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Tribological Behavior of Sponge Gourd Based Hybrid Reinforced Polymer Composite

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Abstract

In recent times natural fibers are more explicitly exploited for design and development of polymer composites. In the present work mat/woven structure of Luffa cylindrica (loofah), coconut coir (medially coarse and fine) particulates and short bagasse fibers from the rind of sugarcane were utilized to form hybrid reinforced polymer composites in epoxy matrix arranged in different stacking sequences. The fabrication was done with the chemically modified (surface modification) natural fibers in epoxy matrix by hand-layup technique. The erosive wear properties of the fabricated composites have been investigated experimentally. The experiments were carried out in an air-jet erosive wear tester at room temperature. The fabricated composites were exposed to a steam of silica sand erodent particles of particle size of (200±50) µm at different impact velocities and pressures for an exposure period of 10 minutes. The erodent was fed at a rate of .5 grams/minute. The impingement angle was set at 30^0, 45^0, 60^0 and 90^0. The erosion rate in each case was calculated by determining the mass loss of test sample and the mass of eroding particles (product of testing time and particle feed rate). The results of the tests were utilized to study the hybrid effect of the natural fibers in natural fiber reinforced polymer composites.

Keywords- loofah, coir, bagasse, epoxy, hand lay-up, erosion

I. Introduction

Natural fibers are an economical and environmental friendly substitute for artificial fibers. In recent times these materials with little environmental concern are of great interest in many technological applications such as composites based on natural fibers are an interesting alternative when moderate mechanical properties are required [1]. The main components of plant fibers are cellulose, hemicellulose and lignin along with pectin, some waxes and some water soluble compounds. Cellulosic fibers, like sisal, henequen, jute, oil palm, bamboo, wood paper in their natural have been used as reinforcements in different thermosetting and thermo plastic resins [2-9]. Plant fibres are appealing due to their low cost, eco-friendly nature, wide availability, renewablity, biodegradility and low density. However, usage of natural fibres in composite materials are subjected to certain drawbacks such as high moisture sorption, poor dimensional stability, low thermal resistance, isotropic fibre resistance and variability of composition [10]. For a fiber to be considered appropriate to be used as a reinforcement in the composite, there must be good strength of adhesion between fibers and matrix. The extent of adhesion depends upon the structure and polarity of these materials [11]. Surface modifications of natural fibers decreases the moisture absorption and increases the wettability of the fibers by the polymer matrix and the interfacial bond strength [12].

The interest in natural fiber reinforced polymer composite materials is rapidly growing in terms of their tribological, industrial applications and fundamental research [12]. There are possibilities where the composites during its service may encounter sand or slurry of solid particles causing its failure due to erosion wear. Hence, erosive wear studies of natural fiber reinforced polymer composite is very essential. The erosion wear of reinforced polymer composite is usually higher than unreinforced polymer matrix [13]. The erosion wear resistance of polymer composites is low as compared to monolithic materials [14]. The different possible application areas of natural fiber reinforced polymer composites are consumer goods, windows, furniture, door paneling elements,designer office chairs, hand friendly Image products, wheels, impellers, seals, brakes gears, cams, artificial prosthetic joints and bearings etc [15].

In the present paper, the erosive wear behavior of bio-wastes (bagasse, coir dust, and luffa) reinforced polymer composites are studied. Experiments are conducted to study the effects of impingement angle and impact velocity of the erodent particle on the erosive wear behavior of the composites.

II. Materials

2.1 Luffa Fiber

Luffa (or in non-technical usage spelled as loofah) is a plant of genus Luffa grown as tropical and subtropical vines belonging to the cucumber or Cucurbitaceae family. Luffa sponge is widely employed as food, daily household cleaning materials, shock absorbers, filters for military use, etc. Luffa fiber is extensively studied by many researchers as reinforcement in natural fiber-reinforced composite. They are of the following species

- Luffa acutangula (Angled luffa, ridged luffa, vegetable gourd)
- Luffa aegyptiaca / Luffa cylindrica (Smooth luffa, Egyptian luffa, dishrag gourd, gourd loofa)

- Luffa operculata (Wild loofa, sponge cucumber)

In the present study, Luffa sponge from Luffa cylindrica plant was used. The hoop wall in longitudinal section (woven mat form) is taken as reinforcement in the present study.

2.2 Bagasse Fiber

Bagasse is the fibrous matter that remains after extraction of juice from sugarcane in sugar and alcohol industry. It is one of the most abundant cellulose based agro industrial by products and fibrous residue. It is used as a biofuel, renewable resource in the manufacture of pulp and paper products, soft and medium density fiber boards or particle boards and high density hard boards. Outer layer is called rind (lignocellulosic layer) and inner layer is called pith (containing most of sucrose). In the present study, outer rind portion of bagasse fibers are taken as short fiber reinforcements of embedded length greater than 9.18 mm such that the fiber does not pullout or rupture during fiber pull out test [16].

