EFFECTS OF MOISTURE ON ASPEN-FIBER/POLYPROPYLENE COMPOSITES

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ABSTRACT

Aspen fiber/polypropylene composites were made using several different levels of aspen fiber (0 to 60% by weight) with and without the addition of a compatibilizer (maleic anhydride grafted polypropylene, MAPP). These composites were tested under various relative humidity conditions and in water soaking, boiling water, cyclic liquid water and oven drying tests. In all moisture test conditions, as the level of fiber increased in the composites, the rate and extent of moisture sorption increased as compared to pure polypropylene. The presence of MAPP in the composites, in general, decreased the extent of moisture pickup in all of the tests.

Key Words: Aspen fiber, polypropylene, composites, moisture sorption.

INTRODUCTION

The use of lignocellulosics as fillers and reinforcements in thermoplastics has been gaining acceptance in commodity plastics applications in the past few (Rowell and Sanadi 1998). The lignocellulosics that can be used in thermoplastics can be obtained from many different sources, both from forestry and agricultural resources. The physical form can vary from a fine flour to long ago-based fibers. The cost and performance of the final composite products dictates the type of lignocellulosic to be used in the plastics.

Blending of the plastics with the lignocellulosics may require compatibilization to improve the contact, dispersion, flow and mechanical properties of the composite and has been reported as far back as the late 1960's. Extrusion of lignocellulosics-filled plastics for the automotive industry is well known and has been used for more than twenty years. Typical blending involves the plastic-filler/reinforcement to be shear mixed at temperatures above the softening point of the plastics. The heated mixture is then typically extruded into "small rods", which are then cut into short lengths to produce a conventional pellet. The pellets can then be used in typical injection or compression molding techniques. The direct injection molding process has limitations on the amount of filler/fiber that can be used in the composite and is also likely to be limited to particulate or shorter fiber.

There is still a great deal of basic research going on in many parts of the world in the area of natural fiber/themoplastic composite materials. This research includes the use of many different types of lignocellulosic-based flours and fibers, different types of thermoplastics, expanding the amount of flour/fiber in the composites, developing better compatibilization systems, developing testing procedures, and understanding performance through testing and modeling. Equipment development is going forward to produce more efficient mixing systems, faster through put, and new methods of molding/injection.

One of the major research areas of interest in the lignocellulosic/plastics composite area is performance of these materials in outdoor applications (Rowell et al. 1998). Issues of ultraviolet degradation (weathering), moisture up-take, swelling, creep, thermal degradation, and mold and decay resistance are important properties to study to determine the change in performance of these composites as a function of environmental stresses Rowell et al. 2000).

The purpose of this paper is to describe recent results on the moisture sorption of aspen fiber/polypropylene composites.

EXPERIMENTAL

Materials

Sets of specimens were prepared as follows: aspen fiber was combined with polypropylene (PP) (by weight) alone or with 2% maleic anhydride grafted polypropylene (MAPP) (by weight). The PP homopolymer had a melt flow index of 12 g/10 min. as measured by ASTM D-1238. The MAPP had a number average molecular weight of 20,000, a weight average molecular weight of 40,000 and about had 6% by weight of maleic anhydride in the polymer.

Aspen Fiber	Polypropylene	MAPP
<-----------------------	% by weight --------------------------	-->
30	70	0
30	68	2
40	60	0
40	58	2
50	50	0
50	48	2
60	40	0
60	38	2

The aspen fiber, MAPP and PP (the latter two in pellet form) were compounded in a high intensity thermo-kinetic mixer where the only source of heat is generated through the kinetic energy of rotating blades. The blending was accomplished at 4600 rpm and then automatically discharged at 190 C. The total residence time of the blending operation averaged about 2 min.

The mixed blends were then granulated and dried at 105 C for 4 hours. Test specimen were injection molded at 190 C using pressures varying from 2.75 MPa to 8.3 MPa depending on the constituents of the blend.

