International Journal of Engineering & Technology, 7 (3.34) (2018) 424-427

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Wear and Water Absorption Behaviour of Banana and Sisal Hybrid Fiber Polymer Composites

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Abstract

Natural fibers are available naturally from geological, animals and plants. The composite materials can be produced by using these fibers for good properties. In this present work the hybridization of randomly oriented Banana [B] and Sisal [S] of proper composition 20%B 30%S, 30%B 20%S and 25%B 25 %S using 50% Epoxy L-12 resin with the hardener K6 in the 10:1 ratio under cold process method was used. According to ASTM G99 specimens are used to calculate the specific wear rate by pin on disc method and using Taguchi technique. The test specimen with 12 X 12 X 40 mm3 was used to calculate the percentage of water absorption.

Keywords: *Taguchi, Banana, Sisal, Tribology*

1. Introduction

Natural fibers are obtained naturally. Because of demand in needs of earth's resources day to day life, polymer based composite fiber reinforced have been mainly used. The natural fibers are renewable resources now-a-days used by researchers and many industries. Natural fibers like banana, jute, hemp, sisal etc, have good mechanical, physical and thermal properties [2-3]. By use of hybrid mixture, that is mixing of two or more fibers in one makes the composite advantages altogether, with proper composition of reinforcement and matrix [4].
The banana fibers are obtained from banana plant which is largely cultivated and available in nature having relatively good characteristic and mechanical properties [5]. Sisal fibers can be easily grown and harvested from sisal plant having relatively good wear and tear properties [6]. With the mixing of both banana and sisal as reinforcement and epoxy resin with hardener as the matrix the material obtained is of low cost, high strength to weight ratio, increases fatigue life, wear, durable and water absorption.
The rice husk of an agricultural waste is available by rice producing counties. It can be used to produce a composite of light weight, using epoxy resin and fibers of modified and unmodified rice husk as reinforcement to study tribological properties [7-8].
Wear and friction is a defined by tribology. There are different types of testing of wear, each type differ with their operation and application [9]. Solid particle erosion strongly affected by material properties. Banana fiber used as reinforcement and epoxy as resin for the calculation of wear property in the laboratory to collect the data to prove the very low density [10]. Carbon-epoxy composite were fabricated using vacuum bag moulding technique. Hardness and wear properties are evaluated. Plain journal bearing with strength and wear resistance are tested for centrifugal pump [11].
Water absorption for the polymer composites include amount of water absorbed with particular duration of time and it is affected by plastic type, additives used and temperature [12]. The hybrid composite finds major applications in aircrafts, automotive, biomaterials and industries.
In the present work, specimens prepared are tested for tribological and water absorption properties, to calculate the amount of wear with respect to time and also percentage of water absorbed.

2. Material, Methods and Experimental Details

There are different types of composite materials like polymers, ceramics and metals. Polymers composites are used because of less cost, complex parts can be fabricated easily and properties of room temperature is excellent, than metals and ceramics. The most commonly used resin epoxy, polyester, vinylester and phenolics.

2.1 Material Used

2.1.1. Sisal Fiber

Sisal fiber is also known as Agave sisalana. These are basically from sword-shaped leaves and are biodegradable. Each leaf having several numbers of long fibers, which can be removed by decortications process. A sisal fiber does not attract any dust particles and moisture. It has very low maintenance with wear and tear rate. The microfibrillar angle is 20^0 for sisal fiber, which is much higher than any other natural fibers [20].The Table I shows the chemical and mechanical properties of a sisal fibers.

Table I: Chemical and mechanical properties of sisal [21]

Sl. No.	Chemical Constituents	Sisal fiber (%)
1	Cellulose (%)	41.6-62.6
2	Hemi cellulose (%)	9.2-14.6
3	Lignin (%)	11.4-19.5
Physical and Mechanical Properties		
1	Density (g/cm^3)	1.28-1.42
2	Tensile strength (MPa)	126-860
3	Tensile Modulus (GPa)	4.6-16.8
4	Elongation (%)	1.54-3.85
5	Fiber diameter (μm)	145-440

2.1.2. Banana Fiber

Banana fiber obtained from pseudo-stem of banana plant which has relatively good mechanical properties. Its height 10-40 feet, with 8-12 leaves and 2 feet wide. Banana fibers are light weight and strong moisture absorption quality. Chemical properties of banana fibers are presented in Table II.

