

ROLE OF PVA MODIFICATION IN IMPROVING THE SLIDING WEAR BEHAVIOUR OF BAMBOO

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This experimental study was conducted to investigate the role of poly-vinyl-alcohol (PVA) treatment in improving the sliding wear behaviour of pure bamboo. The effects of dipping time in PVA solution and applied load on wear behaviour of bamboo samples were determined. The wear volume of bamboo was reduced when it was treated with PVA. The wear volume during sliding was increased with increasing of applied load, whereas the coefficient of friction was reduced on PVA treatment. Worn surfaces were observed by using SEM and discussed to explain the mechanism of wear.

Keywords: Wear; Friction; Bamboo; PVA treatment

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INTRODUCTION

Bio-composites are finding applications in housing, automotive, and in other industrial applications. Natural fibres and bamboo are natural composites, which are used for making handicrafts, mats, and housing structures (Rohatgi et al. 1991; Chand et al. 1985; Chand et al. 2007; Hashmi et al. 2006). Bamboo is a renewable resource, abundantly available and biodegradable. The available literature on bamboo and bamboo/polymer composites attests to its importance. Espiloy (1987) investigated the physico-mechanical properties and anatomical relationships of some Philippine bamboos. Janssen et al. (1995) demonstrated the equivalence of bamboo culm with the trunk of a tree. They described the difference between the culm and the cavity. Cavities are separated from each other by diaphragms and appear as nodes. Structure of bamboo is simpler than that of wood (Liese et al. 1992). Generally chemical constituents of bamboo are holocellulose – 50-70%, pentosans 30%, and 20-25% lignin (Liese et al. 1992). Silica present in bamboo is nearly 0.5-5%, depending upon the species. Silica is situated in the epidermis. Chand and Rohatgi (1994) reported the chemical constituents of different lignocellulosic materials. Tong et al. (1998) studied the dry sliding wear behaviour of bamboo. They found that wear volume increased with the normal load and sliding velocity. Tong et al. (2005) reported the three body abrasive wear behaviour of bamboo. They observed that the abrasive wear resistance of bamboo stem was a function of the vascular fibre content of bamboo. Wear studies on pure bamboo (*Dendrocalamus strictus*) stems have been conducted by Chand et al. (2007), and the effect of fibre's orientation was analyzed. Dwivedi et al. (2007) reported the abrasive wear behaviour of bamboo powder filled polyester composites and found a dependency on filler concentration. Jain et al. (1992) determined the mechanical behaviour of bamboo and bamboo composite. Bamboo can be

used for making a totally green composite if it is combined with a biodegradable resin, such as PVA.

In this paper the effect of PVA treatment on sliding wear of bamboo has been determined for different time periods, and the effects are discussed relative to scanning electron micrographs (SEM) of the worn surfaces.

EXPERIMENTAL

Sample Preparation

Bamboo (*Dendrocalamus strictus*) was obtained from Sehore forest. PVA was obtained from S.D. Fine Chem. Ltd. Mumbai. The 5wt% of PVA was dissolved with water and stirred well for 10 min. to prepare the solution. The solution was kept in a beaker in which bamboo pins of 6mm diameter and 30mm length were dipped at room temperature, 30°C. Bamboo samples were immersed for different time periods, e.g. 1, 1.5 and 2 hrs. Then the samples were taken out from the beakers and dried in air for two days. The dried samples were polished by using 400 grade (grit-23 µm) emery papers and then used for wear and friction measurements.

Sliding Wear Tests

A pin-on-disc type machine, (model type, TR – 201 CL-M2 of Ducom, India) was used to determine the wear and friction properties of samples, and a schematic diagram is shown in Fig. 1. A stainless steel (EN-31) disc of 100 mm diameter and 8 mm thickness was used as counterface. Loads in the multiple of 10N were applied (i.e. 10, 20, 30, 40) on the sample using dead weights through a loading lever. The frictional force was measured by means of a load cell and the coefficient of friction was computed using frictional force and applied load. The wear volume of composites was calculated using weight loss measurements taken after each test, using a balance of 10⁻⁴ g accuracy. The samples were kept in a desiccator to avoid moisture absorption before weighing. Tests were performed under dry sliding conditions. Sample pins were held perpendicular to the counterface rotating at 400rpm. Three tests were performed for each set, and the average values of wear and friction were reported. The roughness of the counterface was kept uniform at the start of each test by polishing for 10 minutes. A new set of pin samples having 6 mm diameter was used for each set of tests. The bamboo pins had a fibre direction normal to the sliding motion. The sliding test was performed for 1hr corresponding to 4.8 km sliding distance. The wear volume V was calculated using formula

$$V = w/\rho, \quad (1)$$

where w is the weight loss and ρ is the density of sample.

