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Effect of nano material ratio on some physical properties of wood plastic nanocomposites

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Keywords

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Abstract

Effect of multi walled carbon nanotubes (CNT) content on some physical properties of wood plastic nanocomposites were investigated. To meet this objective, pine wood flour, polypropylene with coupling agent (maleic anhydride grafted polypropylene), and multi-walled carbon nanotube (0, 2, 4 or 6 wt%) were compounded in a high speed mixer. The mass ratio of the pine wood flour to polypropylene was 50/50 (w/w) in all the composite formulations. Test samples were manufactured using hot pres from the mixture. The thickness swelling and water absorptionbproperties of the wood plastic nanocomposites reinforced with CNT were determined.

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Introduction

Materials formed by combining two or more materials of the same or different groups at the macro level in order to combine the best properties of two or more materials of the same or different groups or to create a new property are called "Composite materials". In other words, it can also be called materials consisting of different types of materials or phases brought together in order to obtain superior properties by correcting each other's weaknesses (Mengeloğlu and Karakus, 2008). Wood-plastic composites (WPC) are composites of lignocellulosic materials and plastics is a general name given to composites formed as a result of mixing. Many wood species, primarily pine, maple and oak, are used in wood plastic composites. Today, the choice of wood species is determined according to availability rather than its properties. In addition, wood-based industrial wastes and agricultural wastes can be utilized in wood plastic composite production (Clemons, 2002; Kylosov, 2007; Mengeloğlu ve Kabakçı, 2008).

Plastics are organic polymeric substances that are generally solid at normal temperature and can be shaped or moulded by mechanical methods using pressure and heat (Hüner, 2008). Wood plastic composites are divided into two main groups depending on the type of plastic used. These are defined as thermoset and thermoplastic based wood composites. In the production of thermoset based wood composites, various adhesives such as urea formaldehyde, phenol formaldehyde, melamine formaldehyde, polyvinyl acetate are generally used as binding materials. is being used. In the production of thermoplastic-based wood composites, wood materials and polyethylene, Plastics such as polypropylene, polyvinyl chloride are used (Birinci, 2011).

Various additives are used to improve the physical, mechanical and thermal properties of wood plastic composites. For this purpose, glass fibers, inorganic fibers such as carbon and borane and synthetic polymers such as kevlar and aramid fibers are used as reinforcements. Despite the many advantages of wood plastic composites, some shortcomings such as relatively low modulus value, low impact resistance and creep performance have led researchers to the necessity of using compatibilizers or nanoparticles acting as various interfacial adhesives to improve the performance of wood plastic composites. Especially today, nanotechnology studies are progressing at a great pace. It seems possible to obtain successful results in wood plastic composites with materials with high specific properties produced with nanotechnology. In this way, it is expected that wood plastic nanocomposites will become high performance and high value-added products for end-use with their advantages such as high modulus value, high impact resistance and thermal stability. The main objective of this study was to evaluate the effect of CNT nano filler content on some physical properties of wood plastic nanocomposites.

Methods and materials

Materials

Yellow pine (*Pinus sylvestris*) wood flour was used as a lignocellulosic filler. The flour was purchased from a wood-plastic composite deck manufacturer (Semadeck, Tekirdag, Turkey). The wood flour (sapwood part) passing through a 40-mesh screen was retained on an 80-mesh screen. Polypropylene (PP) with a density of 0.9 g/cm^3 was purchased from Borealis Incorp in Austria. It has a melting point of 170°C and a melt flow index of 2.5 g/10 min at 230°C. To eliminate the incompatibility between the polypropylene and the pine wood flour and to increase the bonding, maleic anhydride polypropylene (MAPP) (Optim-425; melt flow index about 120 g/10 min at 190°C and a density 0.91 g/cm^3 Pluss Polymers Pvt. Ltd., Gurugram, India) was used. As the reinforcing filler, carbon nanotubes (CNT) (Grafen Company, Ankara, Turkey) was used. Polypropylene, pine wood flour (WF), CNT, and the compatibilizer maleic acid grafted polypropylene (MAPP) were used as purchased from the manufacturer. The readymade wood flour was oven-dried at 103°C ±2°C for 24 h. Drying the wood flour was important because moisture in lignocellulosic fillers causes bubbles to form during the extrusion and injection molding processes, leading to performance loss.