2.3 Coir Dust

Coir is a lignocellulosic fibre obtained from the husk of ripened coconuts grown extensively in tropical countries. It has good wearability and durability. It is used for making wide variety of floor furnishing materials, yarn, rope etc. Research is carried out to utilize coir as reinforcement in polymer composites. In the present study coconut coir was collected was used in fine coir dust form as particulate reinforcement in the fabricated composite.

2.4 NaOH

Sodium hydroxide (IUPAC name Sodium oxidanide also known as caustic soda) was used for mercerization of fibers in the present study.

2.5 Epoxy and Hardener

Epoxy (LY556) also known as DGEBA (Diglycidyl ether of bisphenol-A) resin was used. Hardener (HY951) also known as TETA (triethylene tetraamine) (IUPAC name NN0-bis (2-aminoethylethane-1, 2-diamin)) was used. HY 951 is a low viscosity aliphatic amine.

III. Experimentation

3.1 Chemical Treatment

The fibers were mercerized with 5% NaOH solution for 4 hours at room temperature by maintaining liquor to fiber ratio of 15:1. The treated fibers were then washed several times until a final pH of 7 was attained. The fibers were then dried. The mercerization of natural fiber occurs according to following equation [17].

$$\mathbf{Fiber - OH + NaOH \rightarrow Fiber - O^{-} - Na^{+} + H_2O}$$

3.3 Composite fabrication

Wooden molds were prepared. Composites were fabricated using hand lay-up technique. The matrix was prepared by properly mixing Epoxy LY556 and hardener HY951 in a ratio of 10:1 by weight. The chemically treated fibers were used as reinforcement according to fixed composition as given in table 1.

Table 1: List of fabricated composites

Luffa single mat reinforced composite	L
Bagasse 20wt% reinforced composite	B
Coir dust 10wt% reinforced composite	C
Coir dust 5wt% and bagasse 5wt% reinforced hybrid composite	CB
Bagasse 10wt% sandwiched between two luffa fiber mat reinforced hybrid composite	LBL
Coir 10wt% sandwiched between two luffa fiber mat reinforced hybrid composite	LCL
Coir 5wt% and Bagasse 5wt% sandwiched between two luffa fiber mat reinforced hybrid composite	L(CB)L

3.4 Study of Erosive Wear

Erosion is the process of material removal due to impingement of solid particles on its surface. The factors influencing the erosion rate of the composites are (i) The properties of the target materials (matrix material properties and morphology, reinforcement type, amount and orientation, interface properties between the matrices and reinforcements, etc.), (ii) Environment and testing conditions (temperature, chemical interaction of erodent with the target), (iii) Operating parameters (angle of impingement, impinging velocity, particle flux–mass per unit time,etc.) and (iv) The properties of the erodent (size, shape, type, hardness, etc.) [18-21]. In general, erosive behaviour of materials can be grouped into ductile and brittle when erosion rate is evaluated as a function of impact angle. The ductile behaviour is characterized by maximum erosion at low impact angle in the range of 15°–30°. On the other hand, if maximum erosion occurs at 90°, then the behavior can be termed as brittle. Intermediate behaviour of reinforced composites known as semi-ductile with maximum erosion occurring at an angle in the range of 45°–60° [22].

The composite samples were cut in sizes of (20 x 20 x 4) mm^3 as shown in figure 1. The solid particle erosion wear tests were carried out as per ASTM G76 standard on the erosion test rig as shown in figure 2. The arrangement consists of an air compressor to supply pressurized air, an air and erodent mixing chamber and an accelerating chamber to target the erodents to the composite slabs. The erodent particles impact the composite specimens held at angles of 30^0, 45^0, 60^0 and 90^0 with respect to the direction of erodent flow using a swivel and an adjustable sample clip.

Figure 1. Samples for erosion test

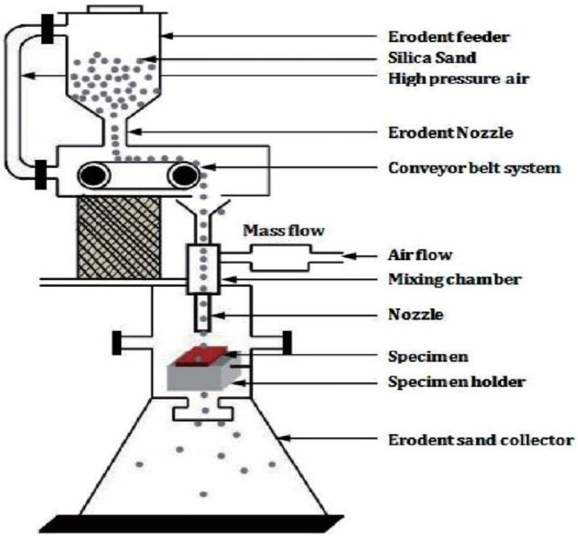

Figure 2. Erosion Test Rig [23]

The experimental details are given in Table 2.

Table 2. Experimental conditions

Erodent	Silica sand
Erodent Size	(200±50) μm
Impact angle	30^0, 45^0, 60^0 and 90^0
Impact velocity	48 m/s, 70m/s
Pressure	1 bar, 2 bar
Erodent feed rate	0.552±0.02 gram/min
Test temperature	Room temperature
Nozzle to sample distance	10mm
Time	10 mins

The wear rate was expressed in terms of $\Delta w_1/ \Delta w_2$
Δw_1 represents the loss in weight of the composite and Δw_2 is the total weight of the erodent used.

