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# THE EFFECTS OF FIBER TREATMENT ON WEAR PERFORMANCE OF LANTANA-CAMARA / EPOXY COMPOSITES

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## ABSTRACT

This work aims to present a study on abrasive wear behaviour of locally available Lantana-Camara fiber **(LCF),** reinforced in epoxy matrix. Effect of fiber surface treatment on abrasive wear performance of **LCF**–Epoxy composites has been determined by using a pin-on-disc machine in dry conditions against 400 grit size abrasive paper with test speed of 0.314 m/s and normal load 5N, 10N, 15N, 20N and 25N. The results show that the incorporation of LCF into epoxy improves the abrasive wear behavior considerably. Incase of Un-treated fiber epoxy composite, optimum wear reduction was obtained when fiber content was 40 vol% by weight. Chemical modification of fiber surface gives better wear resistance as compared to untreated fiber. It has also been found that Benzoyl-Chloride treated fiber epoxy composite gives better wear resistance as compared to the Alkali and Acetone treated fiber epoxy composites. Abrasive wear performance of the composites has been explained with the help of surface microstructures of worn surfaces.

**Keywords:** Lantana-Camara fiber, Abrasive Wear, Chemical modification of fiber surface.

## INTRODUCTION

Now a day's Fiber-reinforced polymer (FRP) composites are widely used in design due to relatively low-density and reliable tailoring capability to provide the required strength and stiffness. Numerous possible material combinations, unique self lubrication capabilities and low noise make the FRP composites as a better substitute over conventional metallic materials for tribological application. The different application areas are gears, cams, wheels, impellers, brakes, artificial prosthetic joints, seals, bushes, bearings, etc [1-2]. Failure of these mechanical components occurs due to different types of wear mechanism. However failure due to abrasive wear alone contributes 60% of the total cost [3]. Abrasive wear is caused by hard particles that are forced and moves along a solid surface. While designing tribo-materials, emphasis is being given by the researchers through out world on the biodegradability due to environmental concern [4]. The environment friendly, natural-fiber reinforced polymer composites are being preferred over the synthetic fiber reinforced composites due to their inherent bio-degradability, low density, low cost, a range of mechanical properties, less abrasiveness, etc [5-9]. Interestingly, several types of natural fibers which are abundantly available like jute, sisal, oil palm, banana, bamboo, wheat and flax straw have proved to be good and effective reinforcement in the thermo-set and thermoplastic matrices [10-14]. However, there are some problems associated with the production of natural fiber-based composites such as high level of moisture absorption, poor wettability and insufficient adhesion between untreated natural fibers and the polymer matrix leads to debonding with age [15]. This problem can be overcome by modifying the fiber surface with suitable chemical treatments.

In the pursuit of visualizing the importance of polymeric composite in tribological application, lots of work already been published on various types of polymer and fibers. Hashmi et al. [16] investigated the sliding wear behavior of cotton–polyester composites and obtained better wear properties on addition of cotton reinforcement. Tong et al. [17] studied the abrasive wear behavior of bamboo and reported that the abrasive resistance of a bamboo stem is affected by the vascular bundle fiber orientation with respect to the abrading surface and the abrasive particle size. Chand et al. [18] while studying influence of wood flour loading on tribological behavior of epoxy composites, reports that the reinforcement of wood flour increases the load carrying capacity of epoxy and decreases its wear resistance. Tayeb [19] studied the tribo-potential of sugarcane fiber reinforcement in the thermo-set polymers, found that addition of sugarcane fiber enhanced the adhesive wear resistance of thermo-set polymer. The adhesion between fiber and matrix plays critical role in the abrasive wear performance of fiber-reinforced polymer composites [20–22]. Chand and Neogi [23] reported that laser irradiation improve the interfacial bonding and hence wear properties. In another paper Chand and Dwivedi [24] while studying the effect on MA-g-PP on the wear properties of jute–PP composite, reports that the MA-g-PP modification improved the wear properties of jute/ PP composites. Recently, Chand and Dwivedi [25] report that the wear resistance of untreated sisal fiber reinforced polyester composite being improved by silane modification.

Lantana-Camara was introduced in India in 1809 as an ornamental plant. This weed at present is posing serious problems in plantation forestry at various locations. Some of the use of Lantana Camara is to make cheap furniture, utility articles, mosquito repellent and as medicine for various cures particularly for skin related diseases [26]. On the other hand the plant is an invasive weed and is almost treated like bamboo in some part of India. The chemical compositions of Lantana-Camara are 75.03% hollocellulose, 8.461% extractive, 18.21% lignin and 2.31% silica, which clearly indicate its potential to be used as reinforcement material in polymer matrix composite. As per the information of the author no work till now has been done on Lantana-Camara Fiber as reinforcement in composite material. Study on Lantana-Camara Fiber as reinforcement in polymer matrix is relatively new. Hence in the present work an attempt has been made to study the tribo-potential of short Lantana-Camara fiber reinforced polymer composite.

