Experimental Analysis on Tribological behavior of Banana Fiber Reinforced Epoxy Composite

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Abstract - *In the contemporary setting of a fast-rising global population, the issue of resource depletion is a major concern for humanity. The creation of alternative materials has become more significant in recent years due to the environmental harm that some material extraction methods cause. As a result, composite materials particularly those made of natural fibers have developed. Due to their strength, stability, and inertness, synthetic fibres make up the majority of today's fibre technology. However, these fibres harm the natural order of things since they are polluting and non-biodegradable. These composites improve the performance of artificial composites. One such ingredient is fibre from Bananas. The banana tree, a native plant of Southeast Asia, is used to make banana fibre. The tribological performance of a banana fiber reinforced epoxy composite was examined in the current work. Wear and frictional characteristics of BFREC were investigated under dry contact condition at different operating parameters such as sliding distance, sliding velocity, applied load. The experimental results indicates that incorporation of banana fiber into epoxy matrix significantly improves the adhesive wear behaviour of BFREC. There was reduction in coefficient of friction, specific wear rate (S.W.R) and % mass loss of developed composites.*

***Key Words*: banana-fiber; natural fiber; adhesive wear ; S.W.R; CoF**

1.INTRODUCTION

There are many resources suited for various purposes all around the nearby population. One of the pillars of human society is the use of fibres. The foundation of human existence and flourishing are fibres. There are essentially two sorts of fibres. They are both synthetic and natural fibres. Natural fibres like cotton, jute, and sisal are examples. Synthetic fibres like glass, nylon, and carbon are examples. Due to their durability, stability, and inertness, artificial fibres now make up the majority of fibre technology. However, because they are non-biodegradable and polluting, these fibres upset the natural order. The use of natural fiber-based composites has increased as they demonstrate a superior alternative to synthetic fiber. Composites are frequently used in our daily lives to promote the sustainable growth of human society. These composites increase the artificial composites' productivity. Banana fibre is one type of natural fibre that is used in reinforced composites nowadays and is a waste product from the banana industry. They have gained a great deal of notoriety in performance applications, aerospace, automotive, and many other industries thanks to their advantageous qualities of low weight and ability to be customised for particular uses. The many advantages of banana fibre, including its low cost, availability, and strength, make it one of many natural fibres that could be used as reinforcement in polymer composites. In turn, banana (Musaceae) fibre reinforced composites allow the creation of tribological components with exceptional wear, friction, and lubrication qualities that have a wide range of industrial uses. A notable advancement in the creation of bio composites has lately been made as a result of the further addition of all features. High-strength banana reinforced composites can thus be used in a range of applications. The nutritional breakdown of a banana (100 g pulp) is as follows: 18.8 g of carbohydrates, 1.15 g of protein, 0.18 g of fat, 73.9 g of water, 0.83 g of other minerals, and 81 kcal [1]. Banana plants often yield 30 large leaves, each measuring over 2 metres long and 30 centimetres wide [2]. Tables 1, and 2 by Venkateshwaran et al. [3] list the physical Properties and chemical composition of banana fibre.

Table 1: Physical properties of the banana fibers [3]

Diameter (μm)	80-250
Length(mm)	1000-5000
Aspect Ratio(l/d)	150
Moisture content (%)	60

Table 2: Chemical composition of banana fibers [3]

Cellulose (%)	60-65
Hemi cellulose (%)	5-19
lignin (%)	6-10
Pectin (%)	3-5
Ash (%)	1-3
Extractives (%)	3-6

The study of friction, wear and lubrication of interacting surfaces in relative motion is known as tribology [4]. The importance of tribology at present time is crucial since most design applications involve 'wear and tear' process when subjected to relative motion. Using the chosen parameters (slide velocities, sliding distances, applied weights, contact conditions, and orientations of the test specimen with respect to the sliding direction of the counter face), a tribo-testing machine is constructed that can replicate the wear and frictional test. There are several sorts of tribo-testing devices based on the published studies that are currently available. They differ from one another according to how well the test fits a certain application. the many tribo-testing methodologies shown in table 6 employed in carrying out various tests

Tribological loadings are one of the most crucial aspects to take into account when developing a Tribological component because every material has some wear and friction qualities that deteriorate over time [5]. Since the changes occur in tribological loading condition approx. 90% failure happens, which modify their wear and friction properties [6]. Tribological properties are varied (either positively or negatively) by using reinforcement method with fibers or polymers [7]. The addition of natural fibres improved the wear performance of polylactic acid, and the wear rate of composites was noticeably lower than the wear rate of clean polylactic acid at higher loads [6]. In their study, for a kind of bearing application Chin and Yousif [8] used Kenaf fibers reinforced with epoxy composite, in which they concluded that wear performance and normal orientation in composites is 85% enhancement.

