Effect of Type of Wood Source on Water Absorption and Mechanical Properties of Wood-Plastic Composites

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ABSTRACT

The main disadvantage of wood application for construction purposes is its high water absorption. In our work a water absorption mechanism of three different types of wood plastic composites (WPCs) was studied. A wood flour, fibers of heat treated wood and pellets were used as a wood component in manufacturing process. All studied WPCs were made from 75 percent wood, 22 percent recycled polypropylene (PP) and 3 percent maleated polypropylene (MAPP). WPCs were compounded in a conical twin-screw extruder. The water absorption and the increase in thickness were determined according to the standard EN 317. Heat treated wood fibers were found to decrease the water absorption and to improve the dimensional stability of the composites.

INTRODUCTION

Water absorption and the consequent thickness swelling are the most important physical characteristics of wood-plastic composites (WPCs) exposed to environmental conditions and thus, determining their end-use applications. Water absorption decreases the mechanical properties of wood-plastic composites.

In practical wood plastic industry, wood is typically used at the loadings level between 40 and 60% by weight in polyolefins and wood content for extruded plastics could reach up to 70% (Li and Wolcott 2006). Clearly, the belief that cellulose fibres or wood particles in composites are encapsulated with plastic is not completely valid. Particularly it is not valid when composites contain a significant amount of cellulose, such as above 40% (Klyosov 2007).

It is known that most of general-purpose thermoplastic polymers, such as polyolefins absorb low amount of moisture in a humid atmosphere and when they are immersed in water. High hydrophilicity of wood fibres is the main reason for water absorption by composite materials. Wood fibre is a natural structure made of cellulose fibres in an amorphous matrix of hemicellulose and lignin. Cellulose contains numerous hydroxyl groups that a strongly hydrophilic. The rate at which water is absorbed by a composite depends on many variables including fibre type, matrix, temperature, the difference in water distribution within the composite, reaction between water and the matrix, among others (Bledzki and Faruk 2004). Some researchers have attempted to reduce the hydrophilicity and water absorption characteristic of natural fibres by applying various fibre-surface modifications such as coupling agents, alkali treatment, latex coating, mercerization and irradiation (Sombatsompop and Chaochanchaikul 2004).

The method of manufacturing wood-plastic composites also affects moisture absorption. Clemons and Ibach (2004) studied 50% wood-flour-filled HDPE composites manufactured by extrusion, compression molding and injection molding. The extruded composites absorbed the most moisture and injection-molded composites absorbed the least moisture.

The purpose of this study was to investigate the effect of type of wood used in formulations on the physical and the mechanical properties of extruded composites (75% wood, 22% PP and 5% MAPP).

MATERIALS

Wood flour and heat treated wood fibres were prepared by our workshop from spruce and birch species, respectively. Wood pellets were purchased from VAPO, Finland. The size of pellets is 6-8 mm diameter, 10-30 mm average length. Polypropylene PP, Eltex P HY001P (Ineos), density 0.910 g/cm^3 and melt mass-flow rate 45 g/ 10 min (230 ^{o}C/ 2.16 kg) was used. The coupling agent used was maleated polypropylene, OREVAC® CA 100 (Arkema).

The wood, plastic powder and additives were compounded using a conical twin-screw extruder. The barrel temperature of the extruder was approximately 170 ^{o}C. The pressure at the die varied between 70 and 100 bar depending on composite formulation, and material output was 25 kg/h.

The density was measured according to EN ISO 1183. The moisture content was determined according to ISO 16969. Water absorption and thickness swelling were determined according to EN 317. The three-point loading tests were carried out according to EN 310. Charpy impact test was carried out according to EN ISO 179.

RESULTS

Physical properties of WPCs

Table 1 shows the density and moisture content of obtained WPCs. The density ranged from 1.04 g/cm^3 to 1.14 g/cm^3. The highest density was found for composites containing heat treated wood fibres. Composites made with pellets were found to have slightly lower density than those containing heat treated wood fibres. Composites made with wood flour had the lowest density.