## EXPERIMENT

### TEST MATERIALS

#### *Lantana- Camara Fiber Preparation:*

Fresh Lantana-Camara stems were collected locally. They were cut to sizes between two nodes. The upper skin was removed by hand scrapping without damaging the fiber surface. Then they were cut to sizes of 100mm lengthwise. Long fibers were washed with pressurized water to remove unwanted organic materials present on the surface and were dried outside at sunlight for 8hrs. From available long fiber small (10 mm) fibers were cut with a pair of scissors. Small fibers are selected in order to design a composite with consistent properties. These fibers were again washed with pressurized water and dried with compressed air.

#### *Epoxy Resin:*

The type of epoxy resin used in the present investigation is Araldite LY556 and hardener HY 951 supplied by Ciba-Geigy of India Ltd. they were mixed in a ratio of 10:1 as recommended.

### Chemical Modifications of Fiber Surface

Untreated and chemically treated LCF fibers were used for fabricating the composites. LCF fibers were subjected to different surface treatments with alkali, acetone and benzoyl chloride.

#### *Alkali treatment:*

The chopped Lantana-Camara fibers were soaked in a 5% NaOH solution at 30°C maintaining a liquor ratio of 15: 1. The fibers were kept immersed in the alkali solution for 2hours. The fibers were then washed several times with fresh water to remove any NaOH sticking to the fiber surface, neutralized with dilute acetic acid and finally washed again with distilled water. Final pH maintained was 7. The fibers were then dried at room temperature for 48 h followed by oven drying at 100°C for 6 h.

#### *Benzoylation treatment:*

Pre-treated chopped Lantana-Camara fibers were soaked in 18% NaOH solution for half an hour, filtered and washed with water. The treated fibers were suspended in 10% NaOH solution and agitated with benzoyl-chloride. The mixture was kept for 15 min, filtered, washed thoroughly with water and dried between filter papers. The isolated fibers were then soaked in ethanol for 1 h to remove the untreated benzoyl chloride and finally were washed with water and dried.

#### *Acetone treatment:*

Thirty gram (30gm) batches of Lantana-Camara fiber were washed in Soxhlet apparatus with acetone for approximately 1–1.5 h. The acetone was evaporated (boiled at $63^0$C) and condensed back into the volume with the fibers. It required 20 min for the acetone to condense and fill a volume of 200 mL. This process was repeated four times for each batch. The used acetone was then discarded before the next batch was cleaned in the same manner. The acetone changed from transparent to parrot-green after treatment due to the presence of waxes and organic materials after the extraction.

## Composite Preparation:

The untreated and treated chopped Lantana-Camara fibers were added separately to the mixture of epoxy resin and hardener at room temperature. The above mixture was stirred for 10 min by a glass rod to obtain uniform dispersion of fiber and then poured into cylindrical mould. The upper and lower portions of the mold were fixed properly. Composite pins of length 35 mm and diameter of 10 mm were prepared by this process. The samples were kept in the moulds for curing at room temperature (29 $^{0}$C) for 24 hr. Cured samples were then removed from the moulds and used for abrasive wear test.

## Experimental Design

The composite systems outlined in Table 1 were manufactured to investigate varying properties such as fiber volume fraction by weight and chemical treatment of fibers. The first group of samples (Group 1) had carefully measured volume fractions by weight at 10, 20, 30, 40 and 50%, respectively. The initial results from abrasive wear testing showed that 40% fiber volume fraction by weight possessed the minimum wear loss. Based on these results the second group of samples of 40% fiber was selected for experimental work (Group 2). The second group of samples involved varying fiber surface treatment, namely (i) Alkali treated fiber, (ii) Acetone treated fiber, and (iii).Benzoyl Chloride treated fiber.