Humidity Tests

Equilibrium Moisture Content, Test specimens were oven dried over night at 105 C and weighed. Specimens were placed in a 90% relative humidity room and left until there was no further weight gain (200 days). The weight gain was determined and used to calculate the equilibrium moisture content. Three specimens of each type were tested and the results averaged.

Cyclic Humidity Tests. Test specimens were oven dried over night at 105 C and weighed. Specimens were placed in a 30% relative humidity room and left for 25 days. After weighing, the specimens were then placed in a 90% relative humidity room and, again, left there for an additional 25 days. After weighing, the specimens were place back in the 30% relative humidity room. This process was repeated four times. Three specimens of each type were tested and the results averaged.

Liquid Water Tests

Rate of Water Sorption. Test specimens were oven dried over night at 105 C and weighed. Specimens were placed in water and weights were taken every 15 minutes for the first hour, every hour for the first eight hours, then once a day for 5 days. Each specimen was wiped with a soft towel to remove surface water before weighing. After 5 days, each specimen was re-oven dried for 24 hours at 105 C and weighed. Three specimens of each type were tested and the results averaged.

Continuous Soaking. Test specimens were oven dried over sight at 105 C and weighed. Specimens were placed in water and soaked for seven days and reweighed. The specimens were then returned to water soaking and the process was repeated for 10 weeks. Three specimens of each type were tested and the results averaged.

Cyclic Water Soaking Tests. Test specimens were oven dried over night at 105 C and weighed. Specimens were placed in water, soaked for 7 days, weighed, and re-ovendried. This process was repeated for 10 cycles. Three specimens of each type were tested and the results averaged.

Boil Test. Test specimens were oven dried over night at 105 C and weighed. The specimens were boiled for 2 hours, weighed, and re-ovendried. The process was repeated for 10 times for a total of 20 hours of boiling. Three specimens of each type were tested and the results averaged.

RESULTS AND DISCUSSION

Humidity Tests

Table 1 shows the moisture uptake of aspen-polypropylene composites in a 90% humidity room over time, At 200 days, the specimens were still gaining weight so they had not yet reached equilibrium. As the level of fiber increases in the composites, the amount of moisture increases. In general, the presence of the MAPP decreased the moisture sorption at a given fiber content. This may be due to more intimate contact between fiber and the thermoplastic protecting the fiber from moisture sorption.

Table 1 - Weight gain in aspen-polypropylene composites at 90% relative humidity after D days

Aspen/PP/ MAPP	Weight Gain 25D	50D	75D	100D	150D	200D
	%					
0/100/0	0	0	0	0	0.2	0.4
30/70/0	0.7	1.4	1.7	2.1	2.4	2.8
30/68/2	0.7	0.7	1.1	1.5	1.5	2.2
40/60/0	0.7	1.4	1.7	2.0	2.4	3.0
40/58/2	0.4	1.2	1.5	1.9	2.7	3.5
50/50/0	1.3	2.0	2.6	3.6	4.3	5.3
50/48/2	1.5	1.8	2.2	2.9	4.0	5.1
60/40/0	3.7	4.5	5.6	6.0	6.3	6.7
60/38/2	1.6	2.2	3.5	4.4	5.1	6.0

Table 2 shows the change in weight of the composites due to moisture sorption from the cyclic humidity tests. There is an increase in moisture sorption after each cycle and, again, the presence of MAPP in the composites seems to lower the moisture sorption.

Table 2 - Weight changes in repeated humidity tests on aspen-polypropylene composites cycled between 30 and 90% relative humidity.

