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Some Mechanical Properties of Wood Polypropylene Composites Filled with Carpenter Wastes

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Abstract:

In this study, we evaluated some mechanical properties of polypropylene composites filled with carpenter waste flour (CWF). To meet this objective, The CWF was compounded with polypropylene with and without coupling agent in a twin screw co-rotating extruder and then were manufactured by injection molding process. The flexural and tensile modulus improved with increasing CWF content while the flexural and tensile strengths of the samples decreased. The use of maleic anhydride polypropylene had a positive effect on the mechanical properties of the polypropylene composites filled with CWF. This work showed that the compositestreated with maleated polypropylene could be efficiently used as decking products, due to satisfactory mechanicalproperties of the composites.

Keyterms: Polypropylene composites, carpenter wastes, mechanical properties

Introduction:

Wood-plastic composites (WPCs) are emerging as one of the dynamic growth materials in the building industry. WPC is manufactured by dispersing wood particles into molten plastic with coupling agent or additives to form composite material through various techniques of processing such as extrusion, compression or injection molding. It was first made commercially from phenol-formaldehyde and wood flour that was used for Rolls-Royce gearshift knob in 1916, and it was reborn as a modern concept in Italy in the 1970s, and popularized in North America in earl y 1990s (Pritchard, 2005). Wood-thermoset composites date back to early 1900s; however, thermoplastic polymers in WPC are a relatively new innovation. In 1983, an American Woodstock company (Lear Corporation in Sheboygan, WI) began producing automotive interior substrates by using extrusion technology from the mixture of polypropylene (PP) and wood flour (Schut, 1999). Since then production and markets demand for the WPCs have been growing rapidly worldwide. Growing demand for wood plastic composites has led to continuous efforts to find new resources as an alternative to wood. With increasing population of the world, the sustainable utilization of forest resources has been adversely influenced. From the literature, we know that mechanical properties lignocellulosic/plastic composites can be influenced by raw material characteristics (Ashori and Nourbakhsh, 2009; Ayrilmis and Kaymakci, 2013; Mengeloglu and Karakus, 2008; Ayrilmis et al, 2010; Kaymakci et al, 2012). The goal of this research was to determine some mechanical properties of wood polypropylene composites filled with carpenter wood wastes.

Materials and Methods

Materials: The carpentry wood wastes (CW) as lignocellulosic material was obtained from local carpenter in İstanbul, Turkey. First the CW was dried in an oven at 60°C for 10 h to moisture content of 20–30% based on the oven-dry SFS solid weight. Following the drying, the CW was then processed by a rotary grinder without adding additional water. Finally, the CW flour passing through a U.S. 35-mesh screen and was retained by a U.S. 80-mesh screen. The CW flour (CWF) was then dried in a laboratory oven at 100°C for 24 h to moisture content of 1–2%. The PP (Tm = 160°C, q = 0.9 g/cm^3, MFI/230°C/ 2.16 kg= 6.5 g/10 min) produced by Likom PP Co., Ukraine, was used as the polymeric material. Maleated polypropylene (MAPP-OPTIM-415) with 1.0 weight % maleic anhydride level was used as a coupling agent.

Manufacture of wood polypropylene composites: The CWF were dried to 1–2% moisture content using in an air dryer oven at 100°C for 24 h and then stored in a polyethylene bag in an environmental controller. The CWF and the PP with and without MAPP granulates were processed in a 30-mm conical co-rotating twin-screw extruder with a length-to-diameter (L/D) ratio of 30:1. The raw materials were fed into the main feed throat using a gravimetric feed system. The barrel temperatures of the extruder were controlled at 170, 180, 190, and 190°C for zones 1, 2, 3, and 4, respectively. The temperature of the extruder die was held at 200°C. The extruded strand passed through a water bath and was subsequently pelletized. These pellets were stored in a sealed container and then dried for about 3-4 h before being injection molded.

The temperature used for injection molded specimens was 170-190°C from feed zone to die zone. The specimens were injected at injection pressure between 4-5 MPa with cooling time about 30 s. Finally, the specimens were conditioned at a temperature of 23± 2°C and relative humidity of 50± 5% according to ASTM D 618-08. The composition of the polypropylene composites is presented in Table 1.