Table 1: Physical properties of WPCs

Sample	Density [g/cm^3]	MC [%]
1^a	1.14 ± 0.03	1.92
2^b	1.11 ± 0.02	2.61
3^c	1.04 ± 0.01	2.41

^{a}Heat treated, ^{b}Pellets, ^{c}Wood Flour

Lower moisture content of composites made of heat treated wood could be due to a lower porosity attributable to the higher density of the composites. Usually, composites with higher density, which means lower porosity, are reported to have lower moisture content. Table 1 shows that for composites containing pellets the moisture content was even higher compared to composites made of wood flour despite of the difference in their densities. Higher initial moisture of pellets could be one reason for the higher moisture content of composites containing pellets.

Figures 1 (left and right) show the water absorption and thickness swelling of studied composites. These figures show water absorption and thickness swelling increase with immersion time. It can be seen that the type of wood has a significant effect on the water absorption and consequently on the thickness swelling. Likewise to the moisture content, the water absorption and thickness swelling of composites containing heat treated wood fibres were found to be lowest among all composites. It is clear seen, particularly for the initial stage of swelling that water absorption and thickness swelling rate decrease with increase of composite density.

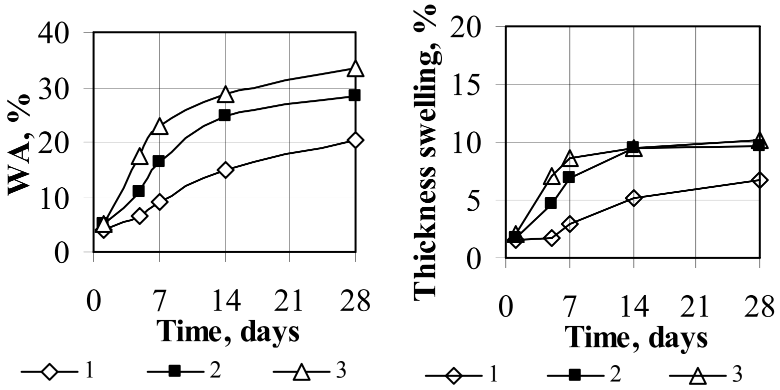

Figure 1: Water absorption and thickness swelling of WPCs (results are average of 20 samples)

Mechanical properties of WPCs

The results of flexural strength and Charpy impact strength are shown in Figures 2 (left and right). As can be seen, use of heat treated fibres improves significantly the flexural strength of studied composites. Flexural strength was found to correlate with moisture content of obtained composites (R^2 = 0.95).

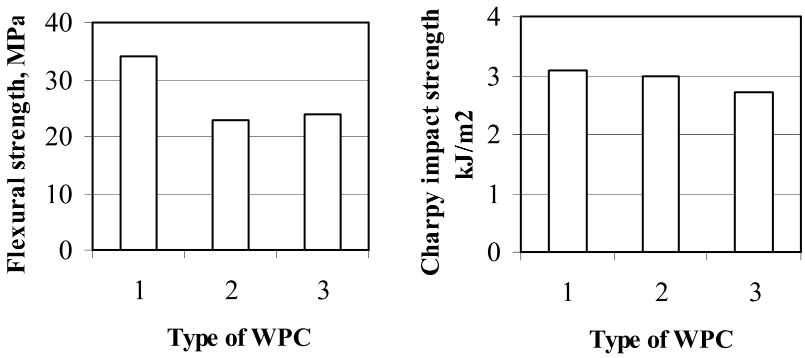

Figure 2: Flexural strength and Charpy impact strength of WPCs (results are average of 20 samples)

No significant changes were found for the Charpy impact strength of composites made of different wood sources. Slightly lower Charpy impact strength of composite containing wood flour could probably be explained by shorter size of fibres compared to other types of studied WPCs. However, in order to prove this hypothesis the analysis of wood fibres has to be done.

CONCLUSIONS

The influence of wood source on the water absorption and mechanical properties of the wood fibre reinforced polypropylene composites were investigated in this study. The several conclusions can be drawn from the experiments. The water absorption and the thickness swelling decrease with increase of density of wood-polypropylene composites. Heat treated wood fibres reduce the water absorption and the thickness swelling, as well as improve the flexural strength of wood-polypropylene composites. Flexural strength increases with the decrease of moisture content. Charpy impact strength was found to be very similar for all types of studied composites. Further research on structure of wood fibres and microstructure of composites is needed to understand better their effect on physical and mechanical properties of WPCs.

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