ABRASIVE WEAR BEHAVIOUR OF BAMBOO (*DENDROCALAMUS STRICTUS*) POWDER FILLED POLYESTER COMPOSITES

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An experimental study was conducted to determine the abrasive wear behaviour of different weight percentage bamboo powder filled polyester composites under the multipass mode. The effect of bamboo powder concentration and sliding distance on the weight loss of composites has been analyzed. Worn surface have been analyzed to observe the mechanism of wear. The weight loss depends on bamboo powder concentration. The weight loss decreases with the increase of sliding distance. Samples having 20 weight percentage (wt%) of bamboo powder show the maximum weight loss during abrasion.

Keywords: Abrasive wear, Bamboo powder, Polyester composite

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INTRODUCTION

Bamboo is a natural composite material. Presently it is used in making baskets and housing structures (Rohatgi et al. 1991; Chand et al. 1985; Chand et al. 2007; Hashmi et al. 2006). Bamboo is available in large quantities. Being lightweight, cheap, and biodegradable, it is a useful filler material to develop polymer composites (Rohatgi et al. 1991). Bamboo powder filled polymer composites have found application in developing structural components. A lot of literature is available on bamboo and bamboo/ polymer composites that deal with mechanical behaviour. Bamboo powder filled unsaturated polyester composites are used for making panels for low stress applications. During use these items are subjected to abrasion, and hence the multipass abrasive wear tests was done to characterize the wear performance of bamboo powder filled polyester composites.

Abrasive wear of composites is strongly influenced by the filler loading and operating parameters (Hashmi et al. 2006; Chand and Dwivedi 2006). The interaction of both parameters influences the abrasive wear behaviour (Chand et al. 1995; Venkateswarlu 2006). Wear studies on pure bamboo (*Dendrocalamus strictus*) stems were reported in the literature in which the effect of fibre's direction was analyzed (Chand et al. 2007). Jain et al. (1992) have studied the mechanical behaviour of bamboo and bamboo composite. They found that bamboo has excellent mechanical properties with specific strength and modulus. Chand and Hashmi (1995) have predicted the tensile behaviour of red mud filled polymers in the past as a function of different experimental conditions such as red mud loading, by using the factorial design approach. In this paper, bamboo powder filled polyester composites having different weight percentage of bamboo powder are developed and their wear behaviour is determined under the multipass mode.

EXPERIMENTAL

Sample Preparation

Bamboo (*Dendrocalamus strictus*) powder, having size less than 355 μm was dried in an air oven at 80°C for 2 h. to remove moisture. Commercially available unsaturated polyester resin, which cures at room temperature, was used as matrix. In the mix of polyester resin, 2% accelerator and 2% hardener were added and stirred for one min., and then different amounts of bamboo powder (10, 20 and 30) wt% were added separately. The final mix was poured into the cylindrical moulds to make composite pins of length 30 mm and diameter 10mm. The mix was kept in the mould for curing at room temperature 30°C for 24 hours. Cured samples were then removed from the moulds and used for multipass abrasive wear measurements.

Tensile Tests

Tensile testing of different bamboo powder filled polyester resin composites was done by using a Tensile tester (Scientific Testing India make). Samples were prepared as per ASTM D638.

Abrasive Wear Tests

Abrasive wear studies were carried out under multipass condition on a pin-on-disc type wear machine model TR-201, Ducom make. Abrasive paper of 400 grade (grit-23 μm) was fixed by double sided adhesive tape on a disc rotating at 200 rpm in a track diameter of 6 cm. Emery paper had irregularly shape embedded SiC particles. The sample pin was fixed in a holder and was abraded at 10 N applied load for varying sliding distance on the same track. The samples were cleaned by using a soft brush to remove particles etc. before and after each run. This work took half an hour, which cooled the samples to room temperature. The wear loss (weight loss) was determined after each run, using a Mettler Toledo higher precession balance of 10^{-5} gm accuracy.

