

# Experimental analysis on tribological behavior of fiber reinforced composites

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**Abstract.** The use of fiber reinforced composites are widely used in many application such as automobile, aircraft manufacturing because they are cost effective and offers high strength, availability and weight ratio compared to other composites with similar applications. In this work, polyester was selected as a matrix material to prepare a composite specimen reinforced with sisal, banana, kenaf, carbon fiber and rice husk with different compositions. Composite specimen is prepared and Taguchi's L<sub>9</sub> orthogonal array method is used to study the Tribological behavior. The test specimen of composite material had been prepared using compression molding method and the same was tested using experimentally to determine the mechanical properties. The equipment used for the experimental work is pin on disc. The weight was measured before and after the experiment is conducted. The effects of the Tribological operating parameters applied load, sliding velocity and sliding distance on the frictional and wear performance of fiber reinforced composites are demonstrated. It was observed that the wear response of the specimens is influenced by the applied load, sliding distance and the speed.

**Keywords:** sisal fiber, banana fiber, kenaf fiber, rice husk, polymer composite

## 1. Introduction

Natural fiber-reinforced composites is developing rapidly due to their mechanical properties, low cost, renewable, recyclable, biodegradable, available of natural fibers such as sisal, banana, kenaf is more in India [1,2]. In recently, the usage of natural fibres to replace synthetic fibres as fiber reinforced composites for engineering applications and developing the materials [3]. Natural fiber reinforced sandwich composite is the increases the mechanical properties like tensile, flexural and impact results [4]. Kenaf fiber plant that can reach 3 to 4 meters it can be harvested 2 times per year. Kenaf fiber composite matrix is to provide strength and rigidity [5-6].

Omran et al. [7] reviewed the tribological performance of natural fiber reinforced polymer matrix composites. Fiber treatments, fiber orientations and fiber volume fractions are the important parameters



affect the tribological performance where treated fibers and normal orientation against the sliding direction provides better wear and frictional properties. Wang et al. studied the wear and frictional properties of basalt fiber reinforced composite filled with graphite and nano SiO<sub>2</sub>. Tribological performance of basalt fabric phenolic composites was improved by the synergistic effect of graphite and nano SiO<sub>2</sub> and suggested for high sliding speed applications [8]. Shalwan et al. investigated the mechanical and wear characteristics of date palm fiber and graphite filler epoxy composites, it reveals that addition of graphite is highly recommended for the natural fiber polymeric composites it reduces friction and provides better wear properties [9].

Banana fiber is taken from plant stem and it is extracted through the hand extraction machine. Rice husk is the major waste product in India and the absorption property of rice husk is more [10]. Carbon fibres are light weight and excellent mechanical properties [11] and the author also attempted to conduct experiment on carbon fibre composites using Electrical discharge machining conditions with the help of different cutting tool materials [12,13]. The wear and friction test using a block on ring test method from the mass loss measurement the wear of the material identified on aramid fiber polyamide composite with and without polytetrafluoroethylene filled composites [14].

