SOME SELECTED PROPERTIES OF BAMBOO THERMOPLASTIC COMPOSITE: INFLUENCE OF PARTICLE SIZE, FILLER LOADING AND MALEATED ANHYDRIDE POLYPROPYLENE ADDITION

JAMALUDIN KASIM[1], KHAIRUL ZAMAN DHALAN[2], JALALUDDIN HARUN[3], ZAIDON ASHAARI[3], ABD. LATIF MOHMOD[4] & MOHD NOR MOHD YUSOF[4]

[1]Department of Wood Industries, Faculty of Applied Science, Universiti Teknologi MARA (UiTM), 26400 Jengka Campus, Bandar Jengka, Pahang, Malaysia

[2]Director, Division of Radiation Processing Technology, Malaysian Institute of Nuclear Technology, Bangi, Malaysia

[3]Biocomposite Technology Centre, Institute of Bioscience, University Putra Malaysia, 43400 Serdang, Selangor, Malaysia

[4]Non-Wood Division, Forest Research Institute Malaysia, 52109 Kuala Lumpur, Malaysia

ABSTRACT

Bamboo particles were used as filler in the manufacture of bamboo-polypropylene thermoplastics composite. Bamboo particles of three different particle size (0.12, 0.18 & 0.25 mm), filler loading of 10, 30 and 50% and maleated anhydride polypropylene at 3% was used in the study. An increase in particle size use decreased significantly all the mechanical properties of tensile, flexural and elongation at break, while the water absorption increased. Increasing the filler loading from 10 to 50% decrease the tensile strength (33.8%). Flexural (47.6%) and elongation at break by 70%, while the water absorption increased from 0.19 to 1.65%. The addition of 3% maleated anhydride polypropylene increased the tensile, flexural strength and decreased the water absorption significantly.

Keywords : *Gigantochloa scortechinii*-bamboo-polypropylene composite-age-filler loading-particle size-Maleated anhydride polypropylene effects.

INTRODUCTION

In Malaysia, there are more than 50 bamboo species, some cultivated while others are found growing wild in the forest. These bamboo species are being used to produce sate sticks, blinds, josspaper, and many other products which are mostly exported. Many of these bamboo-based industries produce substantial quantities of wood waste material which have been burned or left to rot in the open. Abd. Latif (1987) reported that about 27 to 48% of the bamboo used in the bamboo industries are discarded as wastes if converted or use as fillers would generate further income to the industries. Kline (1980) reported that wood flours have traditionally comprised only a small percentage of the filler market for plastics products when compared to inorganic fillers. Recent research on the use of annual growth lignocellulosics fibers suggests that these fibers have the potential for use as reinforcing fillers in thermoplastics (Sanadi et al. 1994b). As compared to wood fillers/fibers, they have the advantage of being low cost, low density and the less abrasive nature (allowing high filling levels), thereby resulting in significant material cost saving.

This paper presents the properties of the bamboo thermoplastic composite produced using *Gigantochloa scortechinii* particles. The effects of particle size, filler loading and maleated anhydride polypropylene (MAPP) addition are also discussed

MATERIALS AND METHODS

The polypropylene (PP) used was bought locally from a plastic manufacturer and had a melt index of 8.0 g / 10 minutes and a density of 0.90 g cm^{-3}. The MAPP was an epolene E-43 wax supplied by Eastman Co. (United States of America) the coupling agent for improving the compatibility and adhesion between the particles and plastic matrix. The bamboo particles in the study were taken from the discards of the screening process (retained on the screen size of < 0.5 mm) of particles utilized in the particleboard manufacture. The bamboo particles were first dried in an oven at 60°C for 48 hours and then screened using a laboratory siever into the desired particle sizes.

The study was designed to determine the effects of particle sizes, filler loading and MAPP addtion on the composite properties. Bamboo particles used were sizes 0.25, 0.18 and 0.12 mm, filler loading were at ratios of 10, 30 and 50%, while MAPP addition was at 0 and 3% of the total composite weight. The compounding of the bamboo particles into the PP was accomplished using a Dispersion mixer D1-5 with a capacity of 1 kg. The mixer was first heated to the working temperature of 185°C, the PP was then melted down in about 10 minutes and the MAPP added followed by the bamboo particles. The compounded admixture was then rolled into thin sheets and fed into a crusher to be pelletized. Tensile and water absorption samples were produced using a chrome-plated mould with a dimension of 150 x 150 x 2 mm. About 70 g (giving a density of about 1000 kg m^{-3} of the pelltized admixture) was placed in the mould and hot-pressed at a temperature of 175-185°C for about 10 minutes and then cooled to ambient temperature using a cold press with running water through the platens. Bending samples were produced using a mould with dimensions of 150 x 25 x 6 mm. A total of 4 to 8 boards and 6 to 12 bending strips were produced at each blending condition depending upon the amount of compounded admixture available. All the test specimens were prepared and conditioned in accordance with the British Standard 2872 : Part 0 : 1992 (Anonymous 1992) for tropical countries. The test specimens were tested for their mechanical properties using a Testometric Testing Machine Model Micro-500.

