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The Impact of Plastics Virginity on Water Absorption and Thickness Swelling of Wood Plastic Composites

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Abstract: Water absorption and thickness swelling of wood plastic composites manufactured from wood flour and virgin and/or recycled plastics, namely high density polyethylene and polypropylene, were studied. Wood flour was mixed with different virgin or recycled plastics at 25% and 50% by weight fiber loading. The samples were made by melt compounding and then injection molding. The amount of coupling agent was fixed at 2% for all formulations. Statistical analysis showed that the type and plastics virginity had significant effects on the water absorption and thickness swelling of wood plastic composites. Results indicated that the water absorption and thickness swelling of composites containing polypropylene is lower than those of polyethylene. Also, the moisture uptake of composites containing made of recycled plastic is higher than those of virgin plastics. The composites containing 50% wood flour with recycled high density polyethylene had the maximum moisture sorption.

Key words: Virginity · Polypropylene · High Density Polyethylene · Water Absorption · Thickness Swelling

INTRODUCTION

Processing of plastic composites using natural fibers as reinforcement has increased dramatically in recent years. Fiber-reinforced composites consist of fiber as reinforcement and a polymer as matrix. Plastic polymers including high density polyethylene (HDPE), low density polyethylene (LDPE), polypropylene (PP), etc. have been reported as the matrices. Traditional fiber-reinforced composites use various types of glass, carbon, aluminum oxide and many others as reinforcing component. Natural fibers, especially fibers, such as wood fiber, flax, hemp, jute, sisal and many others were applied by some researchers as fiber reinforcement for composites in recent years. Advantages of natural fibers over man-made fibers include low density, low cost, recyclability and biodegradablility. These advantages make natural fibers potential replacement for glass fibers in composite materials. Mechanical properties of natural fibers are very good and may compete with glass fiber in specific strength and modulus. Natural fiber-reinforced composites can be applied in the plastics, automobile and packaging industries to cut down on material cost [1-3].

Wood-fiber-reinforced thermoplastic composites (WPCs) have been known for many years. However, the increasing cost of virgin plastic and the limited availability of appropriate wood fiber in the world have restricted their rapid development to a certain degree. The utilization of recycled plastic for the manufacture of wood-fiber-reinforced recycled plastic composites (WRPCs) has been studied by a number of authors. Composites containing recycled plastics and wood fibers offer interesting combinations of properties [4-6].

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 [5-9]. So, the use of plastic and wood wastes seems inevitable and the present opportunities are promising. In this study the effect of plastics virginity on the water absorption and thickness swelling of wood plastic composites was investigated.

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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.

Water uptake tests were carried out according to ASTM D 7031 specification. Specimens with a dimension of 20 × 20 × 20 mm were cut for the water uptake measurement. Five replicates were used for each sample code. To ensure the same moisture content for the specimens before each test, all the specimens were oven-ried at 102±3°C. The weight and thickness of dried specimens was measured to a precision of 0.001 mm. 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 at different time intervals during the long-time immersion. The measurements were terminated after the equilibrium weight and thicknesses of the specimens were reached. The values of the water absorption in percentage were calculated equation 1.

$$WA(t) = \frac{W(t) - W_0}{W_0} \times 100 \quad (1)$$

Where WA (t) is the water absorption at time t, W_o 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.

$$TS(t) = \frac{T(t) - T_0}{T_0} \times 100 \quad (2)$$

Where TS (t) is the thickness swelling at time *t*, To is the initial thickness of specimens and T (t) is the thickness at time *t*.

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 α = 0.05 level.

RESULTS AND DISCUSSION

Statistical analysis showed that the type and plastics virginity had significant effects on the water absorption and thickness swelling of wood plastic composites.

