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Study the Water Absorption of Hybrid Wood Plastic Composites after Accelerated Weathering

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ABSTRACT

Recently, to improve the properties of wood plastic composite incorporation of nanofiller has been considered. In this study, hybrid composites of polyethylene/wood flour/nanoclay with different loading of nanoclay were prepared using melt compounding followed by injection molding. Composites were weathered in a xenon-arc type accelerated weathering apparatus for 2000 hr. Water absorption of the composites were evaluated before and after weathering. The results indicated that water absorption of the composites increased after weathering but addition of nanoclay can reduce intensity of weathering through decreasing of water absorption. Also results indicated that after weathering wood plastic composites containing nanoclay absorbed less water than wood plastic composites.
KEYWORDS: WPC, NanoWPC, Weathering, Water absorption,

INTRODUCTION

Wood plastic composite (WPC) is typically comprised of wood or other natural lignocellulosic fibers in a thermoplastic matrix. These products have found their way into consumer, automotive, and construction applications, and are experiencing tremendous growth in exterior residential construction applications. The introduction of WPCs in the decking market is mainly responsible for this growth (1, 2). A direct result of success in the decking market is that products are now being developed and introduced for new exterior applications such as railings, fencing, roofing, and siding. The growth in exterior applications results in a need to understand the durability of WPCs. Durability issues such as weatherability, moisture resistance, thermal performance, fungal attack, and fire performance need to be addressed. Of specific interest is weatherability, and several research groups have been working on characterizing and understanding changes that occur when WPCs weather (3). The weathering resistance of WPCs is generally poor, and dimensional change caused by outdoor exposure are major problems for their use outdoors (4). The accelerated ultraviolet weathering of hot-press molded recycled polypropylene sawdust composites with combinative UV radiation and water spray was investigated. The results showed that water absorption of the composites was increased after accelerated weathering. (5). Nano science and nanotechnology have opened up a completely new way to develop WPCs (6). Inorganic fillers are often added to polyethylene to form composites or nanocomposites in which the filler serves to enhance the mechanical properties. Nanocomposites are a newclass of filled polymers in which inorganic fillers such as clay platelets at the nanometre scale are dispersed in a polymer matrix. In recent studies on polyethylene degradation, it has been found that polyethylene nanocomposites exhibit greater degradation rate as compared to polyethylene (7, 8). Tidjani and Wilkie reported that the photo-oxidative degradation of polypropylene nanocomposites is greater than that of pure polypropylene (7). Similar results were reported by Qin and co-workers for polyethylene nanocomposites (8). Therefore it seems that nanoparticles have an accelerating effect acting as catalysts to High Density Polyethylene (HDPE) photo-oxidation. Researchers examined different series of HDPE nanocomposites. From Fourier transform infrared (FTIR) spectroscopy study it was found that organically modified montmorillonite cause a serious effect on HDPE during UV degradation and new chemical compounds containing carbonyl, vinyl and hydroxyl groups were formed. This means that nanoparticles have an accelerating effect acting as catalysts to HDPE photo-oxidation (9). With respect to these studies, a comprehensive knowledge on the impact of nanoclay on the photo-oxidation of WPCs is still lacking. The present paper reports a study which investigates the effect of nanoclay, which can be used to improve the water absorption of WPCs, on the photo-degradation of WPCs.

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MATERIALS AND METHODS

The polymer matrix, HDPE with trade name 52518, was supplied by Jam Petrochemical Co. (Iran), with a density of 0.952 g/ml and MFR (190°C/2.16kg) of 18 g/10min. The particle size of aspen wood flour was 80 mesh. Maleic anhydride grafted polyethylene (MAPE) provided by Solvay with a density of 0.965 g/cm^3 (MFI 7 g/10min, grafted maleic anhydride 1 wt %) was used as coupling agent. Cloisite 15A is a natural montmorillonite modified with dimethyl-dehydrogenated tallow–ammonium chloride salt having a d-spacing of 31.5A° and modifier concentration of 125meq/100g clay obtained from Southern Clay Products.

Before sample preparation, wood flour was dried at (70±5) ˚C for 24 h. Then HDPE, wood flour, nanoclay and MAPE were weighed and bagged according to formulations given in Table 1. Mixing was carried out in a Haake internal mixer (sys 90, USA) equipped with cam blade at 150˚C and 60 rpm. First HDPE was fed into mixing chamber, after melting, nanoclay and coupling agent were added. After mixing for 5 min, the wood flour was fed into the system. The total mixing time was 10 min. The compounded materials were then grinded to prepare the granules using a pilot scale grinder (WIESER, WGLS 200/200 model). The resulting granules were dried at 105˚C for 24 h. Test specimens were prepared by injection molding machine (Imen Machine, IRAN) at 190˚C. The specimens were stored under controlled conditions (50% relative humidity and 23˚C) for at least 40 h prior to testing.

Table 1. Composition of the studied formulations.