**Table 1. Types of Lantana-Camara fiber epoxy composite samples used in the experimental research.**

| Group | % Volume Fraction by Weight | Type |
|---|---|---|
| Group1 | 10 | Un-treated Fiber |
| | 20 | Un-treated Fiber |
| | 30 | Un-treated Fiber |
| | 40 | Un-treated Fiber |
| | 50 | Un-treated Fiber |
| Group2 | 40 | Alkali treated Fiber |
| | 40 | Acetone treated Fiber |
| | 40 | Benzoyl-chloride treated Fiber |

## Abrasive Wear Test

Abrasive wear studies were carried out under multi-pass condition on a pin-on-disc type wear testing machine. Abrasive paper of 400 grades (grit-23 µm) was pasted on a rotating disc using double-sided adhesive tape. The sample pin was fixed in a holder and was abraded under different applied loads for five intervals of 5min. where each time interval corresponds to a sliding distance of 94.25 meter. The effects of various loads (5, 10, 15, 20, and 25 N) and sliding velocities (0.314m/s) in a track radius 40mm were studied. The samples were cleaned by using Acetone to remove any debris adhered to sample before and after each test. The weight loss was recorded by weighing the pin to an accuracy of 1×10−3 gm using an electronic balance after each run.

# RESULT AND DISCUSSION

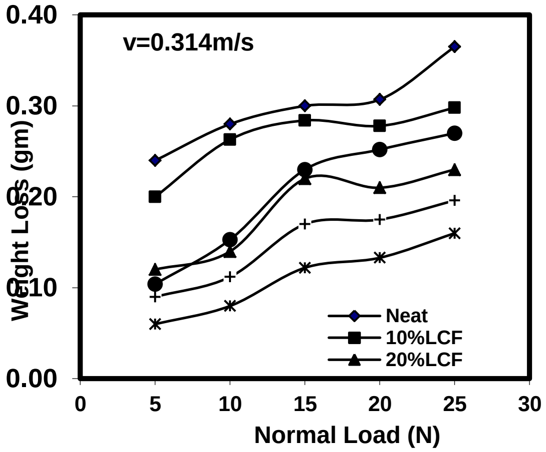

**Figure.1.Abrasive weight loss of the Composites with different normal load.**

Figure.1.Shows the influence of load on the abrasive wear of the un-reinforced and reinforced composites at sliding velocity of 0.314m/s. The weight loss increases with the increase of normal load. Weight loss was relatively low at lower load (5N) load because of less penetration and less numbers of abrasive particles were in action with rubbing surface. The abrasion wear was greatly increased at higher load because most of the abrasive particles were penetrated into the surface and created more grooves resulting in more material removal by severe plastic deformation. The weight loss decreases with addition of Lantana-Camara fiber up to 40wt%. It means that Lantana-Camara fiber is very effective in improving the tribological performance of epoxy, especially for its wear resistance. But at 50 wt% of reinforcement the wear rate suddenly increases. It means that the excessive fiber addition decreases the wear resistance of the composites. This might have happened due to agglomeration of fiber and lower interfacial adhesion when the fiber content is too high (50 wt %), which might have lead to drawing out of the fiber from the matrix resin during the test.

Figure.2. shows the plot between weight loss and applied load at constant sliding velocity (v=0.314m/s) of treated and untreated Lantana-Camara fiber (40% vol by weight) reinforced epoxy composite for 471.25m sliding distance. The untreated chopped Lantana-Camara fiber reinforced composite exhibits higher weight loss compare to the modified fiber composite during abrasion test. This is due to the weak interfacial bonding between Lantana-Camara fibers and the epoxy because the untreated fiber surface is found to be smooth due to the presence of oils and waxy substances.

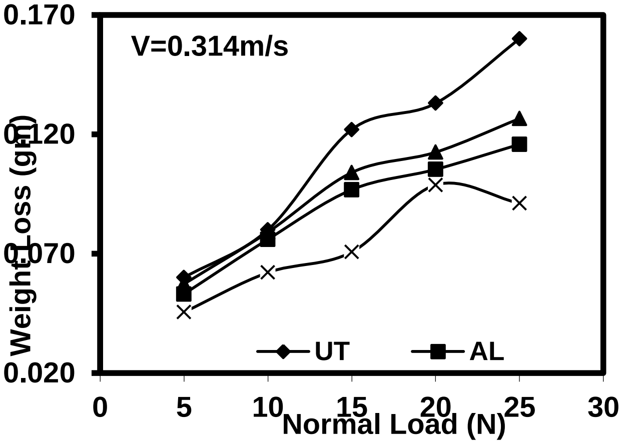

**Figure.2. Plots between weight loss and applied load for treated and untreated Lantana-Camara fiber epoxy composite (40%): (a) UT-Untreated fiber, (b) AL-Alkali treated fiber, (c) AC- Acetone treated fiber and (d) BZ-Benzoyl Chloride treated fiber.**

