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EFFECTS OF MAH-PP TREATMENT AND FIBER FRACTIONS ON PROPERTIES OF WOOD FILLED POLYPROPYLENE COMPOSITE

N. S. Islam[1] and S. Mridha

Department of Manufacturing & Materials Engineering
International Islamic University Malaysia
P.O. Box-10, 50728 Kuala Lumpur, Malaysia
[1]Email: shouvro_12345@yahoo.com

ABSTRACT

An investigation has been carried out on the properties of polypropylene composites reinforced with 100µm or 250µm size wood fibers of different weight fractions. The contributions of MAH-PP (maleic anhydride polypropylene) as a coupling agent and fiber fractions on mechanical properties of the wood plastic composites have been analyzed in terms of tensile and impact strength, Poisson's ratio and hardness. The environmental effect was assessed based on moisture absorption capacity. The strength is found to increase in the samples containing MAH-PP treated fibers compared to the untreated ones. However, the strength decreased in samples containing higher fiber fractions. The water absorption capacity of the samples with MAH-PP treated fibers was found to be less than that of the untreated ones. It is presumed that the coupling agent on the fiber surface restricted water absorption.

Keywords: Wood Plastic Composite (WPC), Coupling Agent, Moisture Absorption Capacity.

1. INTRODUCTION

Natural fibers are promising reinforcements for thermoplastic composite due to their low weight and cost. Moreover the natural fibers are obtained from renewable resources and post industrial sources. For this reason the scopes of fiber reinforced composites with natural fillers are increasing compared to inorganic fiber [1].

Several investigations have been carried out recently on wood fiber filled plastic composite. Bledzki, Sperber and Faruk [2-3] studied the effects of fiber fraction on the properties of wood plastic composites. They observed that MAH-PP treatment reduced hygroscopic nature of wood filled polypropylene composites. Later comparison between different manufacturing processes was drawn by the same research group in terms of mechanical properties in different investigations [4-7]. Their findings suggest that injection molded microcellular wood filled polypropylene composites offer better properties over the composites produced by other processes.

Yuan, Jayaraman and Bhattacharyya [9] found that there is an improved formability around 25wt% of wood fiber filled polypropylene sheets where tensile strength is optimum and after air plasma treatment of the fiber the tensile strength increased by 20%, which is higher than that of the pure polypropylene, whereas without any treatment the average tensile strength of the composite actually decreases.

The effect of MAH-PP coupling agent on hardness and water absorption of natural fiber filled plastic composites has been studied by Chavan, Dusane, Gajre, Mishra and Patil [8]. They observed that MAH-PP treated fiber composite samples swell less water and twice harder than the samples with untreated fibers.

Rowland and Stark [11] found that composite containing 40% wood fiber treated with 3% MAH-PP is stronger than the untreated one. Stark [12] studied the moisture absorption capacity of 20%, and 40% fiber filled samples exposed under 30%, 65%, and 90% relative humidity in 26.7°C (80°F) and found that the 20% wood flour filled composite sample absorbed just over 1.4% moisture, whereas 40% WF samples absorbed approximately 9.0% moisture. In his later works on accelerated weathering of wood plastic composites Stark [13-16] concentrated mainly on UV exposure on wood filled HDPE composites but did not consider the water swelling capacity. He found that the pigment in wood plastic composite provides some protection against UV exposure to change its color but no change in strength.

The major usage of plastic composites in US is in transportation followed by the combined usage in marine and corrosive environment [1]. However, corrosion and marine environment stability of wood plastic composite has not been thoroughly investigated. Manufacturers mostly rely upon some limited laboratory tests whose methodologies are useful for simulations but not for predicting product's service properties. This paper describes the properties of wood plastic composite processed with different fraction of both MAH-PP treated and untreated rubber wood fibers as well as the results of accelerated marine test on these samples.

2. EXPERIMENTAL

2.1 Materials

Rubber wood fiber collected from SAB BAYAN Co. Pvt. Ltd. as sawdust is used as reinforcing materials. Polypropylene co-polymer (AW161BUD410), supplied by Polyolefin Co. Pvt. Ltd. as pellets, is used as matrix. Polypropylene was selected because of its low cost, availability, and low melting temperature (200^{o}C). Low melting temperature is important to prevent degradation of the wood fibers during processing. Commercially available MZ203D maleic anhydride polypropylene (MAPP) copolymer, supplied by SAB BAYAN Co. Pvt. Ltd as granules, is used as coupling agent for treatment of wood fiber. Its melting temperature is 190^{o}C and melting index is 1^{o}C/min at 200^{o}C temperature.