Methods

The production of WPNs was carried out in two stages: pellet production and nano-composite production. In the first stage, small granules (pellets) were produced, while in the second stage the samples were hot pressed into boards. Prior to the production, the wood flour was dried until the moisture was reduced to below 1%. The dried wood flour was melted in the extruder by premixing it with the polypropylene (PP), CNT, and MAPP according to the production prescription (Table 1) and then pushed into the die with the screw in the double screw extruder (temperature of 185°C to 200°C). The molten material that exited through the die in the extruder end was cooled with cold water and left to dry. Composite samples in the shape of fine rods dried at 80°C for 3 h were made into pellets via a plastic crusher.

Table 1. Composition of the evaluated formulations

ID	WF (wt%)	CNT (PhC)*	PP (wt%)	MAPP (wt%)
A	50	0	50	3
B	50	2	50	3
C	50	4	50	3
D	50	6	50	3

A computer-controlled press was used to apply hot pressing to the mats. The maximum press pressure was 45 N/cm^2, the press temperature was 210°C, and the total press cycle was 500 s. Following the hot pressing cycle, the ready panel was moved from hot press to climate controlled room for cooling. Before characterization, the samples were conditioned in a climate room at 23 ±2°C temperature and 65 ±2% relative humidity.

The tests were performed in accordance with ISO 62 for thickness swelling and water absorption. The samples utilized for this purpose were 5 × 5 mm in size. The samples that were conditioned in a climate room at 23 ±2°C temperature and 50% ±5 relative humidity were measured after leaving in water for 1 and 28 days.

Results and discussion

Table 2 represents some of the physical characteristics of CNT-reinforced wood plastic nanocomposites.

Table 2. Some physical properties of WPNs reinforced with CNT (%)

WPN code	Physical properties			
	thickness swelling		water absorption	
	1-day	28-days	1-day	28-days
A	0.78	2.89	0.54	1.48
B	0.75	2.78	0.51	1.42
C	0.66	2.71	0.41	1.32
D	0.61	2.67	0.35	1.30

Due to CNT's hydrophobic nature, incorporation of CNT nanoparticles into the composite structure led to low TS and WA values, as expected. The physical characteristics of the WPNs significantly improved with CNT nanoparticles loading. The control samples without the CNT had the highest TS and WS with value of 0.78% and 0.54% respectively, while the lowest TS and WS with value of 0.61% and 0.35% was found for the samples containing 5 wt-% the CNT with MAPP respectively. The merging of nanoparticles into the composite structure using the dry blending method resulted in poor dispersion of CNT nanoparticles. This situation caused a significant increase in the TS and WS of WPNs produced using the dry blending method.

The addition of the MAPP greatly increased the dimensional stability of the nanocomposites reinforced with CNT. As a consequence of the MAPP's increased coherent interfacial structure between the wood flour, PP matrix, and CNT nanoparticles, there are fewer microvoids and fiber-polypropylene-CNT debondings in the interphase area. Similar results were also found by several researchers (Wang et al., 2001; Kord et al., 2011; Kord, 2012). They found that modification of the nanocomposites with MAPP increased the dimensional stability.

Conclusions

This study was to investigate effect of CNT loading on some physical properties of wood plastic nanocomposites The result showed that the water absorption and thickness swelling properties of the nanocomposites improved with increasing CNT loading. As can be directly seen, water absorption and thickness swelling of wood-plastic nanocomposites reinforced with MWCNTs increased with increasing immersion time.

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