Glass Fiber Reinforcement in Wood/PVC Composites

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Abstract

Two types of E-glass fibers (coded as TP508-6 and ECS12S) having different initial lengths were introduced into wood/PVC composites. The glass fiber contents were varied from 10 to 30 phr. The mechanical and morphological properties of the wood/PVC composites were monitored. The results suggested that the tensile and flexural moduli and strengths of the wood/PVC composites increased with increasing glass fiber contents. At 10-20 phr glass fiber loadings, the tensile and flexural moduli and strengths of the WPC composites with TP508-6 fiber were greater than those with ECS12S fiber while the opposite effect was observed for the composites with 30 phr fiber loading, this being explained in terms of average final length of each fiber and concentration of C=O groups on the fiber surfaces.

Keywords: Glass fiber, Hybrid composites, Surface treatment, Wood, Thermoplastics, Fiber length

1. Introduction

Applications for wood plastic composite (WPC) products include decking, window and door profiles, automobile paneling, panel inserts, and flower pots. These were classified as decorative products while those for WPC products in structural constructions are still questionable due to their strength limitation. There have been a number of works [1-3] attempting to improve the structural properties of the WPC products in various means, such as uses of synthetic fibers and metal inserts. In this article, two commercial grades (coded as TP508-6 and ECS12S) of glass fibers at different lengths were used and added into W-PVC composites at various contents. These two glass fibers had different silane treatments which were referred to as different functional groups on the fiber surfaces. The effect of fiber length and content of glass fibers in the wood/PVC composites were studied by considering the mechanical and morphological properties of the hybrid composites.

2. Experimental

The ingredients of the PVC compounds and composites are previously shown [4]. Two commercial grades of chopped strand glass fibers as E type were used, these being TP508-6 and ECS12S whose descriptions are listed in Table 1. The functional groups on the glass fiber surfaces were characterized using a Fourier Transform Infrared Analyzer (ATR-FTIR; Nexus 470 - Thermo-Nicolet Ltd (USA)). The content

2.1 Preparation of specimens

Before blending between sawdust particles, chopped strand-glass fiber and PVC compound, the sawdust particles were passed to heat treatment in an oven at 80 °C for 24 hours until the weight of the sawdust was constant in order to remove moisture in the wood particles. After that PVC compound were dry-blended with wood particles and chopped strand glass fibers using a high speed mixer for 2min before melt-blended in a twin screw extruder (Haake Polylab-Rheomex CTW 100P, Germany). The blending temperature profiles on the twin screw extruder were 165, 175, 175 and 185 °C from hopper to die zones. The screw rotating speed was 40 rpm, and a slit die having width x height x length of 18.2 x 2 x 16 mm^3 was used to produce slit extrudates. The produced extrudates were then passed through cooling-system and sizing-control device before collections for further composite characterizations.

Table 1. *The descriptions of chopped strand glass fibers used in this work*

Code	L/D ratio (mm/ m)	Source
TP508-6	6/13	Pongpana Co.,Ltd.
ECS12S	12/13	Gettrade Interbusiness Co.,Ltd.

2.2 Composite characterizations

2.2.1 Mechanical properties

Tensile test was performed on a SHIMADZU tensile tester (Tokyo, Japan) at a crosshead speed of 5 mm/min. The tensile test procedure followed the ASTM D638 (1990) Specimen Type I. The flexural property was determined according to ASTM D790 (1990) (the specimen dimensions of 12.7 x 100 mm^2, support span of 40 mm, and a cross-head speed of 1 mm/min).

2.3 Morphological investigations

Interfacial fibre-polymer adhesions were morphologically investigated using a JEOL (JSM-6301F) SEM machine at 20 kV accelerating voltage. The composite fracture surfaces for examination were obtained after a 2 min immersion in liquid nitrogen. The details of the experimental procedure and sample preparations were discussed elsewhere [4]. In addition, the final lengths of glass fibers (after passing the extrusion process) were examined using SEM technique. The investigation of the final length of glass-fibers was carried out by burning off the extruded glass fiber/wood/PVC composites at 500°C for 6 hours.