SEM Observations

Worn surfaces of samples were observed by using scanning electron microscope (model 35 CF JEOL, Japan). The sample surfaces were gold-coated before observation.

RESULTS AND DISCUSSION

In the text that follows, samples are designated as untreated, or as samples 1, 2, and 3 for pure untreated bamboo, PVA treated for 1 hr, PVA treated for 1.5 hr, and PVA treated for 2 hrs, respectively. Figure 1 shows the variation of wear volume with applied load for PVA-treated and untreated bamboo. It was found that untreated bamboo had the highest wear volume. Increase in the time of PVA treatment increased the wear resistance. This effect is attributed to the filling of pores in the bamboo by the PVA treatment, as well as an increased ductile nature, thus providing higher wear resistance. PVA treatment could protect the bamboo against deterioration on sliding contact. PVA also contributed to a self-lubricating property during sliding. The main factor for lowering the wear volume was the minimization of the coefficient of friction. PVA filled in the porous regime of bamboo. A lower coefficient of friction resulted in less frictional heat, causing less thermo-mechanical deformation. During sliding motion massive deformation of untreated bamboo, due to the presence of pores and poor bonding between lignin matrix and bamboo fibre, which caused debris to form easily. On the other hand, PVA-treated bamboo, with almost-filled pores and with better bonding between lignin matrix and cellulosic fibre, provided less debris formation, hence low wear volume. The figure also shows that increase of applied load increased the wear volume, which is attributed to the higher frictional force, causing more frictional heat to be generated. Finally, thermo-mechanical action on bamboo provided higher wear volume.