2.2 Fabrication

Wood fibers were dried in an oven at 80^{o}C for 4h and then sieved up to 100µm and 250µm sizes. Composite samples were fabricated with 40, 50, 60 and 70 wt% of wood filler in the matrix. Mixture of wood and polypropylene were blended using a 32-mm Davis Standard co-rotating, intermeshing, twin screw extruder at 185^{o}C and a pelletizer were employed to pelletize the extruded product. To asses the effect of coupling agent some samples were produced with 50 wt% fiber, after blending the fiber with 5 wt% of MAH-PP. Fig1 shows polypropylene pellets and the extruded pellets of fiber and polypropylene mixture. The pellets were then dried at 100^{o}C for 24h and fed into the 33-ton Cincinnati Milacron (Batavia, Ohio) injection molding machine at 200^{o}C to form the final product.

The injection molded sample for impact testing was of 125mm×12.5mm×3mm size while it was dog bone shaped for tensile testing.

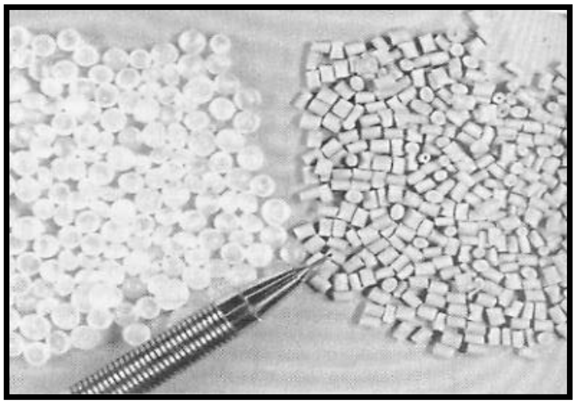

Fig 1: Polypropylene pellets (left) and extruded pellets of pp and fiber mixture (right) prior to injection molding.

2.3 Testing

Universal testing machine was used for tensile test and Poisson's ratio determination (ASTM E 132-97). Pull rate of 10mm/min was maintained due to the viscous elastic nature of plastics at room temperature (23^{o}C). The impact test was conducted using Dynisco Charpy impact tester (Model API230-0) with a pendulum of 40cm (eff. weight 1.82kg) and an impact velocity of 3.6m/s at room temperature. The hardness was measured by Multi-Toyo Micro Vickers harness tester using 50N force.

Accelerated marine test was carried out to assess the water absorption capacity using Ascott (CC1000XP) cyclic corrosion testing machine at 40^{o}C for 48h (Approx. 57.6L of solution flowed by the pump @20ML/min) with water salinity of 3.5 wt% (NaCl) and 100% relative humidity to match the sea surface water salinity. To match the sea water's pH value of 8, (or pOH =14−8 =6); we added 10^{-6}mole 1(N) NaOH into 1L solution; [$\log_{10}$M=−pOH=6 so, M=10^{-6}]. As we know 16drops is equal to 1ML; so 1drop* of 1(N) NaOH was added into the 60L NaCl solution.

* [(60×1,000)ML×10^{-6}mole×16Drops] = 1Drop(nearly).

3. RESULTS AND DISCUSSION

The tensile properties of the composite samples fabricated with different fiber wt% and sizes are shown in Table1. The results show that the tensile strength decreased from 23.7 MPa with 40 wt% fiber sample to 20 MPa with 70 wt% fiber sample. The MAH-PP treated sample with 50 wt% fiber gave slightly better tensile strength compared to the non-treated ones. The coupling agent produced better bonding between the fiber and the matrix which might be responsible for the increased strength with MAH-PP treated sample. Similar result was obtained by Bledzki and Faruk [2] for untreated fiber filled sample. However, in their experiment MAH-PP treated fiber sample exhibited even better tensile strength. Results in Table1 further show that the fiber size does not have much influence on strength. The addition of wood fiber has reduced polypropylene in the processed sample. The density of the composite sample is found to be increased with increasing the fiber content. An increment of about 9% in the density is found with 70 wt% sample compared to the 40 wt% sample. The MAH-PP treatment did not change the density to any considerable level. Reduction of plastic amount decreased the Poisson's ratio from 0.39 for 40 wt% sample to 0.23 for 70 wt% sample containing 250µm size fiber. However, with the addition of MAH-PP the variation in Poisson's ratio is insignificant.