Aspen/PP/ MAPP	Weight Gain 30%	90%	30%	90%	30%	90%	30%	90%
	%							
0/100/0	0	0	0	0	0	0.2	0	0.4
30/70/0	0.6	0.9	0.7	1.4	0.7	1.4	0.9	1.9
30/68/2	0.4	0.9	0.7	1.2	0.7	1.3	0.9	1.8
40/60/0	0.4	0.9	0.7	1.4	0.7	1.6	0.7	2.1
40/58/2	0.2	1.2	0.8	1.6	1.0	2.0	1.2	2.2
50/50/0	0.5	1.5	1.2	2.5	1.2	2.7	1.2	3.2
50/48/2	0.6	1.3	1.1	2.2	1.3	2.2	1.3	2.6
60/40/0	0.7	2.5	1.5	4.1	1.6	4.1	1.3	4.8
60/38/2	0.2	1.5	1.0	2.6	1.3	2.6	1.3	3.3

Liquid Water Tests

The rate and extent of moisture sorption in liquid water is shown in Figure 1. The rate and extent of moisture sorption increases as the amount of fiber increases. All of the

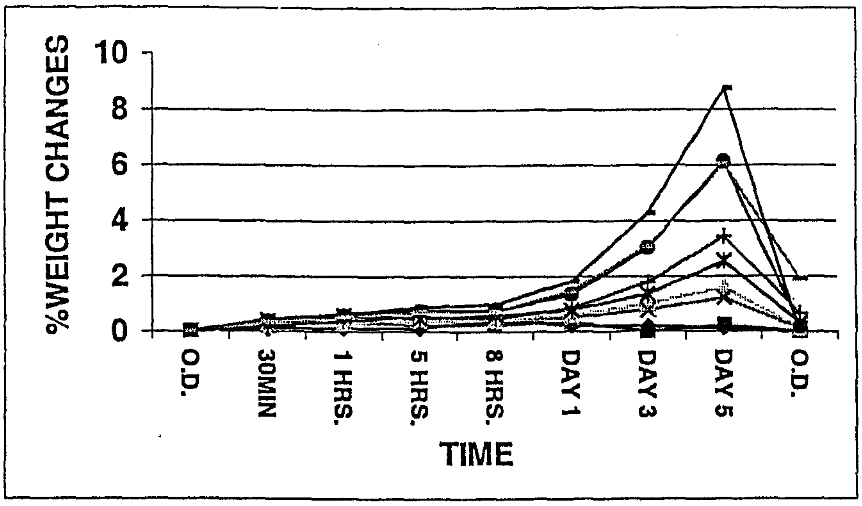

Figure 1 - Rate of moisture sorption of aspen-polypropylene composites in liquid water

data for all composites is shown in Figure 1 and the figure can be read from top to bottom starting with aspen (60%)-polypropylene (40%) then aspen (60%)-polypropylene (38%)-MAPP (2%) then aspen (50%)-polypropylene (50%) then aspen (50%)-polypropylene (48%)-MAPP (2%), etc., down to 100% PP. This explanation of the multi-plot data is also true for Figures 2 and 7. In all cases, the addition of MAPP decreases the moisture sorption of the composite as a given aspen fiber content.

Figure 2 shows the data for continuous soaking of the aspen-polypropylene composites in water for 10 weeks. Again, as the amount if fiber increases in the composites, more moisture is sorbed by the composite and the presence of MAPP

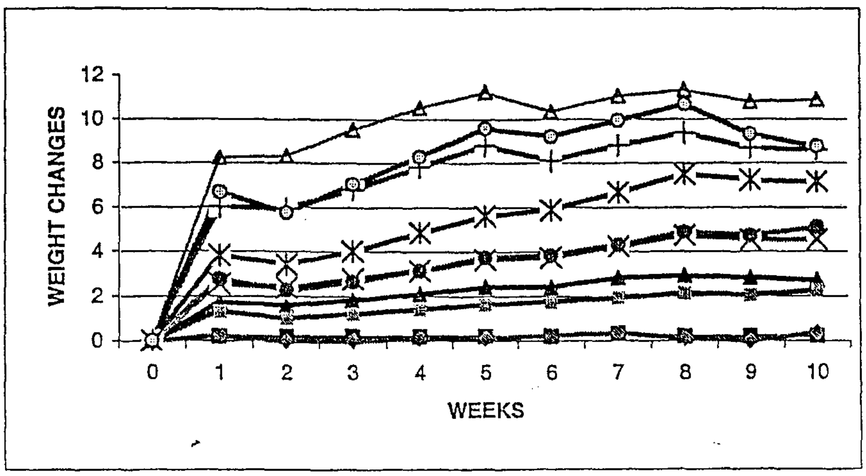

Figure 2 - Extent of moisture sorption of aspen-polypropylene composites in liquid water

decreases the amount of moisture sorbed at a given aspen fiber content.