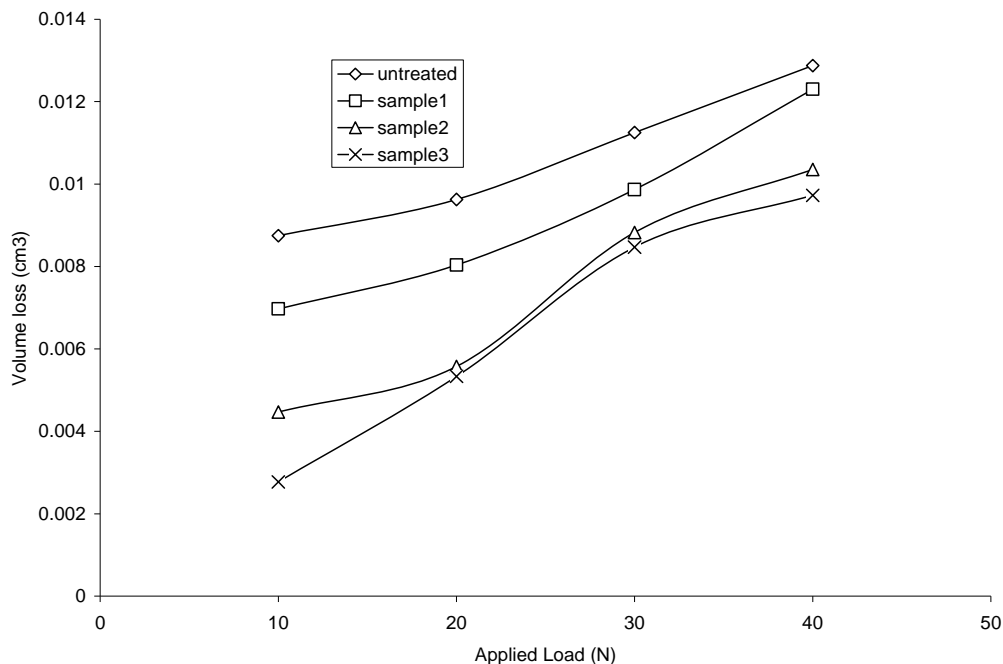


Fig. 1. Variation of wear volume of bamboo with applied load

Figure 2 shows a graph of the coefficient of friction vs. applied load. The coefficient of friction decreased with applied load for all tested samples. PVA-treated bamboo for higher time periods exhibited the lowest values of coefficient of friction. As time of treatment increased, a lower coefficient of friction was observed. Increases in temperature were measured by inserting thermocouples between samples and counterface. While this method does not provide exact temperature information, it gave an indication of the change in temperature. Figure 3 shows a graph of the temperature increase vs. the applied load. It was observed that temperature increased with applied load for all tested samples. This increase in temperature is linked with frictional heat that was generated during sliding test. On increasing load, frictional force increased, which increased the temperature. The untreated bamboo exhibited the greatest increase in temperature during sliding.

Figures 4(a and b) are SEM micrographs showing the worn surfaces of untreated bamboo. In the micrographs, pores are visible in which pulverized powder had become entrapped. Plastic deformation causing overstress of pore edges is also visible. The sliding track is visible in Fig. 5a, where a black area shows the fibre bundle of bamboo having diameter around 400 μm . Figures 5 (b and c) show the SEM results for a PVA-treated sample, where pores are filled by PVA, which offered a low coefficient of friction against a steel counterface. A low coefficient of friction provided less frictional heat so that less thermal deformation occurred. PVA treatment resists the easy removal of material. Ultimately, wear resistance of bamboo during sliding can be enhanced by PVA treatment.

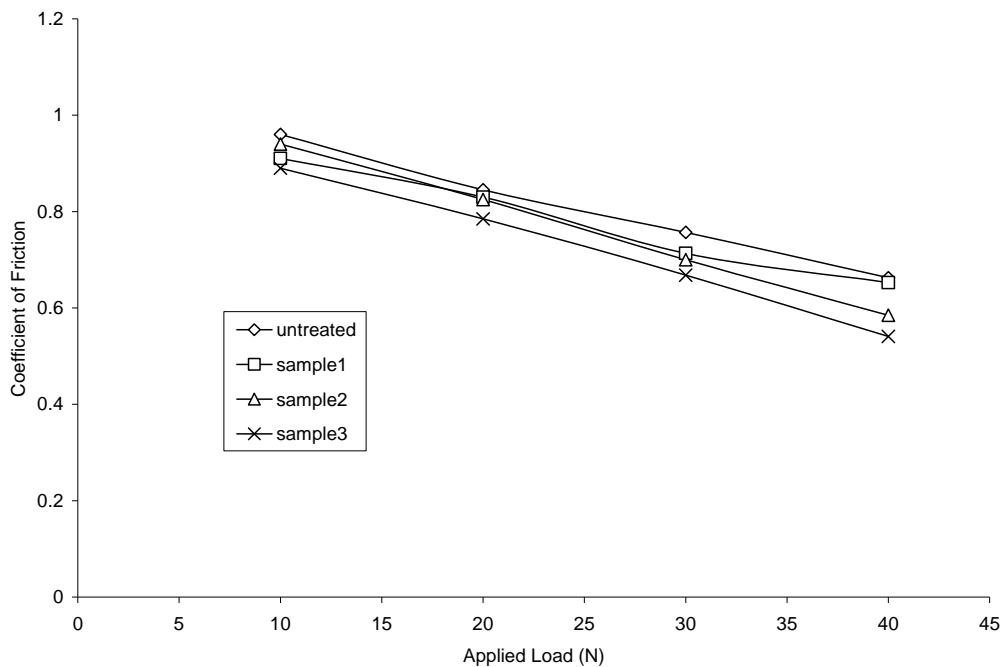


Fig 2. Variation of coefficient of friction of bamboo with sliding distance at 1 kg load