El-Tayeb [9] investigated the wear and friction characteristics of glass fiber/polyester (GRP) and sugarcane fiber/polyester (SCRP). Various parameters, such as speed, the length of the test, and load, were used in the study. According to the study's findings, SCRP and GRP composite are rival products. The same features for sisal fibre reinforced resin brake composites were studied by Xin et al. [7], who found that sisal fibre may be used in place of asbestos in brake pads [10,11].

Yousif [12] investigated on the frictional and wear performance of polyester composites based on coir fibres. Coir fibre composites were developed in a multi-layer foam, mainly in three and four layers. Author carried out the experiment using a block-on-disc machine under sliding contact condition against smooth stainless steel. Author concluded that the interfacial adhesion between the coir fibres and polyester matrix is strong enough to overcome the pull-out of fibres at the interface

Bajpai et al. [6] has studied and estimated three different natural fibers class as Grewia, nettle, optiva, and sisal with PLA polymer and developed composites in which a hot compression procedure was used. The friction and wear characteristics of composites were examined under various conditions, such as dry contact conditions with the availability of varying operating parameters. The applied load was varied between a range of 10 to 30 N with a speed range of 1 to 3 m/s and a sliding distance of 1 km to 3 km. The study's findings demonstrated that adding natural fibre mats to a polylactic acid matrix can improve the way that neat polymers wear and friction. In compared to neat Polylactic acid, there is a roughly 10–44% drop in the coefficient of friction, with a higher reduction of 70% seen in developed composites for specific wear rates.

The coir fibre reinforced polyester composite exhibits a better wear performance than neat polyester. Eduardo et al. [13] performed wear experiments on thermoset matrix reinforced with Musaceae fibre bundles to study the wear resistance of the material. The fibre bundles used by the author were extracted from rachis Colombia Musaceae plants. After the completion of the experiment, the author concluded that the resins hold main role in the friction behaviour. The main wear mechanisms identified in the tested samples were adhesion and surface fatigue. Many studies are still going to improve the wear behaviour of natural fibre-based polymer composites.

T.P. Mohan et al. [14] Aim of this research work was to study the tribological properties of natural fiber-based composites using nanotechnology. The naturally available banana plant fibers were treated with nanoclay particles and these treated fibers were then reinforced in an epoxy polymer to form composites. The friction and wear properties of nanoclay treated banana fiber (NC BF) reinforced composites were compared with untreated banana fiber (UT BF) reinforced composites. Short NC BF and UT BF reinforced composites with fiber concentration ranging from 20 wt.% to 60 wt.% was prepared by vacuum resin infusion processing method. The result indicates that the NC BF reinforced composites has shown improved friction and wear properties. Microscopy examination revealed that NC BF reinforced composites were able to form transfer layer between wear test specimens, resulting in improved wear properties.

S Vigneshkumar et. al [15] has carried out an Experiment with fiber reinforced polymer composite on Pin on disc equipment. And investigated the changes of wear and friction performance of the sisal and rice husk composite weight. The carbon, sisal fiber and rice husk composite wear and frictional performance were improved with the increased load an orthogonal array method. with the increase in the load and sliding velocity the sisal, banana and kenaf fiber composite weight loss was more and Sisal and rice husk composite wear and frictional force was more with respect to increasing the speed and time.

A. Alavudeen al [16] showed in their investigation that a high wear resistant material using banana fibre has been used to develop a hybrid clutch plate composite matrix with strength and rigidity. The composite material also improves the life-cycle of the composite

Subramanian et al. [17] performed wear test on eco-friendly mono-layered PTFE blended polymer composites. The tribo-test was performed for the constant pressure and velocity in a flat-on-flat configuration. A stable friction characteristic was clearly achieved in the steady state which implies the developed material suitable for tribological components such as plain bearings, sliders, hinges etc. To understand the failure mechanism of sliding wear, the morphology of worn-out composite surface and counterpart was analysed using Scanning Electron microscope (SEM).

