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Improving Dimensional Stability of Wood Plastic Composite with Compatibilizer Agent

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Abstract: Poor resistance of the fibers to water absorption can have undesirable effects on mechanical properties and dimensional stability of thermoplastic composites reinforced with lignocellulosic materials. In this study, the water uptake of composite based polypropylene and sawdust flour with different loading of compatibilizer agent was investgated. The results indicated that the water absorption and thickness swelling of composites decreased with increase of coupling agent concentration. Also, morphological study with scanning electron microscopy (SEM) revealed that the positive effect of compatibilizing agent on interfacial bonding between sawdust flour and polymer matrix. It is important to use coupling agents to improve the quality of adhesion between polypropylene and wood flour, to reduce the gaps in interfacial region and to block the hydrophilic groups and dimensional stability enhancement.

Key words: Compatibilzer Agent · Water Absorption · Thickness Swelling · Scanning Electron Microscopy

INTRODUCTION

Wood plastic composites (WPCs) were designed as a direct lumber substitute. These plastic lumber products have been criticized for their low mechanical properties. Wood composites currently dominate the market share of structural and non-structural residential building products [1]. New applications and end uses of wood plastic composites (WPCs) for decking, flooring and outdoor facilities, window frames, various construction materials and bathroom parts for example and their exposure to atmosphere or contact with aqueous media has made it necessary to evaluate the water uptake characteristics of these materials. Water absorption is one of the most important characteristics of WPCs exposed to environmental conditions that determine their end use applications. Therefore, as a limiting parameter, water absorption has to be taken into account in the design of WPCs for final applications [2-3].

Generally, water absorption and thickness swelling in WPCs is governed by two significant mechanisms: the hygroscopic nature of natural fillers/fibers and the penetration of water into the composites (diffusivity) via gaps and flaws at the interfaces between fibers and plastics [4-5]. Poor resistance of the fibers to water absorption can have undesirable effects on mechanical properties and dimensional stability and in longterm, embitterment linked to the degradation of the macromolecular skeleton by hydrolysis [6-8]. Therefore, it is important to study in detail the water absorption behavior in order to estimate not only the consequences that the water absorbed may have, but also how this water uptake can be minimized in some way. A number of attempts have been made to reduce water absorption of WPCs [4-8].

The incompatibility results in a poor interfacial adhesion between hydrophilic wood and the hydrophobic plastic matrix, which results in poor adhesion and therefore in poor ability to transfer stress from the matrix to the fiber reducing mechanical strengths and ductility [9-10]. A lot of literature focuses on this problem by using such chemicals as coupling agents to improve the composite properties. Coupling agents include copper amine, silanes, maleic anhydride and their grafting polymers [9-15]. However, unlike the common polyolefin/wood fiber composites, the well-known claim of converting the hydrophilic surface of wood to a hydrophobic one is not effective enough for enhancing the adhesion of thermoplastic polymer to wood fiber [12-15].

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The aim of this study was to investigate the effect of compatibilizer agent on the physical and morphological properties of polypropylene/ sawdust flour composites.

MATERIALS AND METHOD

Polypropylene, V30S (MFI=18 g/10min, density=0.92g/cm^3) was supplied by Arak Petrochemical Co (Iran). Sawdust flour was collected from carpentries. Maleic anhydride grafted polypropylene (PP-g-MA) provided by Solvay with trade name of Priex 20070 (MFI=64 gr/min, grafted maleic anhydride 0.1 Wt. %) was used as coupling agent.

Before preparation of samples, sawdust flour was dried in an oven at (65 ± 2) °C for 24 hour. Composite profiles consisting of polypropylene and sawdust flour at 50% weight ratios, with various amounts of coupling agent (0, 1 and 2%) The mixing was carried out by a Hakee internal mixer (HBI System 90, USA). First the polypropylene was fed to mixing chamber, after melting of PP, coupling agent was added. At the two minute, the sawdust flour fed and the total mixing time was 10 min. The compounded materials were then ground using a pilot scale grinder (WIESER, WGLS 200/200 Model). The resulted granules were dried at 105°C for 4 hours. Test specimens were prepared by injection molding (Eman machine, Iran). Finally, specimens were conditioned at a temperature of 23°C and relative humidity of 50% for at least 40 h according to ASTM D618-99 prior to testing.

Water uptake tests were carried out according to ASTM D-7031-04 specification. Five specimens of each formulation were selected and dried in an oven for 24 hours at 102±3°C. The weight and thickness of dried specimens were measured to a precision of 0.001 g and 0.001 mm, respectively. The specimens were then placed in distilled water and kept at room temperature. For each measurement, specimens were removed from the water and the surface water was wiped off using blotting paper. Weight and thicknesses of the specimens were measured after 24 hours. The values of the water absorption in percentage were calculated using the following equation:

$$WA(t) = \frac{W(t) - W_0}{W_0} \times 100$$

Where WA (t) is the water absorption at time t, W_0 is the oven dried weight and W (t) is the weight of specimen at a given immersion time t.

Also the values of the thickness swelling in percentage were calculated using the equation 2.

$$TS(t) = \frac{T(t) - T_0}{T_0} \times 100$$

The statistical analysis was conducted using SPSS programming (Version 16) method in conjunction with the analysis of variance (ANOVA) techniques. Duncan multiply range test (DMRT) was used to test the statistical significance at $\alpha = 0.05$ level.

The morphology was characterized using scanning electron microscopy (SEM, Model LEO 440i, Oxford) at 20 kV accelerating voltage. The composite fracture surfaces for examination were obtained after 2min immersion in liquid nitrogen and the fracture surface was sputter-coated with gold.

