Effects of Wood Constituents and Content, and Glass Fiber Reinforcement on Wear Behavior of Wood/PVC Composites

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ABSTRACT

Three different types of wood flour particles: namely; *Xylia Kerri Craib & Hutch, Hevea Brasiliensis Linn and Mangifera Indica Linn*, were used and incorporated into poly(vinyl chloride) (PVC). The wear properties of wood/PVC (WPVC) composites with and without the glass fiber were evaluated for the effects of constituent in wood and wood concentration. The results were reported in terms of specific wear rate as a function of wood content (0-60 parts per hundred ratios, phr) and sliding distance (0 – 2.0 km). The experimental results revealed that the longer sliding distance was greater the specific wear rate in the WPVC composites both with and without E-glass fibers. Without E-glass fiber, it was found that the *Xylia Kerri Craib* at 40 phr of wood flour showed lowest specific wear rate. The wear properties were found to improve with the addition of 10 phr E-glass fibers into the WPVC composites. The *Hevea Brasiliensis Linn* gave lowest specific wear rate for glass-fiber reinforced WPVC composites.

KEYWORDS: Wood/polymer composites; Wear behavior; Mechanical properties

1. INTRODUCTION

Wood polymer composites (WPC) have been developed continuously so that they can now be utilized for buildings and constructions, automotives, gardening and outdoor products as well as marine applications [1], although their mechanical strengths are still lower than the natural woods. A large volume of research works on WPC were published, mostly studying on mechanical, thermal and morphological properties of WPC affected by additions of synthetic fibers and nano-particles [2-6], processing techniques and conditions [7-8], and the design of product-shaping components [9-11], chemical and physical treatments on wood surfaces [12-13] as well as type of thermoplastics used [11,13].

Two-body abrasion process traditionally applied in wood is sanding process, which is important when surface finishing. In contrast, the use of loose particles in three-body abrasion is a problem in wear resistance of PVC and wood/PVC flooring and construction materials [14-15]. The wear behavior of WPC materials could be considered into three separate components which are wood, polymer and WPC. According to existing literatures, information on wear behavior of woods [16-17] and polymers [18-20] have been extensively studied whereas those for WPC materials have been very rare and demanding. A few recent works [1,21] have been attempted for studying the wear properties of WPC.

The objective of this work was to investigate the wear behavior of wood/PVC composites using three different types of wood flour, these being *Xylia Kerri Craib & Hutch, Hevea Brasiliensis Linn and Mangifera Indica Linn,* with and without glass fiber. These wood flour particles and glass fibers were dry-blended and hot press with poly(vinyl chloride) (PVC) to form wood/PVC composites. The mechanical properties and wear behavior of wood/PVC composites was then evaluated through the effects of wood types and concentration with and without glass fibers. Wear mechanism for WPVC composites during wear deformation was proposed and discussed.

2. EXPERIMENTAL

2.1 Raw materials

PVC powder, SIAMVIC 258RB (Bangkok Thailand), having a K value of 58 was supplied by V.P. Wood Co. and was dry-blended with various necessary additives whose compound formulations were the same as used in previous work [22].

Three different types of wood flour particles, namely *Xylia Kerri Craib & Hutch (XK), Hevea Brasiliensis Linn (HB) and Mangifera Indica Linn (MI)* were selected in this work, and varied from 0-60 part per hundred (pph) by weight of PVC powder. The wood particles were chemically surface-treated with 1.0 wt% N–2(aminoethyl)–3–aminopropyl trimethoxysilane (M_w = 222.4) as suggested by our previous work [12]. All types of woods had average particle size of 100-250 μm supplied by Pongsiri Co., Ltd. (Ratchaburi, Thailand). E-glass fibers-chopped strand (ECS) having 3mm long and 13µm in diameter were supplied by Pongpana Co, Ltd (Bangkok Thailand). A fixed content of E-chopped strand glass fibers to be introduced in the wood/PVC composites was 10 phr of PVC compound.

2.2 Preparation of WPVC composite specimens

The WPVC composite specimen was directly prepared by blending PVC and treated-wood flour at wood concentrations of 0, 20, 40, and 60 phr for WPVC composite. The wood/PVC compound was then filled into a compression mould whose dimensions were 180x180x3 mm^3. The processing temperature and moulding pressure were 180^oC and 180 bars, respectively, for 7 min. In glass fibers reinforced WPVC composites, 10 phr glass fibers was used throughout this work and their blending procedures were the same as used for preparation of WPVC composite specimens.