SEM Observation

Worn surfaces of samples were observed by using a scanning electron microscope (model 35 CF JEOL, Japan). The sample surfaces were gold coated before observation. Worn microstructure for the composites having maximum bamboo particles, 30wt%, has been taken to show the maximum effect of bamboo particles under the multi pass wear condition.

Factorial Design

A two-level full factorial design of the experiment has been used in this study. Two parameters were varied on two levels i.e. upper level and lower level. The upper level and lower level of the two parameters i.e. bamboo particles concentration and sliding distance, are given in Table 1. This table also gives the coded values of upper and lower levels of each of the parameters in parenthesis.

Table 1. Bamboo Filler Concentration and Sliding Distance Values along with Coded Values.

Sl. No.	Bamboo Filler conc. (wt%) (upper and lower level)	Sliding Distance (m) (upper and lower level)
1	30(+1)	62.8(+1)
2	30(+1)	15.7(−1)
3	10(−1)	62.8(+1)
4	10(−1)	15.7(−1)

The following regression equations were obtained from full factorial design method.

$$W = 0.0121 + 0.0051\,C - 0.00803\,S - 0.00371CS \quad (1)$$

A positive value of the coefficients signifies an increase in wear loss due to an increase in associated parameters and their interactions. Similarly, a negative coefficient signifies a decrease in the weight loss due to an increase in the associated parameters. The magnitude of the coefficient gives an idea about the extent of influence of the individual parameters or their interactions on the wear rate.

RESULTS AND DISCUSSION

Average tensile strength values determined for 10, 20, and 30wt% bamboo powder filled polyester composites were 10.8, 10.6, and 5.36 MPa respectively. The decrease in strength on adding bamboo powder is because bamboo powder acted as filler, not as reinforcement. The average tensile strain values of 10, 20, and 30wt% bamboo powder filled polyester composites were 0.091, 0.078, and 0.072, respectively. Figure 1 shows the plot for weight loss as a function of sliding distance for different bamboo composites. Initially the wear loss decreased with increase of sliding distance for all the samples. Also initially high wear loss was observed because the abrasive paper was fresh. With consecutive runs, wear loss decreased gradually, because the abrasive grits became less effective. The wear debris filled the space between the abrasives (SiC grits), which reduced the depth of penetration in the sample. In other words, contact stress was reduced when debris came between the surfaces. The composite with 10wt% bamboo powder showed the minimum wear loss. Increase of bamboo content to 20wt% showed the maximum wear loss. Further increase of bamboo powder content reduced the wear loss. This is because at higher bamboo powder loading, wear mechanism was dominated by bamboo powder, which is less brittle than the polyester matrix. Samples having 20wt% bamboo content showed the critical weight percentage for lower wear resistance.

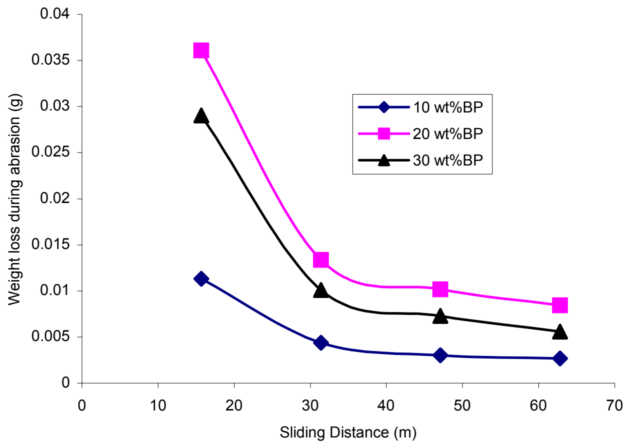

Fig. 1. Variation of wear loss with sliding distance for bamboo polyester composites having different wt% of bamboo.

Figures 2a and 2b show the worn microstructure of 30wt% bamboo powder composite after 62.8 m sliding distance under multipass abrasive wear at different magnification. Wear tracks are formed during multi pass wear due to micro-cutting.