Carlos et al. has worked with Musaceae rachis reinforced with polyester resin, studying the wear and frictional behavior of this composite and the coefficient of frictional range is the 0.25 - 0.5 which is within the typical range for these composites sliding against a steel disc [15]. The different directions of the carbon fabric wet clutch in their whole service life, the Tribological tests were conducted under oil lubricated conditions [16]. Fairuz et al. has worked with oil palm and kenaf fiber with epoxy composite with dry sliding conditions in this test was using pin-on-disc tribometer. Increasing the temperature resulted in increased wear and decreased coefficient of friction in both composites [17]. Nirmal et al. has worked with the betel nut treated and untreated fiber composites with dry and wet contact conditions compared. Anti-parallel fabric mat is under wet condition wear and friction coefficient was reduced compared to dry condition [18]. Wang et al. studied the synergistic effect of short carbon fiber, graphite and nano particles on friction and wear behavior of polyimide composites. The study states that the combination of short carbon fiber, graphite and nano Si<sub>3</sub>N<sub>4</sub> leads to better tribological properties [19]. Zhang et al. carried out the wear and friction studies of polyimide filled with short carbon fiber and micro SiO<sub>2</sub> and graphite. The result reveals that the single incorporation of short carbon fiber and graphite leads to decent increase in wear resistance but adding SiO<sub>2</sub> is harmful to wear and frictional behavior. Combination of carbon, graphite and micro SiO<sub>2</sub> leads to better frictional and wear properties [20]. Yallow et al. examined the sliding wear properties of jute fabric reinforced polypropylene composites. The result shows that reinforcement of jute fabric into polypropylene composite leads to increase in wear resistance by 3.5 to 45% reduction in frictional coefficient and 65% reduction in wear rate [21]. Gokul et al conducted the experiments to check the mechanical properties surface treated sugarcane fiber composites with filler material and compared with untreated composites. it was stated that adding filler material and surface treatments to the sugarcane fiber improves the strength of the composites [22]. Ibrahim et al. investigated the tribological performance of polyester composites reinforced with agricultural wastes such as palm fronds and mango dry leaves. Result show that increase in palm fronds in composites leads to increase in frictional coefficient and decrease in wear rates. Soft mango leaf particle leads to decrease in frictional coefficient and hard coarse particles shows to 30% increase in coefficient of friction [23].

In this work to fabricate the various fiber reinforced polymer composites using sisal fiber, kenaf fiber, banana fiber, carbon fiber and the filler material is rice husk with polyester resin. The samples have been fabricated, Tribological tests wear and friction test would be performed.

## 2 Experimental procedure

### 2.1 Materials

Banana, sisal and rice husk are collected from the southern India. Carbon fiber, Polyester resin and hardener were sourced from Sakthi Fibre Glass, Chennai, India.

### 2.2 Processing

Various types of fiber materials used in this composites are sisal, banana, kenaf and carbon fiber filler material is rice husk is used. The matrix used the unsaturated polyester resin. The composites are prepared as plates with fixed dimensions. The length and width of the plate is 300mm and the thickness of the plate is 3.2 mm. The polyester resin is prepared by adding 1.5% accelerator (Cobalt Octate) and 1.5% catalyst (Methyl ethyl ketone peroxide). Catalysts are added to the resin system shortly before use to initiate the polymerization reaction. The catalyst does not take part in the chemical reaction but simply activates the process. An accelerator is added to the catalysed resin to enable the reaction to proceed at workshop temperature and/or at a greater rate.

The spacer is placed on the plastic sheet. Now a layer of resin is applied on the plastic sheet. A layer of fiber is placed on top of the resin. Resin is applied on top of the layer of fiber and its ensured that the fiber is completely wet. Another layer of fiber is placed on top. These steps are repeated until the desired thickness was obtained. Another plastic sheet is placed on top. Pressure is applied and temperature is controlled using the compression moulding machine.

These steps were followed to make the three different composites. For the hybrid composites, the primary material is the sisal fiber. The other fibers were placed in the middle and top of the composite with sisal fiber around it. The three different types of composites shown in Figure.1.

**Table 1.** Types of Composites fabricated

Composite Type 1	Composite Type 2	Composite Type 3
Sisal fiber	Carbon fiber	Sisal fiber
Rice husk	Sisal fiber	Banana fiber
Sisal fiber	Rice husk	Kenaf fiber
Rice husk	Sisal fiber	
	CARBON FIBER	

The composite material reinforced with carbon, sisal, Banana, Kenaf, rice husk and polyester matrix was analyzed for wear with ASTM G99. Wear and Friction monitor- TR 201,(Pin on disc) wear apparatus specification shown in Table.2.