2.3 Measurements of specific wear rates

Wear tests were performed by taber abraser (Taber Industry 5130) using abrasive wheels (CS-17) which were attached with a load of 250g following the ASTM D4060 (2007) for determinations of specific wear rate of neat PVC, WPVC and glass fiber reinforced WPVC composites. The specimen dimensions were $120x120x3mm^3$. The sliding distance was varied from 0.5 to 2.0km. The specific wear rate was measured by determination of weight loss of the test-specimen which can be calculated using Equation 1 [23].

$$K = \frac{\Delta m}{LF\rho}\mathrm{K} \qquad \text{(Eqn. 1)}$$

where Δm is weight loss (mg), L is sliding distance (m), F is applied load (N) and ρ is specimen density (g/cm^3).

2.5 SEM Investigations

Morphologies of wood particles and worn WPVC composite surfaces, and distribution and orientation of glass fibers in WPVC composites were investigated using a JEOL (JSM-6301F, Japan) SEM machine at 15 kV accelerating voltage. The details of the experimental procedures and sample preparations for SEM studies can be found in the work by previous work [24]. Figure 1 shows initial morphologies for XK, HB and MI wood sawdust particles. The aspect ratios for XK, HB and MI wood flour were measured to be 4.78, 1.63 and 4.96, respectively.

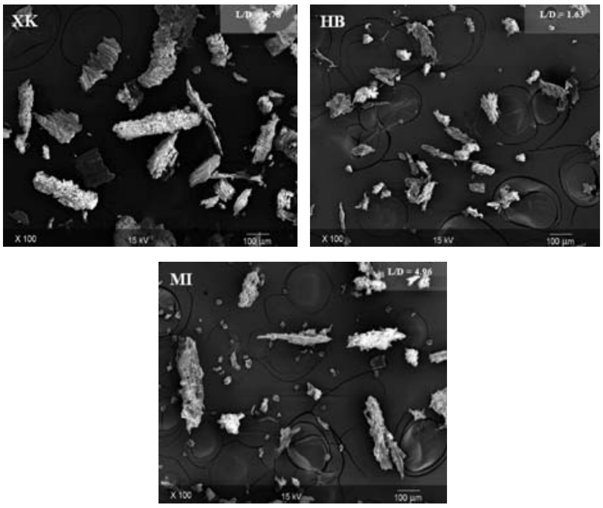


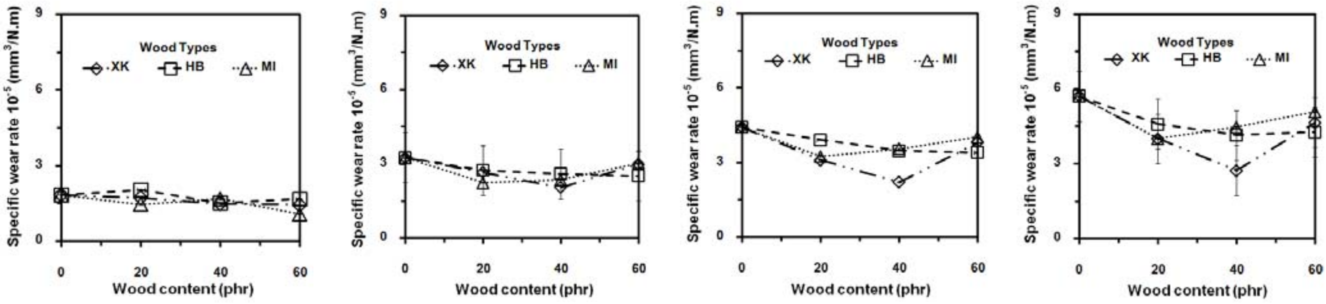
Figure 1 XK, HB and MI wood particles

3. RESULTS AND DISCUSSION

3.1 Specific wear rate of WPVC composites

Figures 2a-2d show specific wear rates for WPVC composites with XK, HB and MI woods for different wood contents (0-60 phr) and sliding distances of 0.5, 1.0, 1.5 and 2.0 km, respectively. In general, as the sliding distance was increased the specific wear rate appeared to increase as one would expect. For 0.5-1.0 km sliding distances, the specific wear rates of WPVC composites for all wood contents were indifferent. However, the effects of wood type and content became more pronounced as the sliding distances were increased to 1.5 and 2.0 km. The addition of wood particles in the PVC matrix enhanced the wear resistance of the WPVC composite, indicating the wood reinforcement in the PVC matrix. The increased wear resistance of the composites by the wood addition was due to rigidity of the wood particles which had ability to resist the force exerted on the WPVC sample. At high sliding distances (1.5-2.0 km), it was found that the specific wear rates for WPVC composites with XK and MI woods appeared to decrease up to 40 and 20 phr, respectively, and then started to increase at higher wood contents. The reductions of the specific wear rates were caused by the wood reinforcement as mentioned earlier.