2.0 Materials and Methodology

2.1 Materials

Shroff Industries, Dist. Burhanpur Madhya Pradesh provided unidirectional combed good grade long banana fibre (shown in fig.1). The epoxy resin LY556 and hardener HY951 (shown in fig. 2) chosen for the matrix are bought from a local market in Indore, Madhya Pradesh. One of the most widely utilised matrix materials is epoxy. The matrix's density was determined to be 1200 kg/mm3. According to the calculations, the amount of hardener and epoxy was measured. The composite is made using LY556, an epoxy with a density of 1.15-1.20 g/cm3, combined with HY951, a hardener with a density of 0.97-0.99 g/cm3. Epoxy and hardener are combined at a weight ratio of 10:1. At 250o C, this has a viscosity of 10–20 poise. In the mechanical department lab of Shri Vaishnav Institute of Technology, composite preparation is done. The tribological test have been performed at Ducom, Bangalore.

Figure 1: Banana Fiber

Figure 2: Epoxy LY556 and hardener HY951

2.2 Fabrication of Composites:

For preparing the wear test specimens we used 10 mm diameter hot water pipe for making the mold, pipes of the length 40 mm were cut. Weight of epoxy and Fiber is taken according to percentage i.e., 10%, 20%, 30% and 40% of banana fiber and remaining portion of matrix (epoxy and hardener) in the ratio 10:1 is poured from the sides followed by inserting the fibers and then again pouring the epoxy throughout the cavity. After removing the specimen from the pipe, it was cut according to ASTM standard.

2.3 Adhesive wear test Characterization

There are several set ups which can be used for conducting wear tests some of them are dry sand rubber wheel, pin on drum, linear tribo machine, block on ring, block on disc and pin on disc (Basic schematic diagram for wear and friction tribometer fig 3) as discussed above. we have used the pin on disc set up.

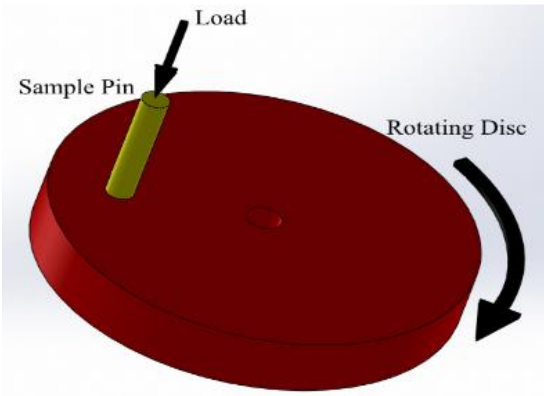

Figure 3: Basic schematic diagram for wear and friction tribometer

A wear and friction tribometer as per ASTM G99 (TR-20-M61, Ducom, Bangalore) was used to assess co-efficient of friction adhesive wear and specific wear rate of polymer composites ASTM G99 is the standard for pin on disc testing as shown in fig 4. The sample is 10 mm in diameter and 30 mm in length. The sample is subjected in a perpendicular direction against a rotating counter face EN31 disc (165 mm diameter, 8 mm thick). The contact with the counter face continuously erodes the material and the wear and the frictional force acting is continuously measured with the help of sensors fitted on the set up. Care should be taken while applying and removing the loads and fluctuations in the load will bring a lot of error in the test.

Figure 4: Experimental setup for wear and friction tester

Table 3: Tribological test characterization.

Method	Standard used	Specimen Specification	Operating Parameters	Ref
Pin on disk	ASTM G99	10mm × 10mm × 20 mm	sliding distance, sliding velocity, applied load, wet or dry sliding, abrasive or adhesive contact condition	[18]-[20]

Equation for volume loss $\Delta V = \frac{\Delta W}{\rho} \times 1000$ (1)

Where, ΔV is volume loss in mm^3; ΔW is mass loss in gram and ρ is density in Mg/m^3.

Archard's wear equation $K_S = \frac{\Delta V}{L \times D}$ (2)

Where, Ks is specific wear rate in $m^3/N\text{-}m$; ΔV is wear volume loss in m^3; L is Load in Newton and D is sliding distance in meter.