**Table 2.** Tribological test specification

Pin size	2mm - 10mm
Disc size	6mm X 100mm
Wear	2000micrometer
Frictional Force	100N



**Figure 1.** Wear and Friction test experimental set up with specimen

### 2.3 Morphological study

Fractured specimens after wear analysis are subjected to Scanning Electron Microscopy of FEI Quanta 200 FEG (FEI Company) at Nanotechnology research centre, SRM University. Images of wear tested specimens are taken under the magnification of 500 to 1000 X respectively.

### 3. Results and Discussion

Wear and frictional force done using an  $L_9$  orthogonal array. Taguchi's method is used when the numbers of inputs are too large to allow for exhaustive testing of every possible input. Three different types of composites were processed and planned to study the wear properties with varying parameters of Load (N), Speed (rpm) and Time (min) which was listed in Table 3.

**Table 3.** Wear Test parameters

S.No	Load (N)	Speed (rpm)	Time (min)
1	40	300	15
2	40	600	30
3	40	900	45
4	60	300	30
5	60	600	45
6	60	900	15
7	80	300	45
8	80	600	15
9	80	900	30

### 3.1 Type 1 Material

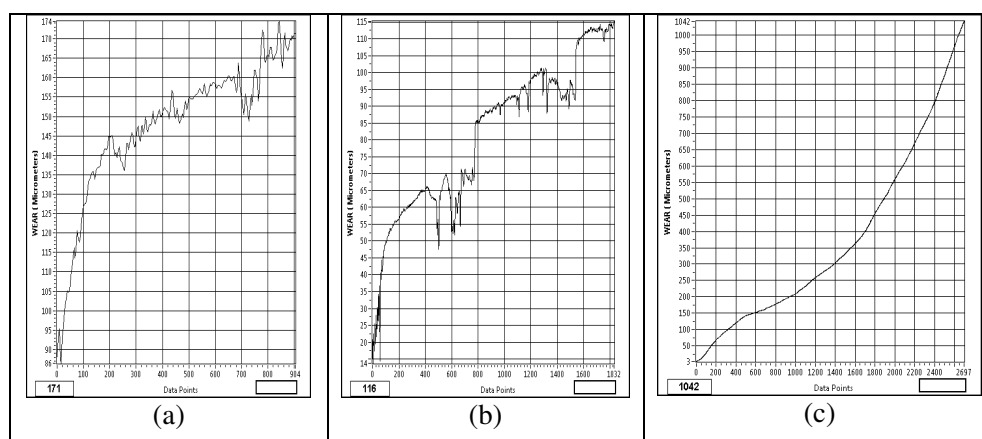
As mentioned above the test is conducted following the parameters mentioned above. Performing this test both wear rate and friction was obtained via a graph and the final value was also obtained. The Figure 2 represents the wear test specimen sisal, banana, and kenaf which are done in Pin on Disc experiment.



**Figure 2.** Wear specimen of sisal + banana + kenaf fiber composite

#### 3.1.1 Wear

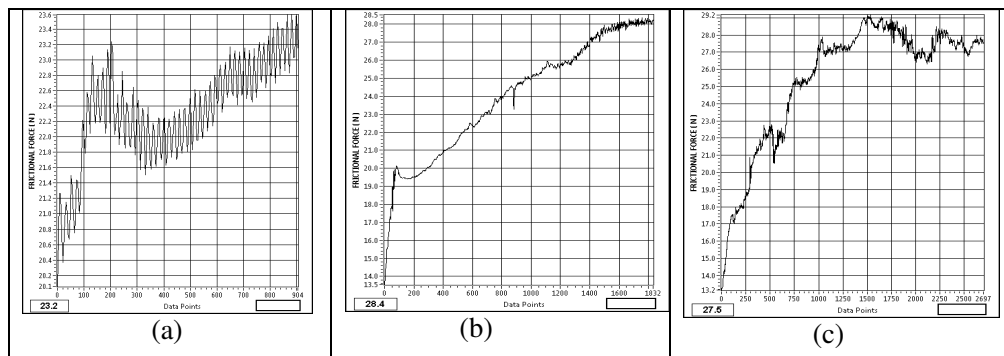
It is the deterioration caused in the composite material due the contact with the spinning disc. The wear is measured in micro-meters. The wear under different conditions is represented with graphs, which also include their final wear. Figure.3 represents the wear of the composite under the various different conditions followed. The load is kept at a constant 40 N. The variations in the parameter are the speed and time. It can be clearly seen with the increase in speed and time the wear also increases. This is because, friction increases with increase in speed which then leads to increase in wear. condition-3 has extremely high wear, which could be due to the high duration and moderate speed.