IV. Results and discussion

Erosion behaviour of the composites depends on the impingement angle. Figures 3(a) and 3(b) show the erosion wear rate dependence on impact angle at different impact velocities.

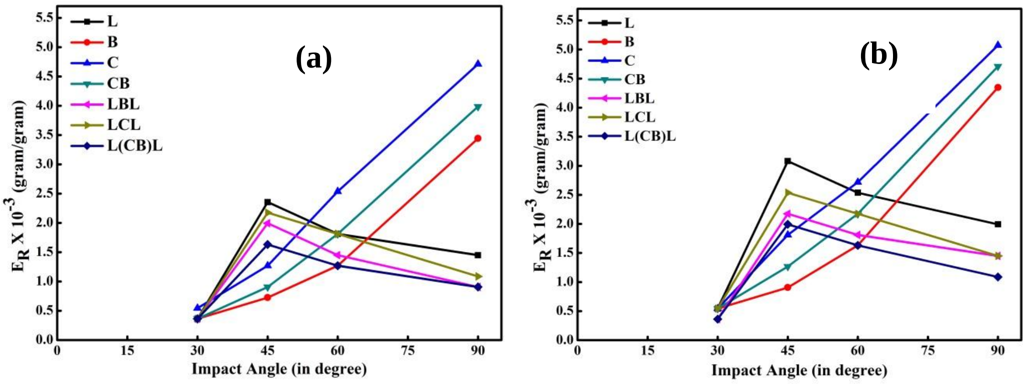

Figure 3. Variation of erosion rate with impingement angle for different composites (a) at an impact velocity of 48 m/s (b) at an impact velocity of 70 m/s

It could be seen that bagasse and coir dust composites depict brittle behavior while only luffa and hybrid composites with first layer as luffa fiber shows semi-ductile behavior. Similar results were obtained for coir dust [24], bagasse [25], luffa fiber [26].

Scanning electron microscopy studies

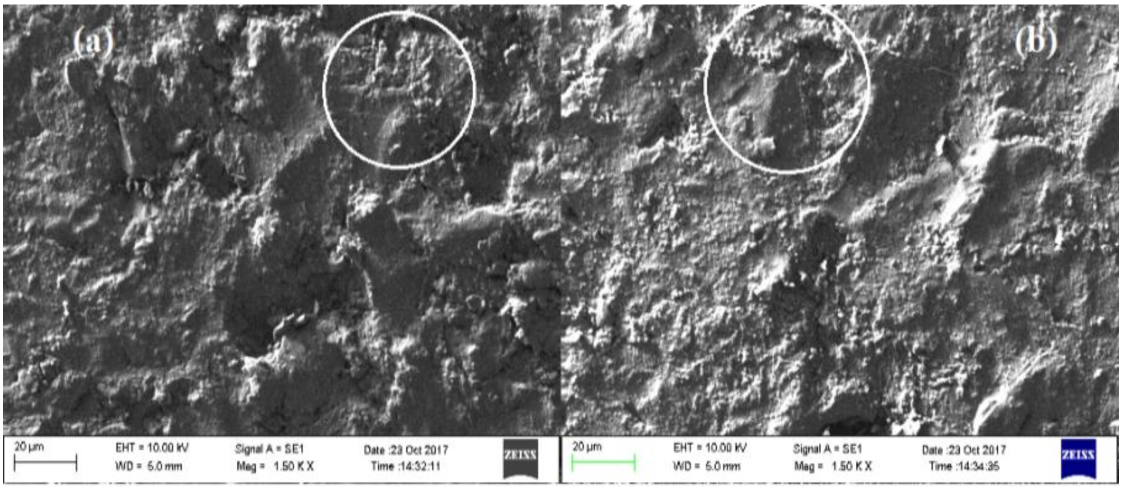

Figure 4. SEM micrograph of eroded surfaces of (a) L- composite (b) LCL- composite

To characterize the morphology of eroded samples are observed under scanning electron microscope The conductivity of the eroded samples are enhanced by coating a thin gold film on to them such that a clear image can be obtained. Figure 4(a) and 4(b) show the SEM micrographgraph for the composites eroded at 45°. It clearly indicates damage to the fibers. It images show the micro-cutting and breakage of the fibers.

V. Conclusions

Erosive wear test was carried out on the fabricated composites. It was observed that bagasse and coir dust composites depict brittle behavior while luffa and hybrid composites with first layer as luffa fiber shows semi-ductile behavior. Similar results were obtained by several researchers as Aireddy et al [24] while studying the tribological behavior of coir dust composites in polymer matrix Mishra et al [25] while studying the solid particle erosion of Bagasse fiber reinforced epoxy composite; and Mohanta et al. [26] while studying the tribological performance of Luffa cylindrica fiber reinforced epoxy composite . The surface morphology of the eroded surfaces were studied using SEM micrographs.

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