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Comparative Investigation on the Mechanical Properties of Wood Plastic Composites Made of Virgin and Recycled Plastics

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Abstract: With growing production and consumption, plastics worldwide is currently resulting in a significant contribution to the municipal solid waste. In a similar way as for the virgin plastics, any recycled plastics that can melt and be processed below the degradation point of wood can be used for manufacturing of wood plastic composites (WPCs). In this study, effect of type and virginity of the plastics on the mechanical properties of wood plastic composites was investigated. To meet this objective, the blend composites were prepared through the melt mixing of wood flour/polymer at 25 and 50% weight ratios, with 2% coupling agent in hake internal mixer then the samples made by injection molding. Two kind of plastic include of virgin and recycled polypropylene (VPP, RPP) and virgin and recycled polyethylene (VPE, RPE) was selected. Results indicated that the mechanical properties of composites containing PP are significantly higher than those of PE. Also, the tensile strength and modulus of the composites decreased with the increase of recycled plastic loading. However, the impact strength of the composites increased with increase of plastic content.

Key words: Wood Plastic Composites · Virgin Plastics · Recycled Plastics · 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. Use of wood as the filler in WPCs has advantages such as low-cost, renewable, biodegradability, low specific gravity and low abrasion to equipment as compared with inorganic fillers [1-4].

With growing production and consumption, plastics worldwide is currently resulting in a significant contribution to the municipal solid waste. Recycling of the waste plastics has benefits of minimizing solid waste disposal problem, reducing the virgin plastics consumption and lowering the production costs. A number of reclamation techniques have been developed to obtain well sorted plastics that can be used or substitute for the virgin plastics in many applications [5-7].

In WPC manufacturing, virgin plastics such as high and low density polyethylene, polypropylene and poly vinyl chloride are commonly used. In a similar way as for the virgin plastics, any recycled plastics that can melt and be processed below the degradation point of wood can be used for manufacturing of WPCs [8-14]. However, limited studies were conducted to evaluate the performance of the WPCs made from recycled HDPE and PP with wood flour. Najafi *et al.* who reported that the composites containing PP (25% each of virgin and recycled) were exhibited statistically similar mechanical properties to those of composites made from virgin plastics. Sellers *et al.* studied the WPC panels using recycled PE or polystyrene (PS) and pine wood fibers at a ratio of 50:50 through high pressure pressing moulding. They reported that the products had good mechanical properties suitable for construction materials. A study by Jayaraman *et al.* showed that the tensile strengths of WPCs made from wood fibers (pine) and recycled HDPE is about 25% higher than those of the entirely virgin HDPE panel.

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Table 1: Composition of the Studied Formulations

	Polypropylene (Wt. %)		Polyethylene (Wt. %)			
Sample Code	Virgin	Recycled	Virgin	Recycled	Wood Flour (Wt. %)	MA (Wt. %)
75W23VPP2M	23	-	-	-	75	2
50W48VPP2M	48	-	-	-	50	2
75W23RPP2M	-	25	-	-	75	2
50W48RPP2M	-	48	-	-	50	2
75W23VPE2M	-	-	23	-	75	2
50W48VPE2M	-	-	48	-	50	2
75W23RPE2M	-	-	-	25	75	2
50W48RPE2M	-	-	-	48	50	2

In this study the effect of type and virginity of the plastics on the mechanical properties of wood plastic composites was investigated.

MATERIALS AND METHODS

Two kinds of most commonly used virgin plastics were selected; virgin high density polyethylene (VPE) with a melt flow index of 11 g/10 min and virgin polypropylene (VPP) with a melt flow index of 18 g/10 min. Two kinds of recycled plastics were also selected; recycled high density polyethylene (RPE) from water bottle with a melt flow index of 18.5 g/10 min and recycled polypropylene (RPP) from waste bags with a melt flow index of 23.36 g/10 min. Maleic anhydride was used as coupling agent; purchased from Iran Polymer and Petrochemical Institute; as a coupling agent. Pine wood flour (WF) is used as the reinforcing fiber material was from Cellulose Aria Co. (Iran); the average particle size of rice husk flour was 60 meshes.

Before preparation of samples, wood flour was dried in an oven at (65±2)°C for 24 hours. Then virgin and recycled plastics, wood flour and coupling agent were weighed and bagged according to formulations given in Table 1. The mixing was carried out by a hake internal mixer (HBI System 90, USA). First the plastics were fed to mixing chamber, after melting of plastics, coupling agent was added. At the two minute, the wood flour fed and the total mixing time was 12 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 prior to testing.

The tensile tests were measured according to ASTM D638, using an Instron machine (Model 1186, England); the tests were performed at crosshead speeds of 2mm/min.A Zwick impact tester (Model 5102, Germany) was used for the Izod impact test. All the samples were notched on the center of one longitudinal side according to the ASTM D256. For each treatment level, five replications were tested.