Table II: Chemical Properties of Banana Fibers [17]

Sl. No.	Chemical Constituents	Banana fiber
1	Cellulose (%)	63-64
2	Micro febrile angle	11
3	Lignin (%)	5-10
4	Density (kg/m^3)	1350
5	Lumen size (mm)	5
6	Tensile strength (MPa)	529-914
7	Young's modulus (GPa)	27-32
8	Hemi Cellulose	6-19

Table III: Mechanical Properties of fibers [18]

Type of Fiber	Density (g/cm^3)	Elongation (%)	Tensile strength (MPa	Young's modulus (GPa)	Specific Modulus (GPa)
Sisal	1.3-1.6	1.9-15	400-700	8.5-4.0	6.5-30.8
Banana	0.5-1.5	2.4-3.5	711-789	4.0-32.7	3.6-27.3

2.1.3. Matrix

Matrix phase forms a solid mass, that bonds hybrid fiber tighter. It forms a weakest and least wear resistant phase. Epoxy resin [L-12] is a thermoset resins undergo a chemical cross-linking reaction of bisphenol A and epichlorohydrin. The epoxy resin has better adhesive properties, fatigue and micro cracking properties. It has a increased resistance to Osmosis, very good mechanical properties. It finds major applications in protective coatings, structural composites, Electrical laminates and adhesives.

2.1.4. Hardener

A hardener [K6] is a component of certain types of mixtures. In some mixtures a hardener is used simply to increase the resilience of the mixture once it sets. In other mixtures a hardener is used as a curing component.

2.2 Methods

2.2.1. Specimen Preparation Method

The fibers were cut equally 10mm in length and mixed using random mixing technique. The composite preparation process was fabricated by hand layup technique for different fiber composition as shown in Table IV.

Table IV: Composition of the Hybrid Composites

Composite	Composition (wt. %)		
	Banana fibers	Sisal fibers	Epoxy resin
A	30%	20%	50%
B	20%	30%	50%
C	25%	25%	50%

2.2.2. Mould Box

The mould box is prepared of mild steel with dimension of volume 300 X 300 X 25 mm^{3}as shown in Fig. 1. The proper composition of banana, sisal, epoxy and hardener in mixed as shown in Table IV. Using hydraulically operated compression moulding machine, the specimen is prepared according to standard.

Fig. 1: Mould Box

2.3 Experimental Details

2.3.1. Wear Test by Pin on Disc Setup

The prepared specimen is of ASTM G99 standard of size 12 X 12 X 40 mm^{3}as shown in Fig. 2. The electronic sensors monitors friction force and wear with the function of load, speed, lubrication or environmental conditon as shown in Fig. 3. The test carried out by applying normal load (1 Kg, 2 Kg and 3 Kg), run for a sliding distance (400m, 500m, 600m) at veloctiy (1m/s, 2m/s, 3m/s) for A, B, C composition.
At the end of the test, the sample was again weighed. The difference between the intial and final weights was measured of weight loss. The experiments were conducted on the basis of L_9 orthogonal array by smaller the better formula for calculation of signal to noise ratio (S/N ratio).

Fig. 2: Specimen Samples

Fig. 3: Wear testing setup

2.3.2. Water Absorption Test

The effect of water asorption on hybrid composite fibers in accordance with ASTM D570 with specimen size 12X12X40 mm^3. Water absorption tests were conducted by measuring the composite specimen in distilled water in beaker at room temperatiure for different tme durations as shown in Fig. 4. After immersion for 24 hr, the specimen were taken out from the water and weighed regularly. Water absorption is calculated as per Equation (1).
Water absorption in % =
((wet weight – initial weight))/(Initial weight) ×100 1

Fig. 4: Water absorption testing

3. Result and Discussion

3.1 Taguchi Experimental Design For Wear Studies

The response curves, using smaller the Better characteristics formula has been used to identify the combination of influence parameters to enhanced the wear rate of optimum as shown in equation 2. The unit will be in terms of db [19].

$$S/N = -10 \log (1/n \ \Sigma Y_i^2) \qquad 2$$

Where n is the number of tests in trial, Y_i Shrinkage value and S/N is the signal to noise ratio

The L_9 orthogonal array experimental result of wear test as shown in Table V with velocity change in m/s, finds the optimum value of response.