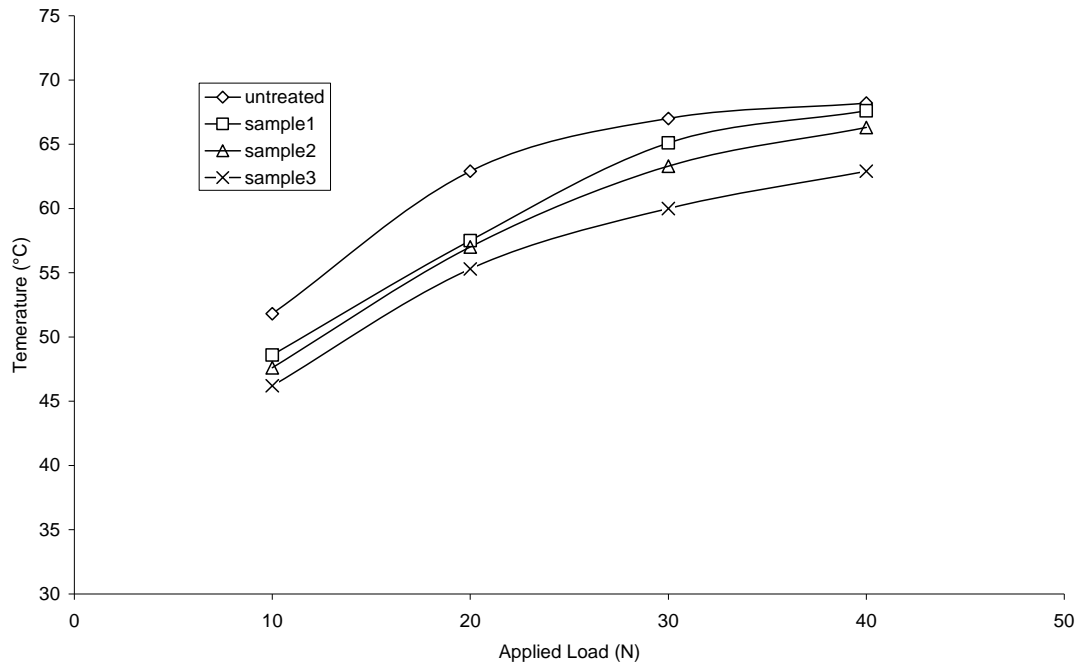


Fig 3. Variation of raised temperature of bamboo with applied load

5(a)

5(b)

