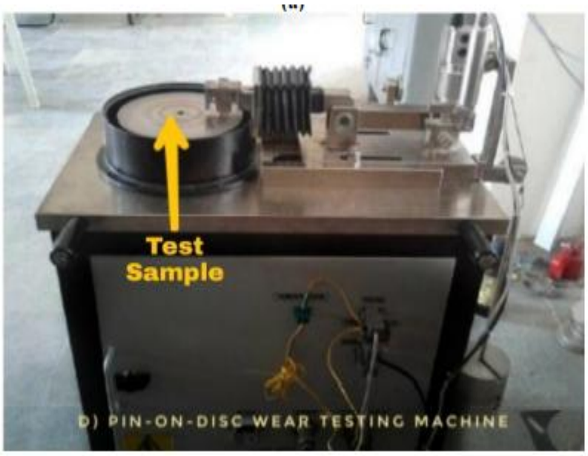


Figure No – 4: UTM Machine

III. RESULTS AND DISCUSSION

3.1: Tribological Characteristics

Two fixed parameters and one variable were used in the test. A 200rpm sliding rate and a 1000m centre distance were the set specifications. The specific wear rate (mm3/Nm) of banana-coir composite samples, however, has been examined in response to increments in loads of 10, 20, 30, and 40 Newton. Due to frictional forces and heat buildup on the mating surfaces, Figure 4 shows that as load increases, so does the specific wear rate for all samples. The specific wear rate of composites increases with increasing load for all samples. Each asperity penetrates the surface more deeply as the applied stress increases since the applied load on the asperities is the same everywhere across the irregularity.

A higher wear rate is brought on by deep penetrations. The worn surfaces might heat up due to plastic deformation at the body, which causes the matrix and fibre contact to debond. As a result, when a larger stress is applied, a sizable percentage of the material from the worn surface is lost, as seen in Figure 4. Because the tribological characteristics of composites are influenced by the reinforcing of natural fibres, the volume proportion of natural fibres in the composites, and the chemical treatment of the composites. The NaOH alkali treatment helps the fibresdebond from the matrix, allowing the composite to support greater loads. The specific wear rate of the banana-coir epoxy composites is further decreased by using thermoset epoxy resins.

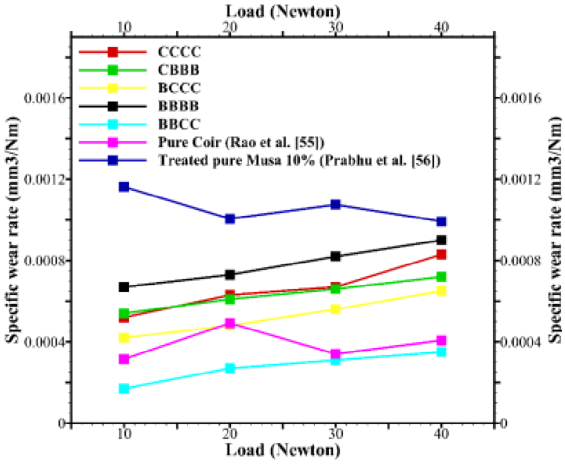


Figure No. 5:Specific wear rate for banana-coir epoxy samples under different loads (N)

3.2: Tensile Test

The composite specimens and the results of their tensile tests are shown in Figure 5. The mechanical qualities of epoxy composites based on banana coir are influenced by the fibre characteristics. The graph demonstrates that the tensile strength of composite samples rises together with the volumetric % of banana fibre loading. The samples with the greatest and lowest tensile strengths, respectively, are BBBB and CCCC. In comparison to coir, banana fibre enhances structural stability as the banana fibre content rises in banana-coirepoxy-based hybrid composite.

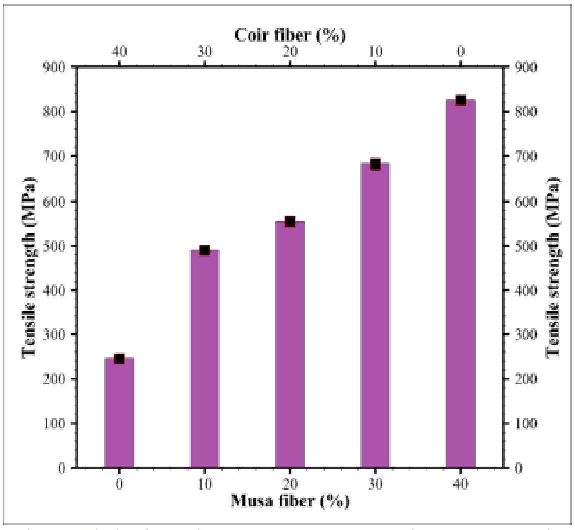


Figure No. 6: Variations in banana and coir fibre loading on banana-coir epoxy hybrid composites cause changes in tensile strength, according to earlier research.

IV. CONCLUSION

This experimental analysis of the mechanical and wear behavior of a unique hybrid composite made of banana coir and epoxy yields several important and ground-breaking results.Combining banana and coir fibre increases the wear profile of composites. As the amount of banana fibre loading increases, composites' tensile strength rises. As load values rise, more wear is visible on all specimens. This research demonstrates that the minimal wear strength isobtained by mixing banana and coir fiber in equal amounts.

The results demonstrate that BBCC (20% coir, 20% banana, and 60% epoxy) provides the lowest specific wear rate, while BBBB (0% coir, 40% banana, and 60% epoxy) delivers the highest mechanical strength.

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