It is clear that composite material 'A' shows better wear resistance as compared to other composites. Decreased weight percentage of banana fiber resulted in lower wear resistance compared to others. Minimum wear is observed when experimenting with sliding distance 600 m, load 3 Kg and sliding velocity 3m/s. wear resistance increases with increase in load, sliding distance for all composites.

Table V: L_9 Orthogonal Array and performance results

Exp.	Load (Kg)	Sliding Distance (m)	Velocity in (m/s)	Composite Materials	Specific wear rate (mm^3/Nm)	S/N Ratio (db)
1	1	400	1	A	0.008755	41.15457
2	1	500	2	B	0.00704	43.04867
3	1	600	3	C	0.005568	45.08605
4	2	400	2	C	0.00522	45.64663
5	2	500	3	A	0.002783	51.10993
6	2	600	1	B	0.003435	49.28071
7	3	400	3	B	0.003721	48.58738
8	3	500	1	C	0.003305	49.61632
9	3	600	2	A	0.001798	54.90438

The average S/N ratio is shown in Fig. 5 and Fig. 6, represents main affect plots for S/N ratio and means effect plot. These graphs are plotted using Minitab V17.

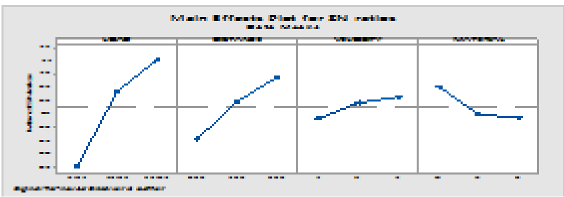

Fig. 5: Main effect plot for SN ratio of fiber composition on wear test

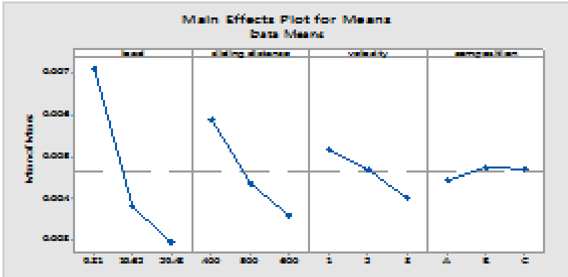

Fig. 6: Main effect plot for means of fiber composition on wear test

3.2 Water Absorption Result

It is very much clear from Fig. 7 that the percentage of water absorption increased with increase in banana fiber loading. This behaviour can be explained based on the fact that natural fibers are hydrophilic, with the increase in the composition of sisal fiber than banana fibers, water absorption is decreased. The three main areas where water can exist in composite are lumen, cell wall and the gaps between fiber and resin in case of weak interface adhesion. A proper chemical treatment of natural fibers reduces moisture absorption.

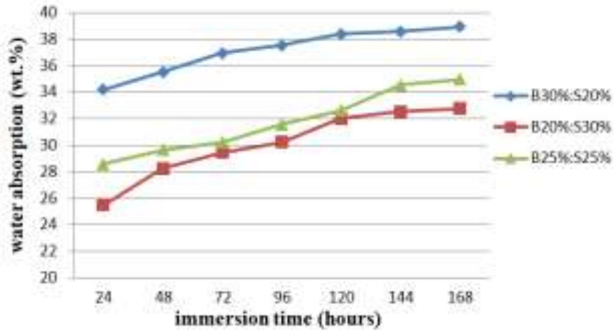

Fig. 7: water absorption behaviour

4. Conclusions

From the result obtained, it is clear that, the wear resistance reduces with increasing weight ratio of banana fiber in epoxy composite. Optimum specific wear rate was observed for composition "A" at load 3 Kg, sliding distance 600m, velocity 3m/s by using taguchi technique. Analysis of variance shows the percentage of contribution of each parameter effect on the performance on the composites.

The water absorption test which is performed for 7 days proves the absorbing rate gradually increased with increase in banana fiber loading and the minimum water absorption is obtained with 30% sisal fiber and 20 % banana fiber loading.

Acknowledgment

The author wishes to thanks Karthik A J, Nagraj Deshbhandari, Pavankumar J and Phani Kumar Y students of AIET, Moodbidri for supporting this work.

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