In all the experiments, below mentioned (in fig 5) test procedures were followed

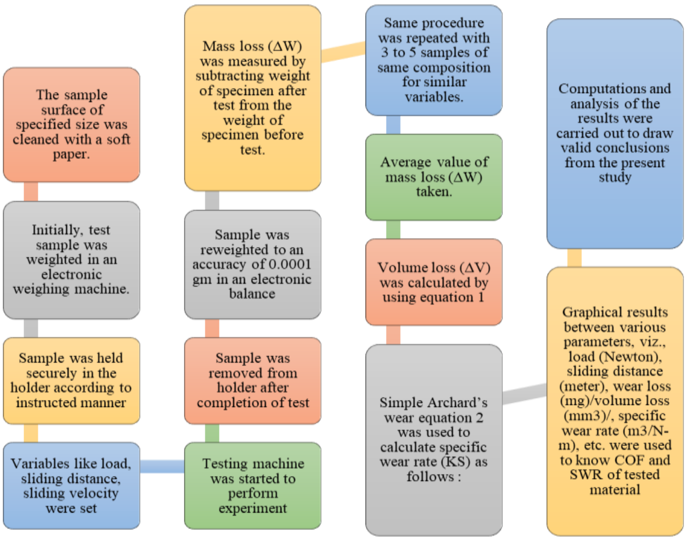

Figure 5: Test procedure for wear test

3.0 Results and Discussions

3.1 Tribological tests

3.1.1 Adhesive wear test

For the wear test we have taken readings against three different rpms (300,400,500) rpm against 30N load and tested it against different sliding distances, wear graphs were plotted and alongside graphs for coefficient of friction and specific wear rate is also provided. Sliding distance for 1000 m 1500 m and 2000 m were calculated using the formula

$$\omega = 2*\pi*N/60 \quad (3)$$

For V=1.57 m/s. time taken to cover 1000 m,1500 m and 2000 m distance are 10.6 mins, 16 mins and 22 mins. Hence for the sliding distance the machine was adjusted to a time limit of 22 mins and the specific wear rate was calculated using the formula:

$$\text{Specific wear rate} = (\Delta m)/\rho FL \quad (4)$$

Where Δm stands for change in mass and ρ for the density, F for the normal force acting or the load acting and L is the distance travelled or slides.

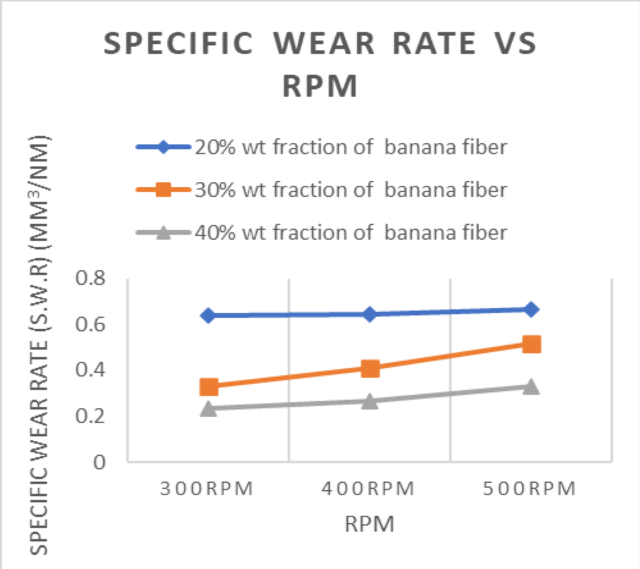

Figure 6: Specific wear rate of Banana fiber reinforced epoxy composite at different rpm

Table 4: Values of specific wear rate for 1000 m 1500 m and 2000 m distance on 400 rpm and 30N load

Fiber %	1000 m	1500 m	2000 m
Banana fiber 20 %	1.118	0.886	0.678
Banana fiber 30 %	0.824	0.603	0.478
Banana fiber 40 %	0.632	0.412	0.298

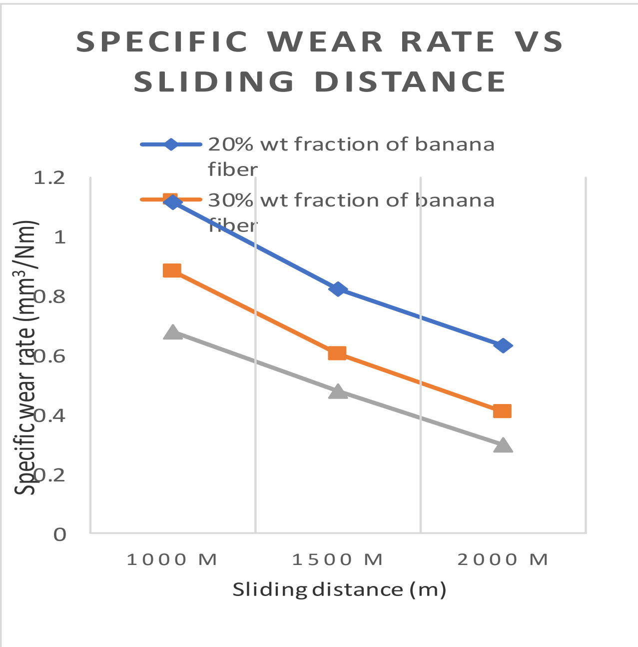

Figure 7: Specific wear rate of Banana fiber reinforced epoxy composite at different sliding distance.