RESULTS AND DISCUSSION

Effect of Particle Size

The particle size (PS) of wood fillers plays a significant role in modifying the mechanical properties of wood-filled thermoplastic composites. For this reason three different sizes of bamboo particles namely 0.25, 0.18 and 0.12 mm PS were evaluated in this work. The most prominent effect of fillers is the stiffening or modulus increase in composites (Ferrigno 1978). The effect of PS on the thermoplastic board properties are shown Figure 1. An increase in PS significantly decreased the TEN, Elong, MOR, FMOE and the WA properties while TMOE was unaffected. The correlation analysis (Table 1) further revealed that the decrease in TEN (r = -0.18) and MOE (r = -0.37) are negatively correlated while the decrease in Elong (r = -0.09), MOR (r = -0.02) and WA (r = -0.05) with an increase in PS being insignificant. However, the increase in TMOE (r = 0.04) with an increase in PS was observed to be insignificant. The above findings exhibits similar trends as those reported by Maldas et al. (1988), Woodhams et al. (1984) and Kokta et al. (1983).

The better properties shown by smaller particles are due to their compatiblity with polypropylene i.e smaller particles share a greater interaction with the polymer

matrix. This could be explained by the fact that small particles offer a larger specific surface area in composites than the same weight of larger particles. Moreover, the distribution of small particles are more homogenous compared to larger particles. Nielsen (1974) stated that the amount of stress created by larger particles is another probable cause in reducing the strength of composites.

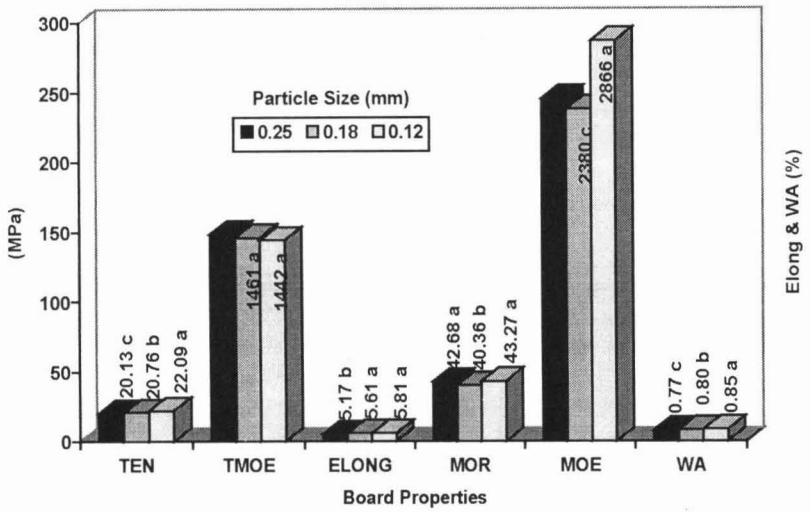

Figure 1. Effect of Particle Size on the Properties of Thermoplastic Board

Table 1: Summaries of the Correlation Coefficients of Particle Size, Filler Loading and MAPP Addition with the Board Properties

Property	TEN	TMOE	ELONG	MOR	MOE	WA
Particle size	-0.18**	0.04ns	-0.09ns	-0.02ns	-0.37**	-0.05ns
Filler loading	-0.79**	0.74**	-0.89**	-0.94**	0.49**	0.82**
MAPP	0.37**	0.38**	-0.16**	0.11ns	-0.22**	-0.29**

Note: ns - not significant at $p < 0.05$, ** - highly significant at $p < 0.01$

Effect of Filler Loading

Fillers are normally used to modify various properties of polymers, and it is essential to know the dependence of such properties on the composition / filler content / filler loading in order to achieve the optimum desired properties. Zaini et al. (1996) stated that incorporation of filler to a polymer may increase or decrease the tensile and bending strength of the resulting composite. Fiber type fillers normally improve tensile strength while for irregularly shaped fillers the strength of composites decreases due to the inability of the filler to support stresses tranfsered from the

polymer matrix. Bamboo particles are classify as irregularly shaped particles, therefore the strength of the resultant composites should decrease with higher filler loading.