Table 1. Compositions of the Unfilled and Filled PP Composites

Composite Type	Composition		
	Carpentry Wastes Flour (CWF)	Polypropylene	Coupling Agent (MAPP)
A	30	70	-
B	40	60	-
C	50	50	-
D	30	70	3
E	40	60	3
F	50	50	3

Two different polypropylene composites groups were produced. The first group consists of PP and CWF in varying proportions. Second group had PP, CWF in different proportions and MAPP coupling agent in the formulation. The formulations of the composites are given in Table 1.

Determination of mechanical properties: The tensile tests were conducted in accordance with ASTM D638 using a Lloyd testing machine at a rate of 5 mm/mincrosshead speed. The flexural test was conducted in accordance with ASTM D 790 using a Lloyd testing machine at a rate of 1.3 mm/minwas performed at a rate of 5 mm/min. The izod pendulum impact strength of the notched specimens (notch tip radius: 0.25 mm) was performed according to ASTM D 256 (2010) using a Devotrans impact testing machine. Seven specimens were tested for the tensile, flexural and impact properties of each composite formulation.

Table 2: Some mechanical properties of the PP composites filled with CWF

Composite type[1]	Mechanical properties				
	Flexural strength MPa	Flexural modulus MPa	Tensile strength MPa	Tensile modulus MPa	Impact strength J/m Notched
A	42.16**(1.18)***	3567**(156)**	23.14**(2.13)**	3867**(214)**	29.61**(1.07)**
B	37.56**(2.43)**	3819**(215)**	26.45**(2.56)**	4216**(153)**	28.43**(1.07)**
C	34.76**(3.36)**	4126**(173)**	21.56**(1.76)**	4546**(123)**	24.31**(0.98)**
D	46.84**(3.14)**	3684**(112)**	26.74**(1.69)**	4156**(261)**	32.20**(0.68)**
E	39.16**(2.78)**	3996**(181)**	30.17**(2.29)**	4436**(221)**	28.82**(1.07)**
F	36.28**(2.06)**	4475**(371)**	24.45**(3.16)**	4851**(187)**	26.84**(0.88)**

*** The values in the parentheses are SDs**

Flexural properties: The flexural strength and modulus values of the CWF -filled polypropylene composites are presented in Table 2. As the CWF loading increased. the flexural strength values of the polypropylene composites with and without MAPP decreased. The flexural modulus of the samples increased by 15% as the CWF increased from 30 to 50 wt%.where the flexural strength decreased by 18% (for without MAPP). The increase in the modulus suggests an efficient stress transfer between the polymer and filler. At similar filler loading. the PP composites without MAPP had lower flexural strength value than the ones with MAPP. The MAPP improves the interfacial adhesion between hydrophilic lignocellulosic filler and hydrophobic polymer matrix. leading to less micro-voids and fiber-polyethylene debondings in the interphase region (Ayrilmis et al. 2013).

Tensile Strength: The results of the tensile strength and modulus of the CWF -filled samples with and without MAPP are presented in Table 2. The results of the tensile modulus test were similar to the results of the flexural modulus test; the composites with high CWF content and treated with the MAPP had better flexural modulus than the untreated ones. All the polypropylene composites filled with CWF flour showed higher tensile modulus than the neat polypropylene which was 1250 MPa. The tensile strength of the samples increased from 26.74 to 30.17MPa as the CWF increased from 30 to 40 wt% (for with MAPP). This result was consistent with the results of previous studies. For example in a previous study. it was observed a similar trend with wood flour filled polypropylene composites. They also reported that dissimilarities between polar wood flour and nonpolar polymer matrix caused poor adhesion and resulted in lower tensile strength (Ayrilmis and Kaymakci, 2013).

Impact strength: The results of the notched impact strength of the CWF -filled samples with and without MAPP are presented in Table 2. The results of the notched impact strength decreased with increasing the wood flour content. The impact strength of the uncoupled specimens decreased by 20% when wood content increased from 30 to 50 wt%. The incorporation of the wood flour into the polypropylene composite creates the regions of stress concentration that require less energy to initiate a crack in the composite. thereby decreasing the impact strength (Gacitua. 2008; Rowell et al.. 1997).

Conclusions: 1- Utilization of carpenter wastes flour (CWF) in a polymer matrix in general results in improvement in flexural and tensile modulus.

2- The flexural strength, tensile and impact strength of the composites were negatively affected by increasing CWF content.

3- The composites coupled with MAPP showed better mechanical properties compared with untreated ones.

4- Based on the findings obtained from the present study, the optimum mechanical properties for the composites were found 30/70/3 formulation of CWF, PP and MAPP.

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