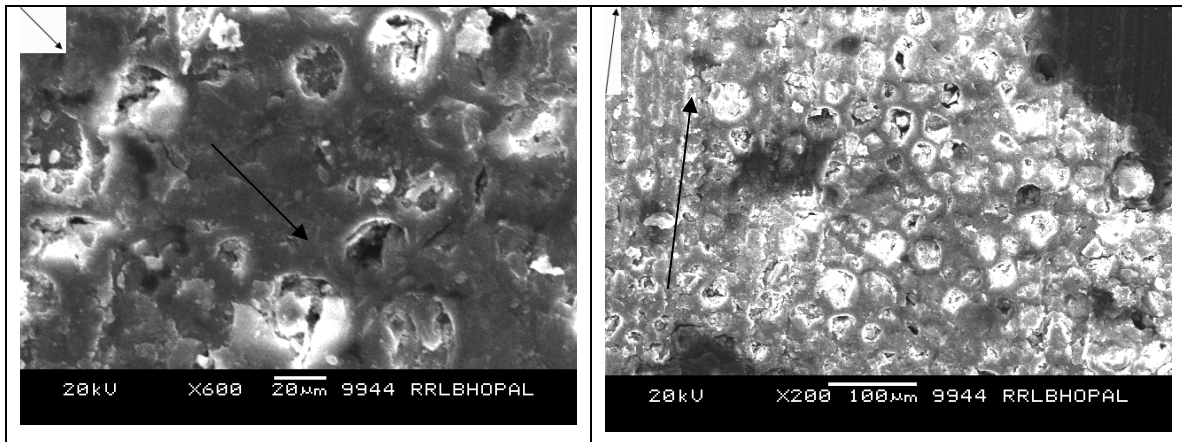


Fig 5a-b. Scanning electron micrographs showing worn microstructures of bamboo

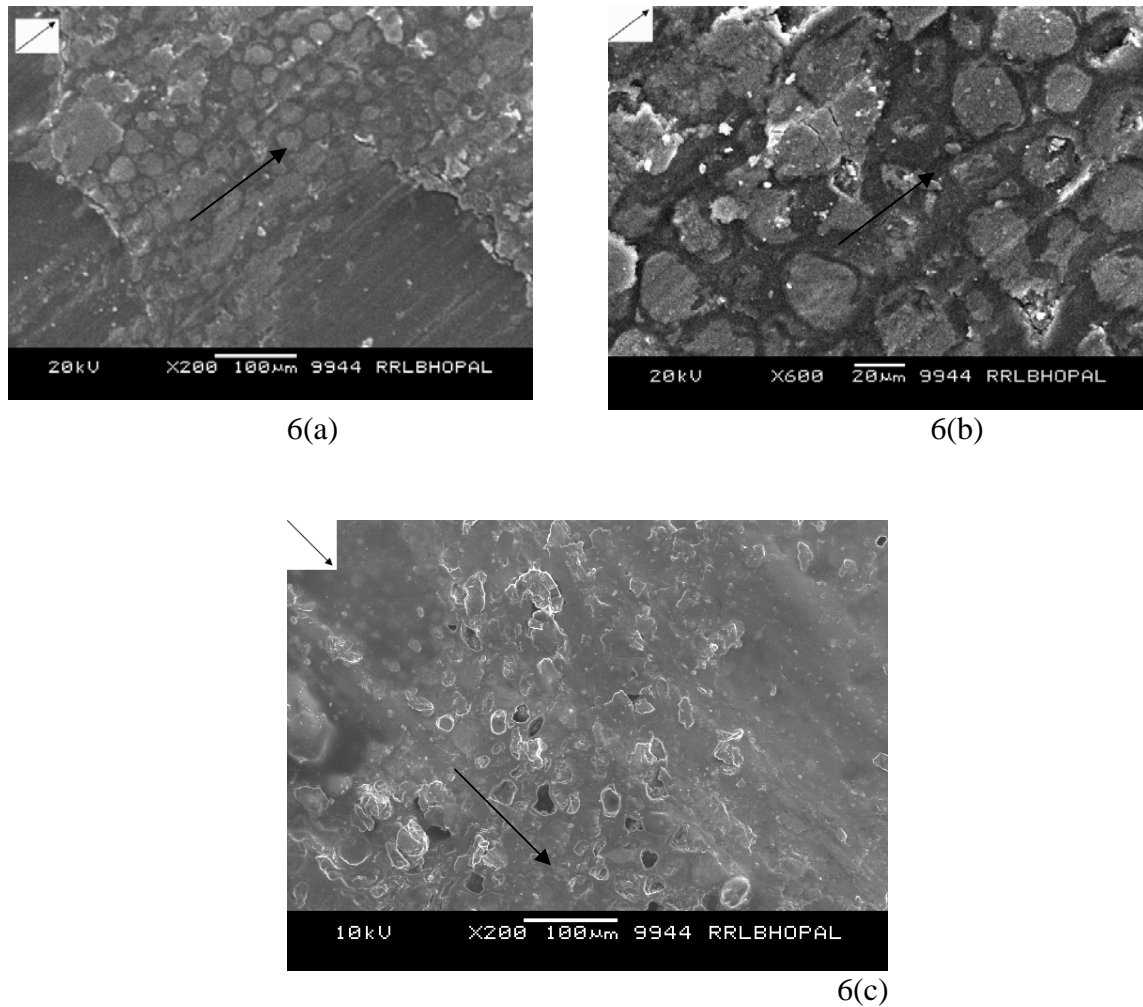


Fig. 6a-c. Worn microstructures of PVA-treated bamboo composites

CONCLUSIONS

Wear properties of bamboo can be improved significantly by PVA modification. The wear volume increased with increasing applied load and decreased with increasing dipping time in PVA solution. The value of coefficient of friction decreased with increasing applied load. SEM observations showed clearly that the changes occurred due to pores being filled by PVA treatment. PVA treatment also may provide ductility to the bamboo.

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