Figure 3 shows the results of a cyclic test done on aspen (30%)-polypropylene (70%) composites. Figure 4 shows the results of the same test on the same composite except 2% MAPP has been added. It can be seen that the presence of MAPP decreases

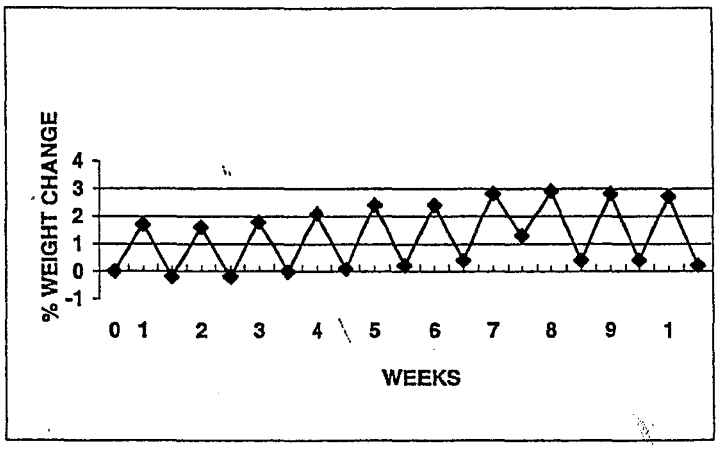

Figure 3 - Cyclic water soaking and oven-drying of aspen (30%)-polypropylene (70%) composites

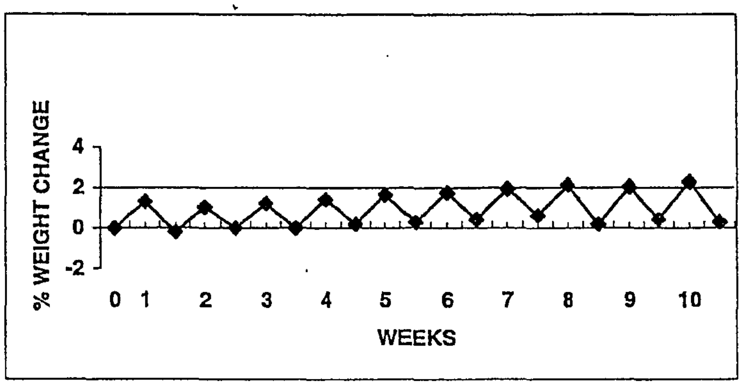

Figure 4 - Cyclic water soaking and oven-drying of aspen (30%)-polypropylene (68%) and WP (2%) composites

the amount of moisture sorbed in each cycle and the swings in moisture content are decreases.

The same trend is shown in Figures 5 and 6 where aspen (60%)-polypropylene (40%) is compared with aspen (60%)-polypropylene (38%)-MAPP (2%). The presence of MAPP reduces the amount of moisture sorbed.

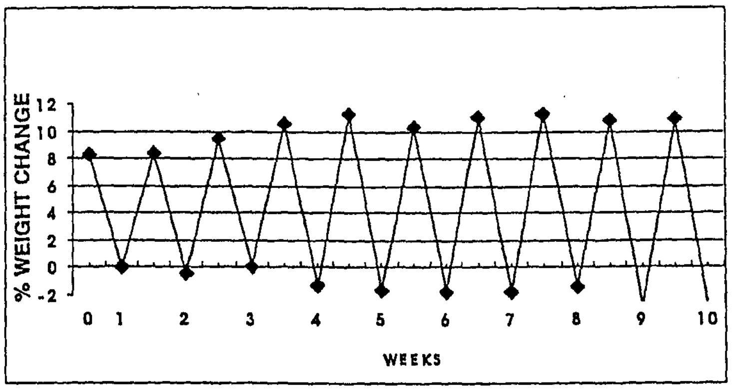

Figure 5 - Cyclic water soaking and oven-drying of aspen (60%)-polypropylene (30%) composites.