**Figure 3.** Wear for Different Speed and Time for 40 N

### 3.1.2 Frictional Force

Frictional force is the force exerted by a surface as an object moves across or makes an effort to move across it. The frictional forces under the various different conditions are represented by the graphs shown in Figure 4. Weight loss was more with the increase in the load and the sliding velocity of the composite and compared to other composite wear and friction also more is shown in Table 4.



**Figure 4.** Frictional Forces Different Speed and Time for 40N

**Table 4.** Wear test weight loss of sisal, banana and kenaf fiber composite

S.No	Load (N)	Speed (rpm)	Time (mins)	Before experiment (g)	After experiment (g)	Weight loss (g)
1	40	300	15	2.4987	2.4940	0.0047
2	40	600	30	2.3886	2.3788	0.0097
3	40	900	45	2.5046	2.4189	0.0857
4	60	300	30	2.6809	2.6749	0.0059
5	60	600	45	2.6491	2.5361	0.1130
6	60	900	15	2.4911	2.3926	0.0985
7	80	300	45	2.5896	2.5412	0.0484
8	80	600	15	2.2653	2.2590	0.0063
9	80	900	30	2.3933	2.2765	0.1168

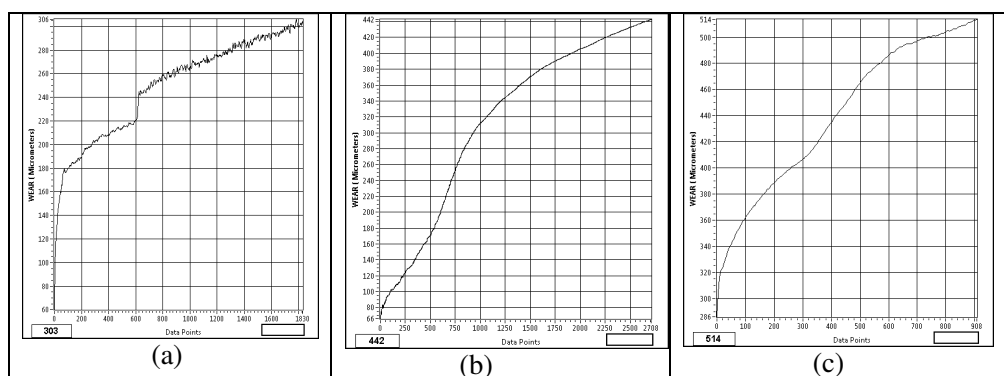
### 3.2 Type 2 material

As mentioned above the test is conducted following the parameters mentioned above. Performing this test both wear rate and friction was obtained via a graph and the final value was also obtained. The Figure 5 represents the wear test specimen carbon, sisal and rice husk which are done in Pin on Disc experiment. That material is prepared by ASTM standards.