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

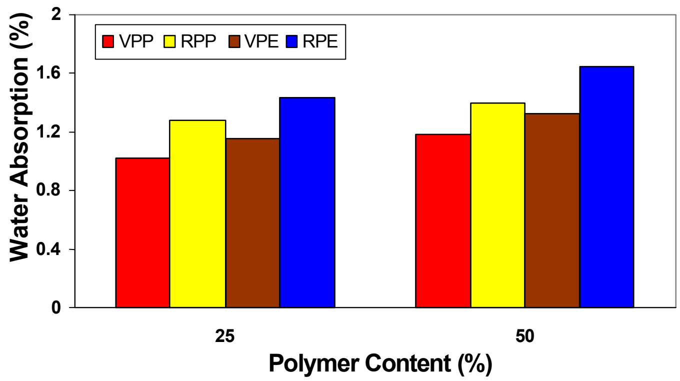

Fig. 1: Effect of plastics virginity and type on the water absorption of composites

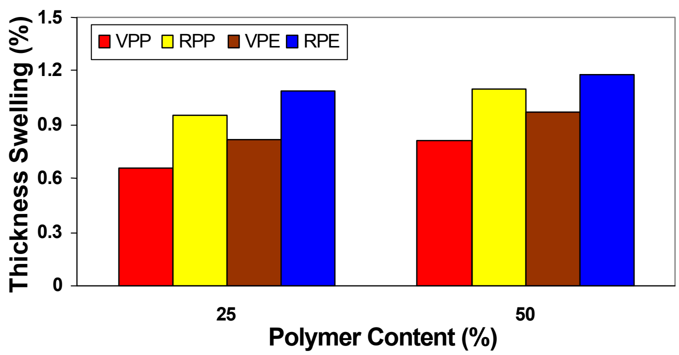

Fig. 2: Effect of plastics virginity and type on the thickness swelling of composites

The influence of the type and plastics virginity on the water absorption of wood plastic composites was shown in Figure 1. As can be seen, the water absorption of composites was affected by plastic type. The water absorption of composites containing polypropylene (PP) is lower than those of polyethylene (PE). It is because of that molecule structure of polypropylene matrix is stronger and stiffer than polyethylene, therefore, there is less void in polypropylene which cause to the less water absorption.

Also Figure 1 shows that the water absorption of composites containing made of recycled plastic is higher than those of virgin plastics. It is well known that the different water absorption between all manufactured composites can be attributed to the virginity of plastics. During the recycling process of plastics there is a generation on the crystalline structure and degradation of the mechanical properties of recycled plastics is possible. Therefore, the water absorption of recycled plastic composites was higher than those of virgin plastics. 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 [5-9].

The effect of the type and plastics virginity on the thickness swelling of wood plastic composites is shown in Figure 2. The variation in thickness swelling of the composite is similar to water absorption.

The hydrophilic nature of wood flour causes the water absorption and thickness swelling in wood plastic composites manufactured (the plastics have negligible water absorption). Figures 1 and 2 showed that the water absorption and thickness swelling of composites increased with increase of wood flour loadings. It is well established that the water uptake in natural fibers (lignocellulosic plant fiber) under fiber saturation point is mainly due to their hydroxyl groups on cellulose or hemi-cellulose that can react with water and increase gap between the cellulose chains. The absorption of water by non-polar polymers that contain fillers depends on the nature of the filling material. In the case of cellulosic fibers, which are hydrophilic, an increase in water sorption can be expected. Because polymer is hydrophobic and the wood flour is hydrophilic, the absorption of water depends solely on the fibers. As the wood flour loading increases, the cellulose content increases, which in turn results in the absorption of more water [10-12]. When wood-plastic composites are exposed to moisture, the water absorption and swelling wood fiber can cause local yielding of the plastics due to swelling stress, fracture of wood particles due restrained swelling and interfacial breakdown. Initially, there is adhesion between the wood particles and matrix in a dry WPC. As the wood particle absorbs moisture, it swells. This creates stress in the matrix, leading to the formation of microcracks. It also creates stress in the wood particles, causing damage. After drying composites, there is no longer adhesion at the matrix and wood particles interface. Cracks formed in the plastics and the interfacial gap contributes to penetration of water into the composite at a later exposure [10-12].

CONCLUSION

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

- Statistical analysis showed that the type and plastics virginity had significant effects on the water absorption and thickness swelling of wood plastic composites.
- The water absorption and thickness swelling of composites containing polypropylene (PP) is lower than those of polyethylene (PE).
- The moisture uptake of composites containing made of recycled plastic is higher than those of virgin plastics
- The 50W48VPP2M and 75W23RPE2M samples showed the minimum and the maximum water uptake, respectively.

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