3. Results and Discussion

Figure 1 shows the effect of glass fiber type and content on the tensile and flexural moduli of wood/PVC (WPC) composites. Generally, it was found that the tensile and flexural moduli of the composites increased with increasing fiber contents. The increase in the moduli was expected since the stiffness of the glass fibers was relatively higher as compared to that of wood sawdust or PVC alone. The results in Figure 1 can be explained in terms of the effect of glass fiber type, in two different regions, one being at 10-20 phr glass fiber contents and the other being at 30 phr glass fiber content. It can be seen that at 10-20 phr glass fiber the tensile and flexural moduli of the WPC composites with TP508-6 fiber were greater than those with ECS12S fiber while the opposite effect was observed for the composites with 30 phr fiber loading. In this respect, two possible reasons were proposed for explaining the differences in the tensile and flexural moduli of the composites added with these two glass fibers (TP508-6 and ECS12S), these being average final length and functional groups on the fiber surfaces. It was postulated that the significance of these two reasons were dependent on loading levels of the glass fibers.

The changes in the fiber length were caused by the breakage of the fibers during extrusion process [5]. In relation to this work, it was proposed that the differences in the tensile and flexural moduli of the WPC composites at 30phr glass fiber content resulted from the differences in final length of the glass fibers used. This is widely accepted that composites having longer glass fibers have greater stiffness and strength than those having shorter glass fibers [6]. Secondly, the functional group on glass fiber surface was given for explaining the differences in tensile and flexural moduli of the composite at 10-20 phr glass fiber.

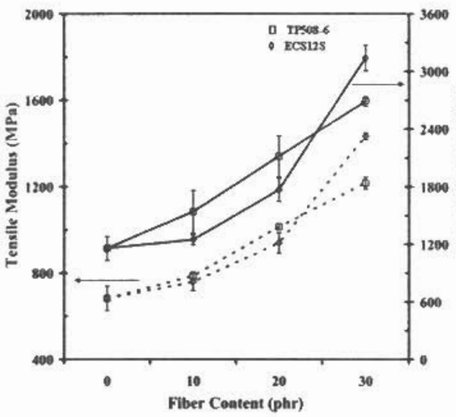


Figure 1. *Effect of type and content of glass fibers on tensile and flexural moduli for PVC/sawdust composites*

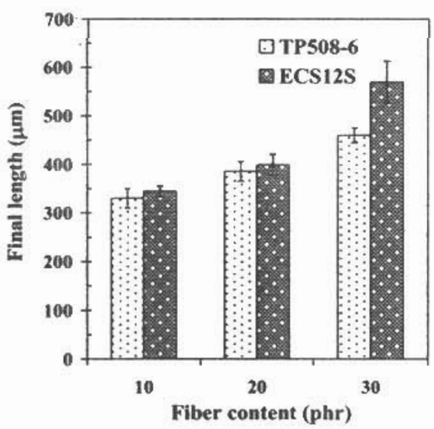


Figure 2. *Influence of glass fiber content on final length of glass fibers after extrusion process*

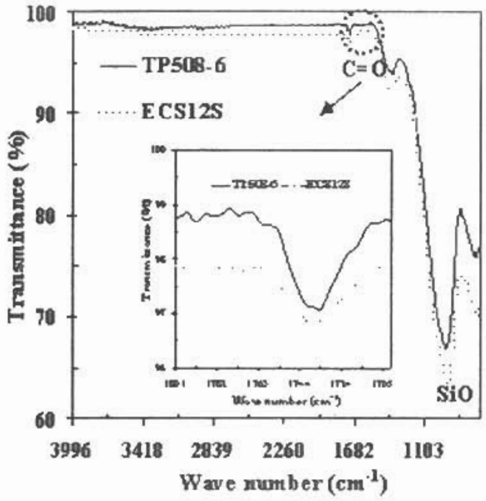
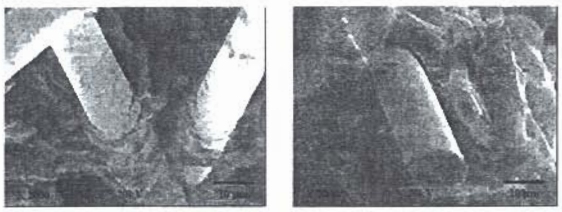