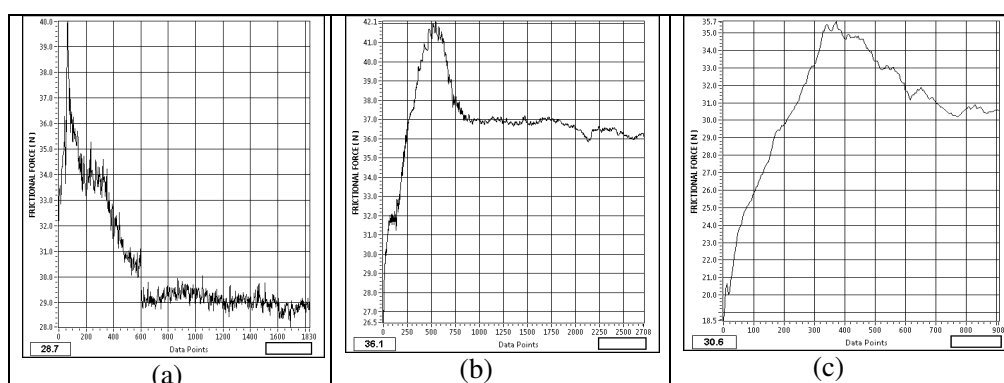
**Figure 5.** Wear specimen of carbon + sisal + rice husk fiber composite

Figure 6. represents the wear of the composite under the various different conditions as mentioned in Table 5. The load is kept at a constant 60 N. The variations in the parameter are the speed and time. It can be clearly seen with the increase in speed and time the wear also increases. This is because, friction increases with increase in speed which then leads to increase in wear. condition-9 has extremely high wear, which could be due to the high duration and moderate speed



**Figure 6.** Wear test results of carbon, sisal and rice husk composite for 60N

Frictional force is the force exerted by a surface as an object moves across or makes an effort to move across it. The frictional forces under the various different conditions are represented by the graphs shown in Figure 7.



**Figure 7.** Frictional Forces Different Speed and Time for 60N

Weight loss of the composite specimen before testing and after testing shown in Table 5.



**Table 5.** Wear test weight loss of carbon, sisal fiber and rice husk composite

S.No	Load (N)	Speed (rpm)	Time (mins)	Before experiment (g)	After experiment (g)	Weight loss (g)
1	40	300	15	2.4987	2.4940	0.0047
2	40	600	30	2.3886	2.3788	0.0097
3	40	900	45	2.5046	2.4189	0.0857
4	60	300	30	2.6809	2.6749	0.0059
5	60	600	45	2.6491	2.5361	0.1130
6	60	900	15	2.4911	2.3926	0.0985
7	80	300	45	2.5896	2.5412	0.0484
8	80	600	15	2.2653	2.2590	0.0063
9	80	900	30	2.3933	2.2765	0.1168

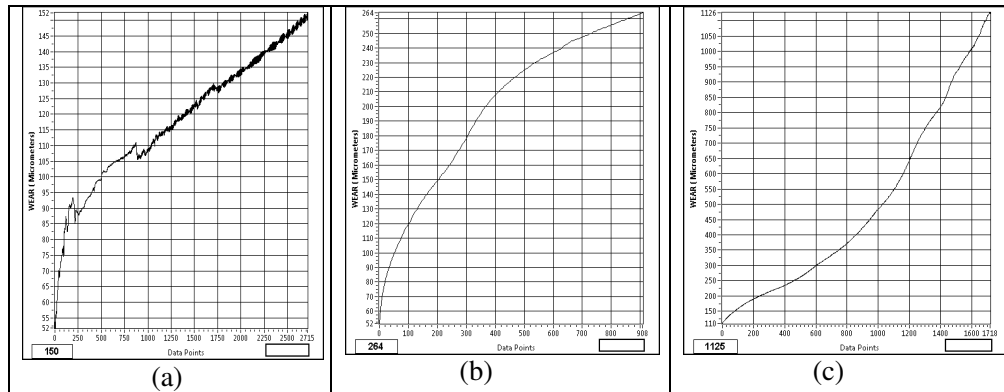
### 3.3 Type 3 material

Material with the combination of sisal fibres filled with rice husk was named as type 3. As mentioned above the test is conducted following the parameters mentioned above. Performing this test both wear rate and friction was obtained via a graph and the final value was also obtained. The Figure 8 represents the wear test specimen sisal and rice husk which are done in Pin on Disc experiment.