Above the optimum contents (40-60 phr for MI and 60 phr for XK) the wear rates increased. This was probably caused by three-body abrasion effect[25], the wood particles escaping from the WPVC surface during the abrasion testing and this exhibited abrasive action of hard wood debris on the surface of the WPVC sample, which can be seen by SEM micrograph in Figure 3.



(a) 0.5 km (b) 1.0 km (c) 1.5 km (d) 2.0 km

Figure 2 Specific wear rates of WPVC composites without glass fiber reinforcement for different sliding distances

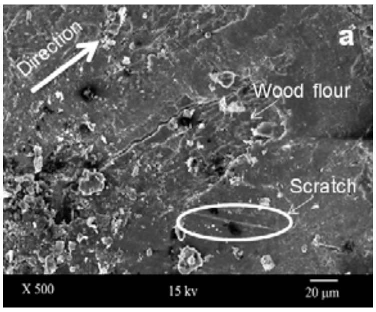
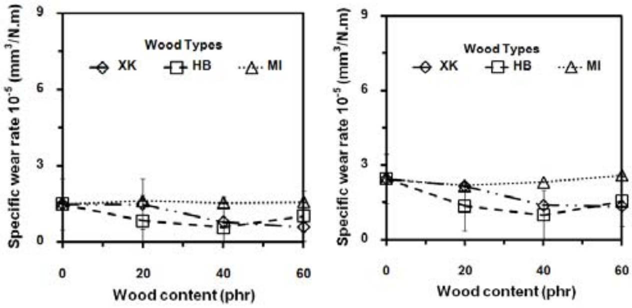


Figure 3 Debris on the WPVC surface

In the case of WPVC composite with HB wood, it was noticeable that the specific wear rate gradually decreased with increasing wood content, and showed no optimum wood content for specific wear rate under the experimental conditions used in this work. Again, the effect was more evident for higher sliding distances (1.5-2.0 km). The wear behavior for WPVC composite with HB was different from that with XK and MI woods because the HB wood had much low aspect ratio and tended to give relatively low reinforcement than XK and MI woods.

3.2 Effect of glass fiber reinforcement

Figure 4 shows specific wear rates for WPVC composites with 10 phr glass fiber reinforcement at a sliding distance of 0.5 and 2.0 km. As compared the results from Figure 2, the results clearly indicated that the addition of glass fiber have greatly improved the wear resistance of WPVC composites, the effect being more pronounced at the sliding distance of 2.0 km. The decreased specific wear rate of WPVC specimen with glass fiber at 2.0km in Figure 4 could be supported by SEM micrographs showing the appearances of glass-fibers on the WPVC surface to resist the abrasive forces exerted (see Figure 5). The *Hevea Brasiliensis Linn* gave lowest specific wear rate for the glass-fiber reinforced WPVC composite samples.



(a) 0.5 km (b) 2.0 km

Figure 4 Specific wear rates of WPVC composites with 10 phr glass fiber reinforcement

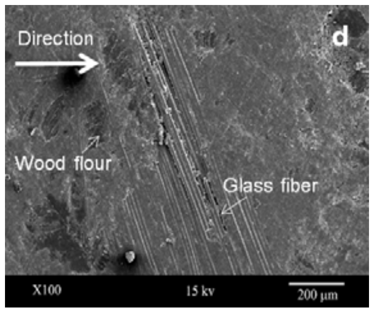


Figure 5 Glass-fiber on WPVC surface

4. CONCLUSIONS

The experimental results suggested that the wood particles with high aspect ratio, which were referred to as *Xylia Kerri Craib & Hutch and Mangifera Indica Linn,* could act as reinforcement by reducing the specific wear rate of PVC. The *Xylia Kerri Craib & Hutch* gave the lowest specific wear rate for WPVC composites at 40 phr wood content and at the sliding distance of 2.0 km. The addition of 10 phr glass-fibers increased the wear resistance, the effect being more pronounced at the sliding distance of 2.0 km. The *Hevea Brasiliensis Linn* gave lowest specific wear rate for the WPVC composites containing 10 phr glass-fibers. The longer sliding distance was greater the specific wear rate in the WPVC composites both with and without E-glass fibers.

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