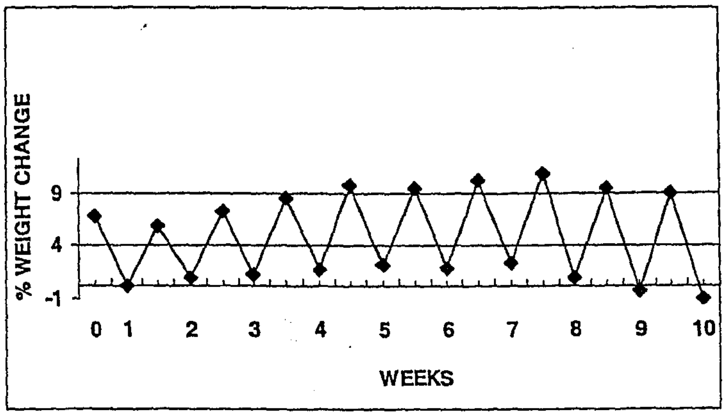

Figure 6 - Cyclic water soaking and oven-drying of aspen (60%)-polypropylene (28%)-MAPP (2%) composites.

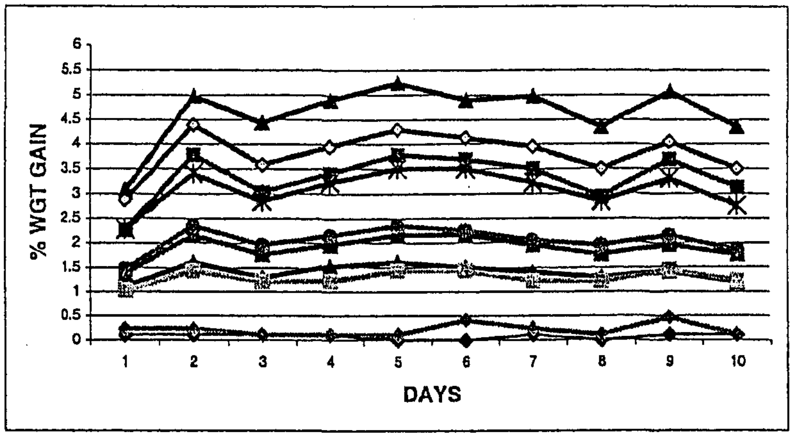

Figure 7 - Moisture sorption of aspen-polypropylene composites after the boiling-oven drying tests.

Figure 7 shows the results of the boiling test. Most of the weight gain that results from boiling takes place in the first boiling cycle and little change occurs in following boiling cycles.

CONCLUSIONS

Adding agro-based fibers to polypropylene composites provides a strategy to produce composites that are lower in cost, less abrasive on processing equipment than mineral fillers, and improves strength properties as compared to composites containing no fiber. The addition of maleic anhydride grafted polypropylene to these composites improves strength properties even more.

Composites exposed to high humidity or submerged in water or boiled for long periods of time resulted in a continual increase in moisture content. Under cyclic humidity and water soaking conditions, the composites showed a small but steady increase in moisture sorption with each humidity/wetting cycle. As the aspen-fiber content increases in these composites, more fiber to fiber wicking is possible so moisture gain continues with time.

The presence of MAPP decreases moisture sorption in both high humidity and liquid water tests as compared to specimens at the same aspen fiber content. This may be due to the increase in compatibilization resulting from more contact between hydrophilic fiber and hydrophobic plastic.

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