**Figure 8.** Wear specimen of sisal + rice husk

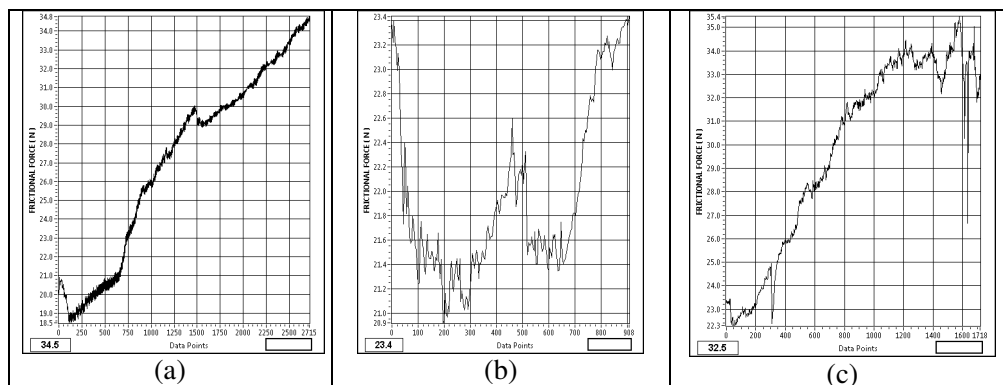
Figure 9. Represents the wear of the composite under conditions 7, 8 and 9. In this case the load is kept at a constant 80N. Under this condition the wear seems to increase with increase in the duration of the test irrespective of the speed of the disc. Condition-9 has the longest duration and thus has the highest wear amongst the three.





**Figure 9.** Wear test results of carbon, sisal and rice husk composite

Figure.10 represents the frictional forces experienced by the composite under the conditions 7, 8 and 9. The load is maximum here at a constant 80N. Here the highest frictional force is experienced under condition-7, where the speed is moderate along with medium duration of the test. This is followed by condition-9, where the speed is maximum for the shortest duration. Finally the lowest is experienced following condition-9, where the speed of the disc is the lowest. The weight loss of the composite shown in Table. 6.



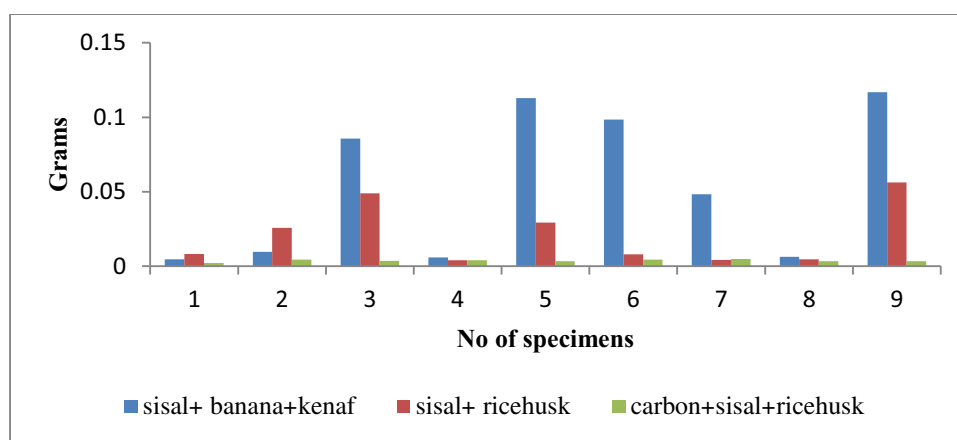
**Figure 10.** Frictional Forces for Different Speed and Time for 80N