The level of adhesion between fiber and matrix greatly affects the abrasive properties of the composites. The chemically modified fiber reinforced composite showed reduction in weight loss as compared to the unmodified fiber composite. This is due to the improved fiber–matrix adhesion, caused by the chemical surface treatment of fiber. It can be clearly seen in the figure.2 that the composite with benzoyl chloride treated fiber exhibits less weight loss compare to all other treated and untreated fiber. This may happen due to benzoylation, the fiber diameter decreases and hence the aspect ratio increases. This may be due to the dissolution of alkali soluble fractions like waxy layer, lignin, etc. during alkali treatment and benzoylation. Moreover, the treatment provides a number of small voids on the surface of fiber that promote mechanical interlocking between the fiber and the epoxy matrix. As a result of benzoylation, the hydrophilicity of the fiber is greatly reduced; this makes the fiber more compatible with hydrophobic epoxy matrix, thereby increasing the properties of the composite. But in case of acetone and alkali treatment the improved property of the composite may occurs due to dissolution of hemicellulose, development of crystallinity and fibrillation of fiber.

# MICROSTRCTURAL OBSERVATION

The worn surface morphologies of neat epoxy and its composites were examined by scanning electron microscopy (SEM). Figure 3.a. shows the worn surface of epoxy sample at 15N normal load. It can be seen that neat epoxy was characterized by plastic deformation and adherence. The worn surface of untreated fiber (40 wt. %) composite under 15N load shown in Figure 3.b. There is no indication of plastic deformation and adherence but debonding, fiber micro-cutting and micro-ploughing are the dominant wear processes. After the debonding, between fiber and matrix, abrasive particles easily remove fragmented fibers from the surface, which come out in the form of debris. In other words cut fibers easily worn out in debris form from untreated fiber composite. Figure 3.c to figure 3.e shows the worn surface of composite with alkali, acetone and benzoyl chloride treated Lantana-Camara fiber respectively. The treated fiber and epoxy resin was still bonded to some extent after abrasion was observed. This indicates that surface treatment improved the interfacial bonding between the fiber and the epoxy resin matrix for which the wear resistance has been greatly improved.

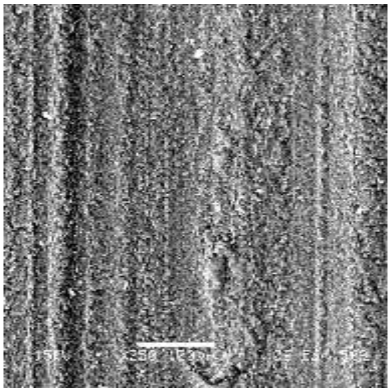

**Fig. 3.a**

**Fig.3.b**

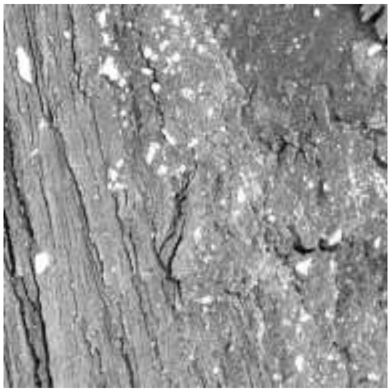

**Fig.3.c**

**Fig. 3.d**

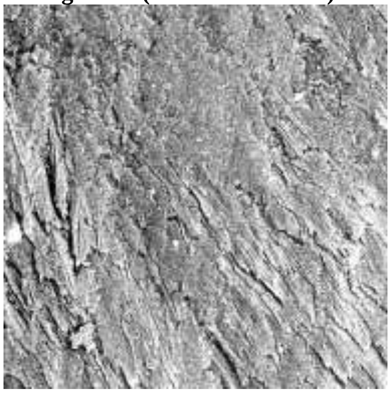

**Fig.3.e**

**Fig.4. Scanning electron micrograph of wear surface of treated and untreated Lantana-Camara fiber (40 wt. %) reinforced composites under 15N load. (a) Neat epoxy, (b) Un-treated fiber, (c) Alkali treated fiber, (d) Acetone treated fiber, (e) Benzoyl Chloride treated fiber.**

# CONCLUSION

On the basis of this study, the following conclusions are drawn:

- Lantana-Camara, though treated as an invasive weed can successfully be utilized to produce composite by suitable bonding with resin for tribo application.

- The incorporation of Lantana-Camara fiber into epoxy can significantly reduce abrasive wear loss of neat epoxy. The optimum wear resistance property was obtained at the fiber content of 40 wt %.

- Fiber surface treatment plays significant role for reducing the wear of Lantana-Camara fiber epoxy composites due to increased adhesion between fiber and matrix. It is also observed that Benzoyl-Chloride treatment yielded best results compare to Alkali and Acetone treatment.

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