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

RESULTS AND DISCUSSION

The results of an ANOVA indicated that the type and virginity of the plastics had significant effects on the tensile strength and modulus of wood plastic composites. The tensile strength and modulus of composites are shown in Figures 1 and 2, respectively. It can be observed that the tensile strength and modulus of composites containing PP is significantly higher than those of PE. It is because of that molecule structure of polypropylene matrix is stronger and stiffer than polyethylene.

Figures 1 and 2 also show that the tensile strength and modulus of the composites decreased with the increase of recycled plastic loading. It is well established that during the recycling process of plastics there is a generation on the material mechanical properties [8-14] and it possible to degrade the mechanical properties of recycled plastics. Therefore, it can be seen that the mechanical properties of the wood flour/recycled plastic composites were slightly lower than those of virgin plastics. The increase in crystallinity is the result of molecular weight reduction [8-14] that can occur during recycling process. Therefore, the tensile strength and modulus of composites from virgin plastics was higher than those of recycled plastics.

Another interesting result in Figure (1) is that, the tensile strength and modulus of the composites decreased with increase of plastic content. It is well established that

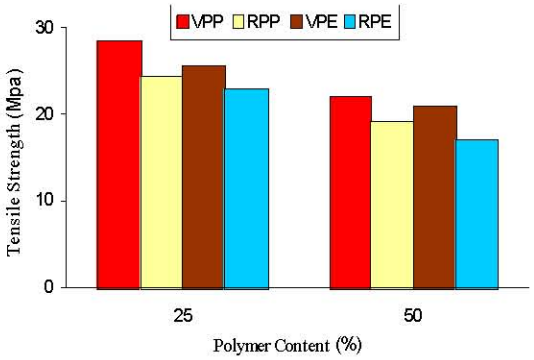

Fig. 1: Tensile strength of wood plastic composites made of virgin and recycled plastics

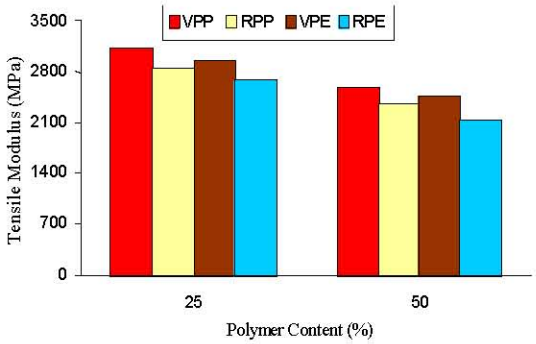

Fig. 2: Tensile modulus of wood plastic composites made of virgin and recycled plastics

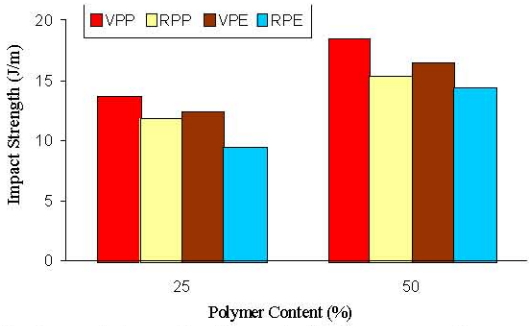

Fig. 3: Impact strength of wood plastic composites made of virgin and recycled plastics

the presence of the fillers had reduced the ductility of the composites and increased their stiffness. This is true for WPCs in which fillers added to a polymer restrains the movement of its chains, thereby increasing its modulus [3-4].

The results of an ANOVA indicated that the type and virginity of the plastics had significant effects on the impact strength of wood plastic composites. The impact strength of composites is shown in Figures 3. It can be observed that the impact strength of composites containing PP is significantly higher than those of PE. Figures 3 also show that the impact strength of the composites decreased with the increase of recycled plastic loading. It seems some factors such as crystallinity, melt flow index and oxidation of recycled plastics higher than virgin plastics which cause to crack propagation mechanism between the filler and the matrix polymer.

Another interesting result in figure (1) is that, the impact strength of the composites increased with increase of plastic content. It is well established that, the impact properties are affected by the crack initiation and crack propagation mechanism between the filler and the matrix polymer. This is likely due to the fact that the wood particles acted as stress concentrators and decreased the impact strength [1, 3-4].

CONCLUSION

The Following Conclusions Could Be Drawn from the Results of the Present Study:

- ANOVA indicated that the type and virginity of the plastics had significant effects on the mechanical properties of wood plastic composites.
- The mechanical properties of composites containing PP are significantly higher than those of PE.
- The tensile strength and modulus of the composites decreased with the increase of recycled plastic loading. However, the impact strength of the composites increased with increase of plastic content.

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