Table 1: Tensile Properties of Rubber Wood Fiber Filled Polypropylene Composites **[**M^{P} denotes MAPP Treated**]**.

Filler wt %	Size, µm	Density, g/cc	Tensile Strength, MPa	Poisson's Ratio
40	250	1.07	23.7	0.38
50		1.12	21.7	0.31
60		1.15	20.2	0.26
70		1.17	20.0	0.23
50M^{P}		1.13	22.0	0.33
40	100	1.02	25.2	0.39
50		1.05	21.2	0.35
60		1.09	20.2	0.27
70		1.12	19.4	0.23
50M^{P}		1.06	22.2	0.35

Table2 shows that for the 250µm size fiber samples the impact strength is higher compared to the 100μm size fiber samples. The impact strength for 40 wt% fiber sample is 12KJ/m^2 with 250μm size fiber and 11KJ/m^2 with 100μm size fiber but for other samples the difference is less than 1KJ/m^2, even with the MAH-PP treated fiber samples.

Table 2: Impact Property of Rubber Wood Fiber Filled Polypropylene Composites [M^P denotes MAPP Treated].

Fiber wt %	Fiber Size,	Absorbed Energy,	Impact Strength,	Angle,
	μm	Milli Joules	KJ/m^2	Deg
40	250	483.7	12	128
50		382.1	9.1	128
60		298.1	7.1	129
70		255.4	6.1	128
50M^P		422.6	9.5	132
40	100	457.1	11	127
50		358.7	8.5	128
60		269.9	6.5	128
70		225.8	5.4	127
50M^P		395.2	9.0	130

Accelerated marine test results in Table3 show the water absorption increased with the increment of wood fiber into the composites. Wood fiber is the main water swelling component in the composite and increased water absorption is considered to be related with the higher fiber content. The water absorption is found to be about 50% higher with 100μm size fiber samples compared to those corresponding samples processed with 250μm size fiber. Bledzki and Faruk [2] found that adding 5 wt% MAH-PP reduces the water absorption capacity by 75%. However, the water absorption result in their experiment was very low compared to the result shown in Table2, which might be caused by different experimental setup. In their experiment wood filled polypropylene samples of 50 × 50 × 4 mm size were put in a water filled container at 23^oC for 48h which is quite different from the cyclic corrosion test at 40^oC.

Table 3: Water Absorption Property of Wood Fiber Filled Polypropylene Composites [M^P denotes MAPP Treated].

Fiber wt %	*Size*	*Wt. Before Test*	*Wt. After Test*	*Wt% of H_2O Absorbed*
	μm	gm	gm	gm
40	250	5.1	5.5	7.8
50		5.25	5.7	8.5
60		5.4	5.9	9.2
70		5.5	6.1	10.9
50M^P		5.3	5.6	5.6
40	100	4.8	5.3	10.4
50		4.95	5.6	13.1
60		5.1	5.8	13.7
70		5.25	6.0	14.3
50M^P		5.0	5.3	6.0

Samples with MAH-PP treated fiber showed significant reduction in water absorption (about 35%). It is presumed that the addition of coupling agent created a protective layer over the fiber surfaces and restricted the fibers from absorption of water.

Table 4: Hardness Variation of WPC samples after the accelerated marine test [M^P denotes MAPP Treated].

Fiber wt %	Size	Hardness Before Test	Hardness After Test
	μm	MVK-H	MVK-H
40	250	6.57	6.49
50		6.51	6.49
60		6.06	6.00
70		6.00	6.00
50M^P		6.67	6.62
40	100	6.66	6.49
50		6.38	6.25
60		6.00	5.90
70		5.83	5.50
50M^P		6.66	6.59

The hardness is found to decrease in samples processed with higher fiber fractions. The hardness of composite samples in Table4 shows a reduced value after cyclic corrosion test. This may be caused by the moisture absorption which might have damaged the bonding between fiber and matrix. MAH-PP treated fiber samples exhibited highest hardness after marine test.