**Table 6.** Wear test weight loss of sisal and rice husk composite

S.No	Load (N)	Speed (rpm)	Time (mins)	Before experiment (g)	After experiment (g)	Weight loss (g)
1	40	300	15	2.4721	2.4639	0.0082
2	40	600	30	2.3953	2.3696	0.0257
3	40	900	45	2.2018	2.1529	0.0489
4	60	300	30	2.2903	2.2862	0.0041
5	60	600	45	2.1040	2.0747	0.0293

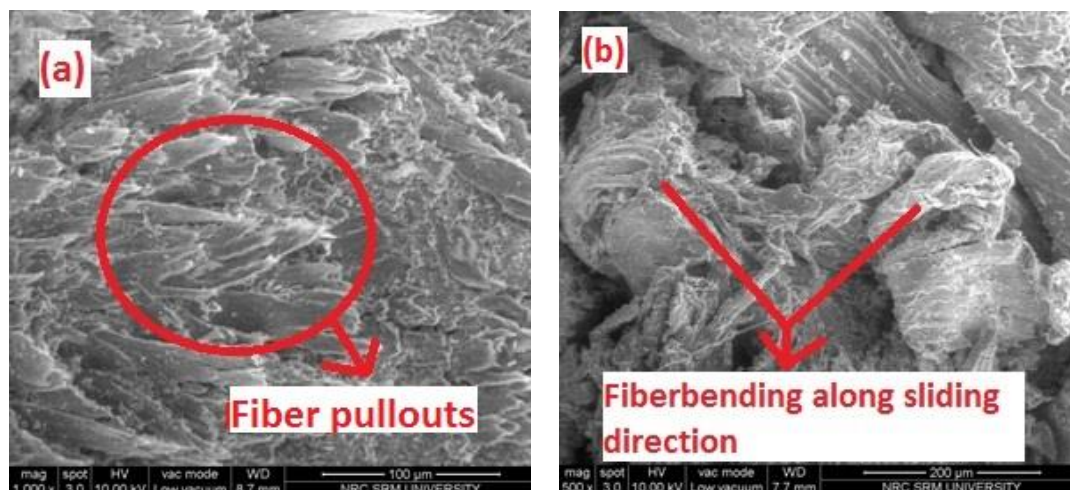
6	60	900	15	2.0908	2.0829	0.0079
7	80	300	45	2.3223	2.3181	0.0042
8	80	600	15	2.3072	2.3026	0.0046
9	80	900	30	2.3061	2.2498	0.0563

Taguchi  $L_9$  orthogonal array method is used for the composites. Wear and frictional force is measured all three composites by Wear and Friction monitor- TR 201. The test equipment used, is the Pin on disc wear apparatus. Sisal, banana, and kenaf fiber composite weight loss was more after increasing the load compared to the other composites shown in Figure 11.



**Figure 11.** Weight loss of the different composite

### 3.4 Microstructure analysis using Scanning Electron Microscope



**Figure 12.** SEM image of wear and frictional tested composite specimen (a) sisal, banana & kenaf composite (b) sisal & rice husk

The morphological study was performed on the wear tested samples of both compositions. It reveals that the fiber pullouts due to the applied load and sliding speed is found to minimum in sisal/banana/kenaf composite samples when compared to sisal rice husk composite samples. Fiber bending and fracture due to the high sliding speed and load is maximum in sisal/rice husk composite compared to sisal/banana/kenaf composites shown in Figure 12.

#### 4. Conclusion

- The changes of wear and friction performance of the sisal and rice husk composite weight have been investigated. The sudden weight loss appear when increasing the speed and time
- Experiment was carried out with fiber reinforced polymer composite on Pin on disc equipment. The carbon, sisal fiber and rice husk composite wear and frictional performance was improved with the increased load an orthogonal array method.
- The sisal, banana and kenaf fiber composite weight loss was more with the increase in the load and sliding velocity.
- Sisal and rice husk composite wear and frictional force was more when we increasing the speed and time

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