Figure 3. *FTIR spectra of TP508-6 and ECS12S glass fibers*

From Figure 1, it was found that the composites with shorter initial fiber length (TP508-6) had higher moduli than those with longer initial fiber length (ECS12S). This means that the final length of the fibers were not the cause for the differences in the composite moduli at 10-20 phr glass fiber. In this work, we proposed the FTIR results of these two glass fibers (Figure 3) to reveal the chemical functional groups on the fiber surfaces. It was found that TP508-6 and ECS12S possessed carbonyl groups (C=O), which could react with PVC via polar-polar interaction, at wave-number of about 1737-1738 cm^{-1}[7]. However, the amounts of carbonyl groups, which could be determined from the area under the C=O peaks, the results being listed in Table 2. It can be seen that TP508-6 fiber had higher carbonyl content (C=O of 0.29) than ECS12S fiber (C=O of 0.24). The greater the carbonyl content that better the adhesion between the fiber and WPC matrix. This was why the TP508-6 fiber, which had shorter initial fiber length, exhibited higher moduli than ECS12S fiber, which had longer initial fiber length. The better adhesion of the WPC composites with TP508-6 could be substantiated using SEM micrographs as shown in Figure 4.

Table 2. *Peak area under carbonyl peaks from FTIR spectra for TP508-6 and ECS12S glass fibers*

Type	Wave number (cm^{-1})	Functional groups	Peak area
TP508-6	1737	C=O	0.29
ECS12S	1738	C=O	0.24



(a) (b)

Figure 4. *SEM micrographs for glass fibers filled wood/PVC composites: (a) TP508-6 and (b) ECS12S*

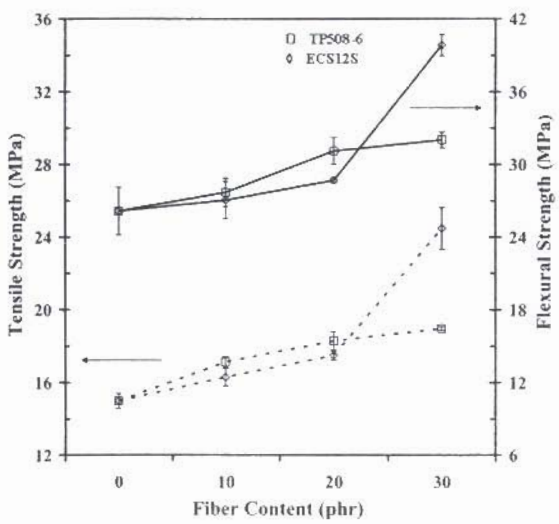


Figure 5. *Effect of type and content of glass fibers on tensile and flexural strengths for PVC/sawdust composites*

Figure 5 shows tensile and flexural strengths of wood/PVC composites with different loadings of TP508-6 and ECS12S fibers. It was found that the tensile and flexural strengths increased with increasing glass fibers, this being also found by Thomassan [8]. The changes in tensile and flexural strengths were similar to the tensile and flexural moduli discussed in Figure 1. Thus, similar reasons could be used to explain the changes in the tensile and flexural strengths of the composites, the average final length of the fiber being the main factor at fiber loadings of 30phr and the C=O groups on fiber surface being the cause at fiber loading of 10-20 phr. It was interesting to mention that the effect of fiber loading on the composite strength was less pronounced than that on the composite moduli due to the fact that the presence of glass fibers in the wood/PVC matrix had increased interfacial defects and heterogeneities in the composite phases.

4. Conclusion

The results in this work suggested that the stiffness and the strength of the wood/PVC composites increased with increasing glass fiber contents. At 10-20 phr glass fiber loading, the stiffness and strength of the WPC composites with TP508-6 fiber were greater than those with ECS12S fiber while the opposite effect was observed for the composites with 30phr glass fiber, this being explained in terms of average final length of each fiber and concentration of C=O groups on the fiber surfaces.

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