3.1.2 Friction test

For the wear rate the coefficient of friction and % mass loss during the test for 1000 m distance and 400 rpm at 30 N load is applied for different volume fraction banana fiber. The average values of 5 samples in figure 22 and 23 is found to be maximum for 40% of volume fraction of banana fiber. For a constant load, sliding distance and rpm the % mass loss of Banana fiber reinforced epoxy composite is dropped from 2.14% to 1.43% of 20% and 40% banana fiber respectively.

Table 5: Values of Coefficient of friction (CoF) and % mass loss for 1000 m distance on 400 rpm and 30N load

Fiber %	CoF (μ_s)	% Mass loss
Banana fiber 20 %	0.432	2.14
Banana fiber 30 %	0.456	1.74
Banana fiber 40 %	0.474	1.43

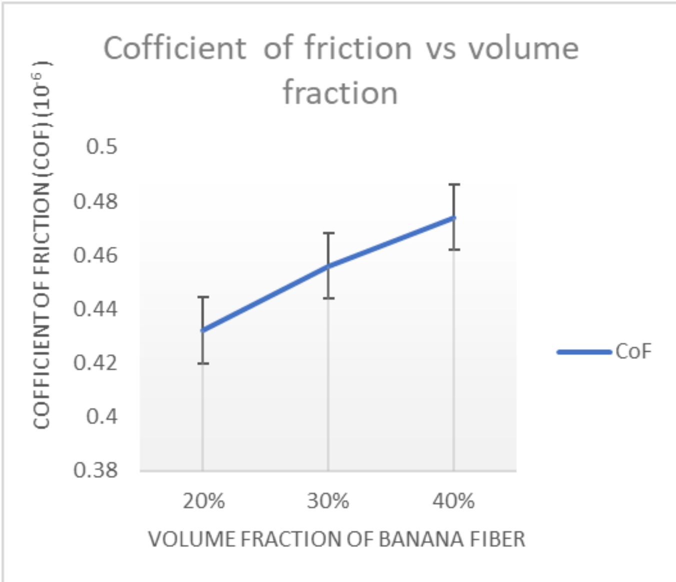

Figure 22: Coefficient of friction for different volume fraction of Banana fiber reinforced epoxy composite.

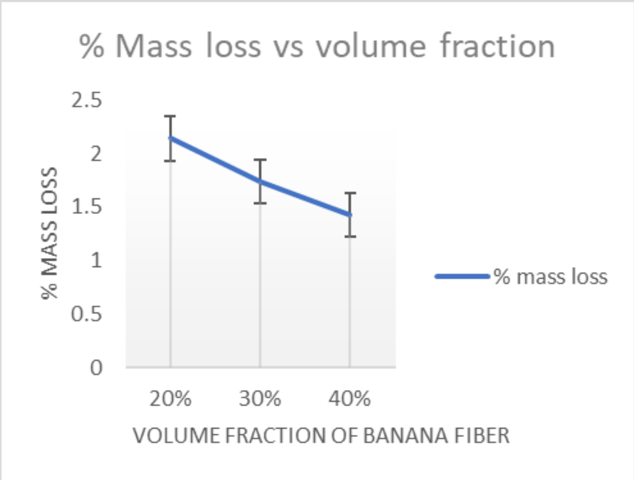

Figure 23: % mass loss for different volume fraction of Banana fiber reinforced epoxy composite.

4.0 Conclusions

Tribological characterization were assessed by determining the various volume fraction (10% to 40% V_f) of banana fiber on Banana Fiber Reinforced Epoxy Composite (BFREC). Tribological behavior of BFREC investigations leads to the following assertions.

- Tribological characterization for Specific wear rate vs speed it is clearly evident that the specific wear rate will increase because for same load and sliding distance with increase in speed the composite wears more
- Specific wear rate vs sliding distance the value decreases with the increase in sliding distance.
- With increasing the fibre content from 20% to 40% the wear rate of the material decreases.
- With increasing the fibre content from 20% to 40% the % mass loss of the material decreases.
- With increasing the speed wear rate increases for the same fiber content. Coefficient of friction(μ_s) increases the volume fraction of the composites and results in lower wear.
- Banana fiber has the lowest specific wear rate and would be better if considered for tribological applications in rotating and sliding parts.

5.0 Reference

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