In the magnified worn microstructure, initially micro-cracks are formed around the bamboo particles, and particles were removed under compression and shear. Increase of the bamboo content to 30wt% increased the resistance to shear force due to its fibrous and cellular structure.

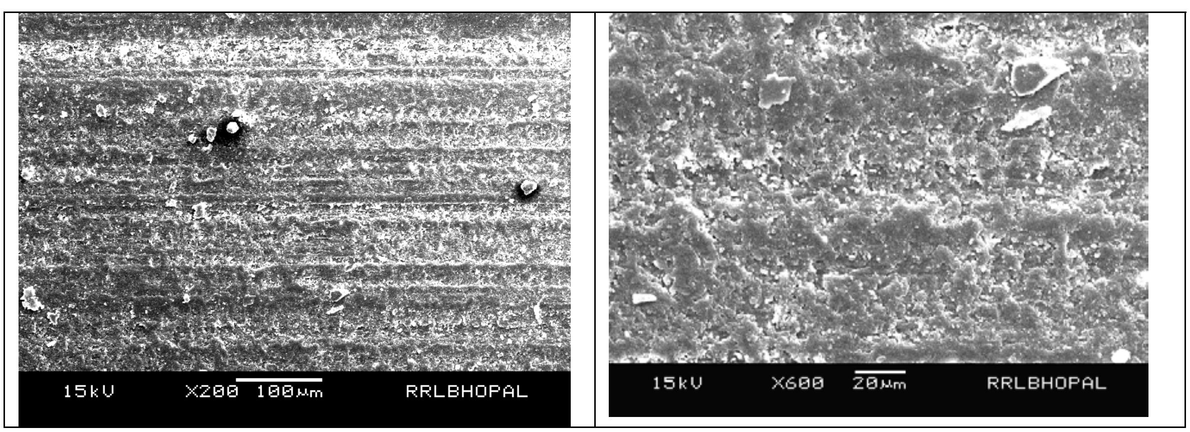

Fig. 2 a (x200) and b (x600). Worn microstructure of 30wt% bamboo powder unsaturated polyester composite after 62.8 m sliding distance.

Validity of the Weight Loss Data

The validity of the equation was tested by conducting a series of tests at randomly selected experimental parameters such as filler concentration (*C*), and sliding distance (S). The calculated values under such selected experimental parameters were compared with the experimental values. During the calculation of the wear loss under selected experimental conditions, the coded values of the experimental parameters were considered. The calculated value (CV) is defined as follows (**Venkateswarlu** et al. 2006):

$$CV = \frac{(SL-BL)}{Abs(BL-UL)} \quad \text{or} \quad \frac{(SL-BL)}{Abs(BL-LL)} \qquad (2)$$

where SL is the selected value, BL, UL, and LL are values of the selected parameters in the base level, the upper level and the lower level, respectively. The experimental values of wear loss at randomly selected experimental parameters (Table 2) were in agreement with the wear loss calculated using the coded values of the experimental parameters in equation (1). In most cases, the variations between the experimental and the calculated values were of the order of 8-18% The factorial design approach could be used for developing a regression equation to predict the wear behaviour that depends upon the composition, and experimental parameters.
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Table 2. Experimental and Calculated Values of Wear Loss

S.N	Experimental value of weight loss in g	Predicted value of weight loss in g
1	0.00438	0.008426
2	0.00303	0.005574
3	0.03608	0.02013
4	0.01334	0.01475
5	0.01015	0.00945
6	0.00843	0.00407
7	0.01011	0.021074
8	0.0073	0.016813

CONCLUSIONS

Based on the wear studies carried out on bamboo powder filled polyester composites in abrasive wear mode, it was found that bamboo powder loading influenced the wear behaviour. Composite containing above 20wt% bamboo powder exhibited the lowest wear resistance. However, increase in sliding distance decreased the wear loss.

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