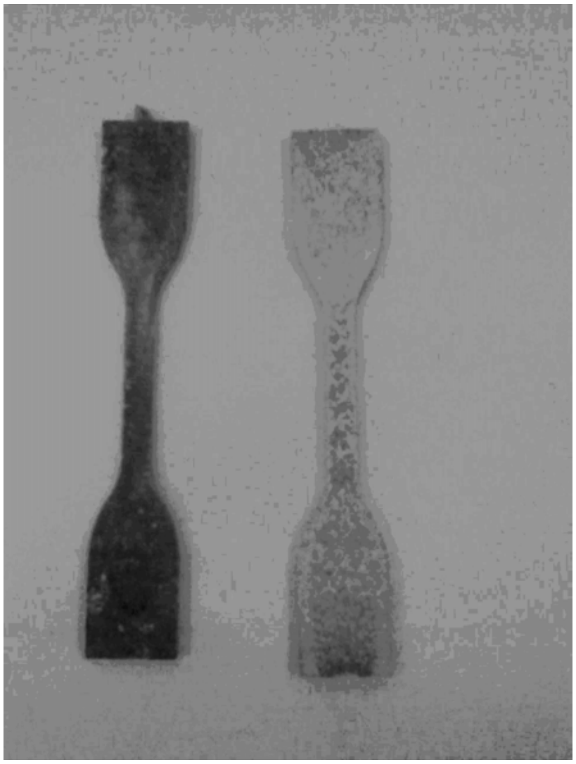

Fig 2: (Left) Tensile test specimen after processing and (Right) after accelerated marine test.

The color of the samples changed after accelerated marine test (Fig2). The optical microscopic views of the sample surface in Fig 3a and 3b suggest that the surface has smoothened by water solution during the test and the fiber particles have been exposed.

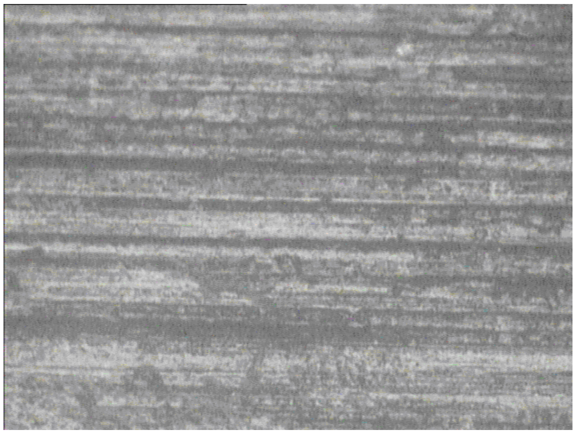

Fig 3a: Optical microscopic view of 50 wt% fiber filled untreated surface before marine test (Magnification 100X)

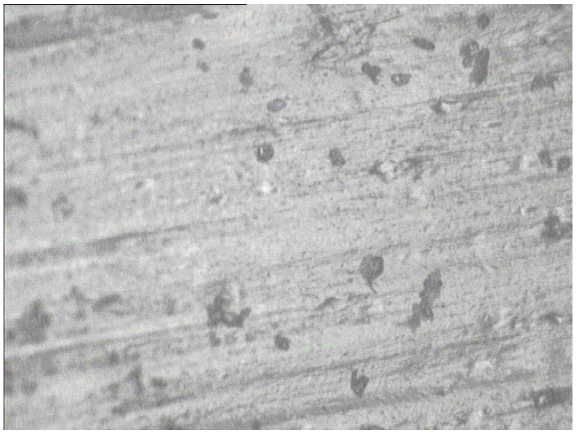

Fig 3b: Optical microscopic view of 50 wt% fiber filled untreated surface after marine test (Magnification 100X).

4. CONCLUSION

- The water absorption is about 50% higher with the 100µm size fiber samples compared to the 250µm size fiber, processed with the same weight fraction
- The addition of 5 wt% of MAH-PP reduced the water absorption by 35% for 250µm fiber sized samples and more than 54% for 100µm fiber sized samples.
- The difference between impact strength of same amount of fiber wt% samples with 250µm and 100µm fiber sizes is near about 0.6KJ/m^2 for almost every wt% sample even with the MAH-PP treatment.
- The hardness reduction is 83% for MAH-PP treated fiber samples compared to the untreated one for 250µm sized fiber; whereas 54% for 100µm sized fiber.

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