Sample Code	HDPE Content (wt%)	WoodFlour Content (wt%)	Nanoclay Content (wt%)	PE-g-MA Content (wt%)
45W	52	45	0	3
45W2N	50	45	2	3
45W4N	48	45	4	3

Weathering

Composites were placed in a xenon-arc type light exposure apparatus (Atlas Xenotest Beta) operated according to ASTM D 2565. Samples were mounted on a drum that rotated around a filtered xenon-arc bulb at 1 rpm. Each 2h weathering cycle consisted of 102 min of UV exposure and 18 min of simultaneous deionized water spray and UV exposure with a black panel temperature of 63±2˚C. Irradiance was monitored (41.5±2.5 W/m^2) and voltage to the bulb was changed periodically to maintain constant irradiance. Samples were removed for analysis after 2000 h of weathering.

Water absorption

Water absorption tests were carried out according to ASTM D-7031-04. Five specimens of each formulation were selected and dried in an oven for 24 h at 102±3˚C. The weight of dried specimens was measured to a precision of 0.001 g. 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 of the specimens was measured after 20 days (480hr). The values of the water absorption in percentage were calculated using the following equation:

$$WA_t = \frac{W_t - W_o}{W_o} \times 100$$

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.

RESULTS

Water absorption

Fig 1 shows the water absorption of the samples versus nanoclay content. For all of the samples it can be observed that the water absorption decrease as nanoclay increase. Also it can be seen that the water absorption of all samples is higher after weathering. The comparison of water absorption of WPCs, before and after weathering shows that it increases by 29.84% while for nanoWPCs containing 2 wt% and 4 wt% nanoclay, it reaches 24.40% and 23.49%, respectively. Therefore it can be concluded that the water absorption of WPCs after weathering is higher than nanoWPCs.

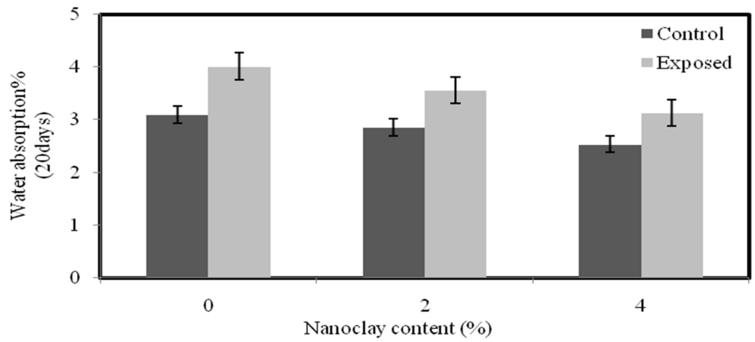

Fig. 1. Effect of nanoclay on water absorption (20 days) of exposed and control samples.

DISCUSSION

Generally, water absorption in WPCs is governed by two significant mechanisms: the hygroscopic nature of natural fillers/fibers and the penetration of water into the composites (diffusivity) via gaps and flaws at the interfaces between fibers and plastics (10). Since composite micro voids and the lumens of fibers were filled with nanoclay, penetration of water into the deeper parts of composite is prevented (11). On the one hand, weathering increases the wet ability of the composites. Researchers stated that the weathering increases the wet ability of the wood component by reducing the water repellent effect of extractives, degrading the hydrophobic lignin component and exposing the cellulose-rich wood component at the composite surface layer. The increased hydroxyl groups from the exposed cellulose then promoted the water absorption of the composites (12). On the other hand, it is well known that photo degradation of HDPE can be accelerated by metal ions which can be found in catalyst residues or in used additives like nanoparticles and finally resulted in increasing of water absorption of composites. It has been stated that organically modified montmorillonite have an accelerating effect acting as catalysts to HDPE photo-oxidation (9). It seems that both the clay and the ammonium modifier of the clay cause higher degradation in nanocomposites (13). Therefore, it is expected that UV exposure of nanoWPCs resulted in more severe weathering than WPCs and subsequently further increasing of water absorption. But, on the contrary, our results indicated that the water absorption of nanoWPCs (containing 4 wt% nanoclay) caused by weathering, is lesser than WPCs. As mentioned above, nanoclay can fill composite micro voids and the lumens of fibers and so penetration of water into the deeper parts of composite is prevented. It seems that this role of nanoclay for decreasing of water absorption is more important than the role of nanoclay for increasing of weathering. Water accelerates oxidation reactions and also water absorption decreased with increasing of nanocaly content (14, 15). Therefore it can be concluded that nanoclay content can decrease carbonyl index.

Conclusion

This article addresses some key issues related to the weathering of WPC_S including nano particles. In this work, hybrid composites based on HDPE/WF/Nanoclay were prepared with different nanoclay concentration. The accelerated weathering conditions (2000hr and xenon) were applied to the samples and the properties of samples determined after weathering. The following results can be concluded from this study:

The general trend of WPC weathering shows that surface oxidation increased after exposure. The water absorption of the weathered samples was increased compared to those of the corresponding control samples after 20 days water exposure. Addition of nanoclay to the composites improved the water absorption. However water absorption of weathered nanoWPCs was less than that of weathered WPCs.

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