RESULT AND DISCUSSION

The effect of compatibilizer agent loading on the water absorption and thickness swelling of polypropylene/sawdust flour composites is shown in figures 1 and 2. As can be seen, the water absorption and thickness swelling of composites decrease with increase of coupling agent. This means that it is the interface region which influences the water absorption of the composite. Because uncompatibilized wood flour composite has weak fiber/matrix adhesion in nature, at the presence of the compatibilizer the interface is enhanced. Generally it is necessary to use compatibilizers or coupling agents in order to improve the polypropylene/sawdust flour bonding and in turn to enhance water resistance. The compatibilizer agent, chemically bonds with the OH groups in the sawdust flour and limits the water absorption and thickness swelling of the composites. As a result, it is important to use coupling

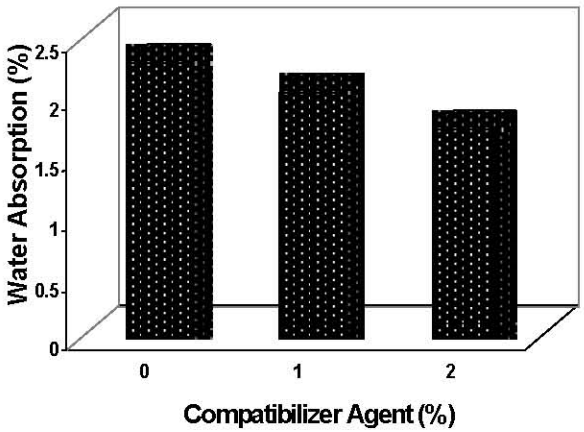

Fig. 1: Effect of compatibilizer agent loading on the water absorption of polypropylene/wood flour composites

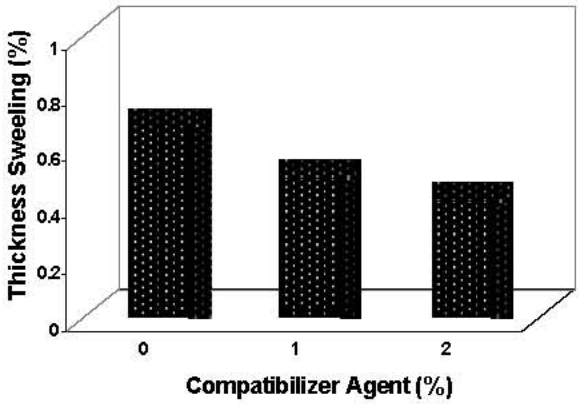

Fig. 2: Effect of compatibilizer agent loading on the thickness swelling of polypropylene/wood flour composites

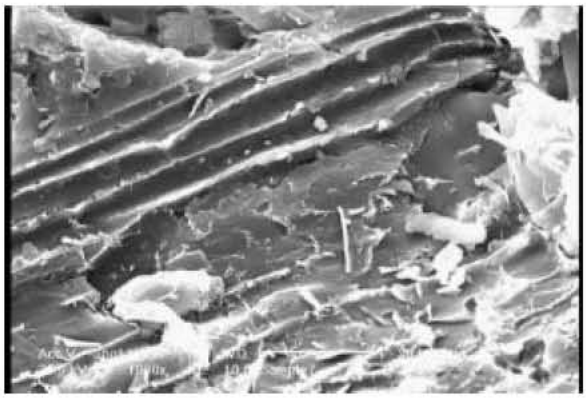

Fig. 3: SEM micrograph of the fracture surfaces in polypropylene/wood flour composite without compatibilizer

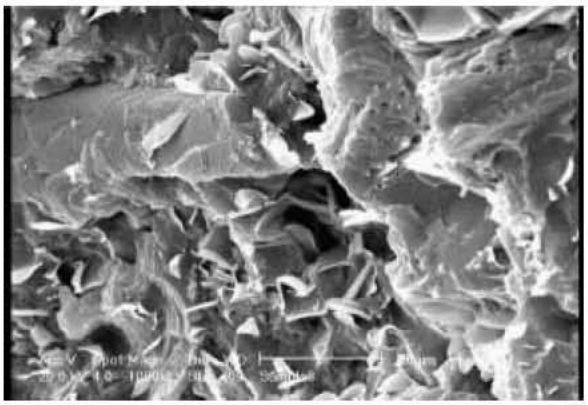

Fig. 4: SEM micrograph of the fracture surfaces in polypropylene/wood flour composite with 2% compatibilizer agent

agents to improve the quality of adhesion between polypropylene and wood flour, to reduce the gaps in interfacial region and to block the hydrophilic groups.

SEM micrographs show the fracture surfaces of the composites at different loadings of compatibilizing agent are shown in figure 3 and figure 4. In the case of the composite without any compatibilizing agent few sawdust flour particles are to be seen at the fracture surfaces, with the main component being matrix polymer and some cavities are to be seen where the wood flour has been pulled-out. The presence of these cavities means that the interfacial bonding between the sawdust flour and the matrix polymer is poor and weak.

In the case of the composite made with compatibilizing agent, the interfacial bonding between the sawdust flour and the matrix polymer is strong and the fracture occurred not at the interface but at the sawdust flour itself. It is well established that presence of the coupling agent enhances the interface adhesion between sawdust flour and pp matrix and brings better encapsulation of wood particles by the plastic which consequently results in higher dimensional stability [4-15].

CONCLUSION

The following conclusions could be drawn from the results of the present study:

- The water absorption and thickness swelling of polypropylene/sawdust flour composites decreases with increase of compatibilizing agent concentration.
- Morphological study revealed that the positive effect of compatibilizing agent on interfacial bonding between sawdust flour and polymer matrix.
- By addition of coupling agent the dimensional stability of wood plastic composite product will be improved.

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