The effects of filler loading on the thermoplastic board properties are shown in Figures 2 to 4. Increasing the filler loading from 10% to 50%, resulted in a significant decrease in TEN (33.8%) and MOR (47.6%)(Figure 2). Incorporation of bamboo filler to 50% into polypropylene decreased the elongation (Elong) at break of the composite by about 69.6%. Zaini et al. (1996) stated the decreases in TEN, MOR and Elong are common observations in all filled polymer systems and are probably due to the decreased deformablity of a rigid interphase between the filler and the matrix material. The correlation analysis showed that TEN (r= -0.79), Elong (r = -0.89) and MOR (r = -0.94) are correlated negatively with filler loading.

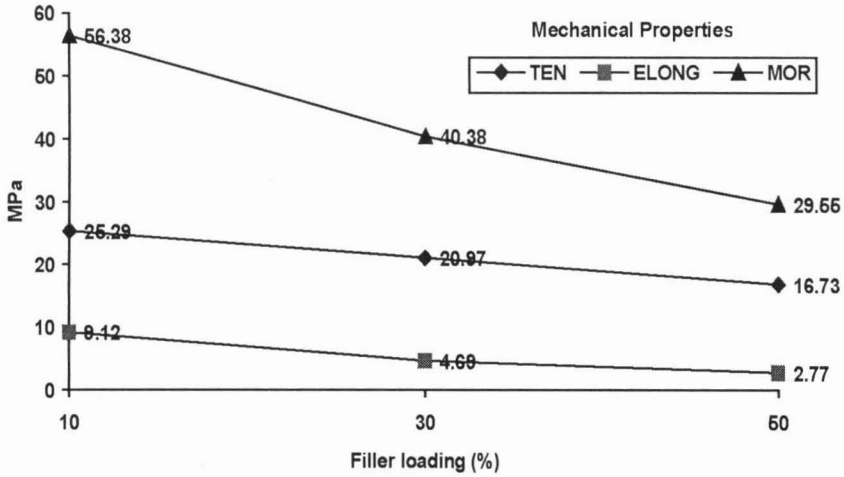

Figure 2. Effects of Filler Loading on the TEN, Elong and MOR

Modulus of elasticity (stiffness) is one of the basic properties of composites where the primary intention of filler incorporation is to increase the stiffness of the resultant composite. The effects of filler loading on the TMOE and FMOE were shown to be significant (Figure 3). Increasing the filler loading from 10% to 50%, TMOE and FMOE were observed to increased by about 95.6% and 22.9%, respectively. It was further revealed from the correlation analysis that the properties of TMOE (r = 0.38) and FMOE (r = 0.49) showed a positive correlation with filler loading. loading According to Fuad et al. (1995) and Bigg (1987) the increase in modulus with an increase in filler is a common phenomenon.

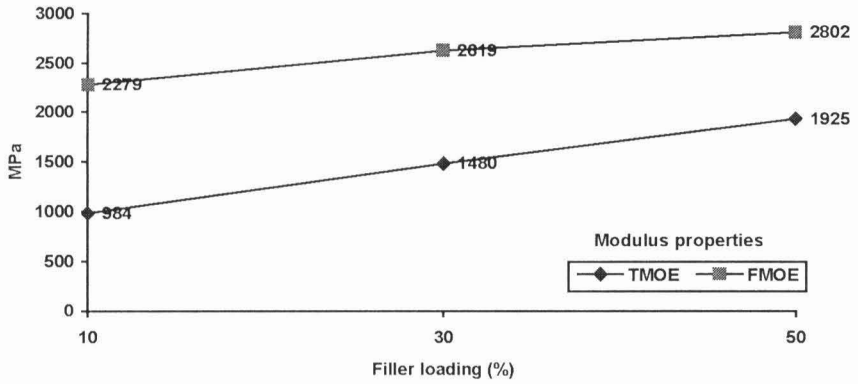

Figure 3. Effect of Filler Loading on the Tensile and Flexural Modulus

The WA properties influences composite product usage and could pose a big problem in composites with high filler content. Filler loading was shown to significantly affects the WA properties (Figure 4) where an increase in the WA (750 %) was observed when the filler loading was increased from 10% to 50 %. This tremendous increase in WA would have a dramatic effect on the final product. The correlation analysis further showed that WA (r = 0.82) was positively correlated with filler loading. The increase in WA could be explained by the increase in surface area of the fillers which are hygroscopic in nature.

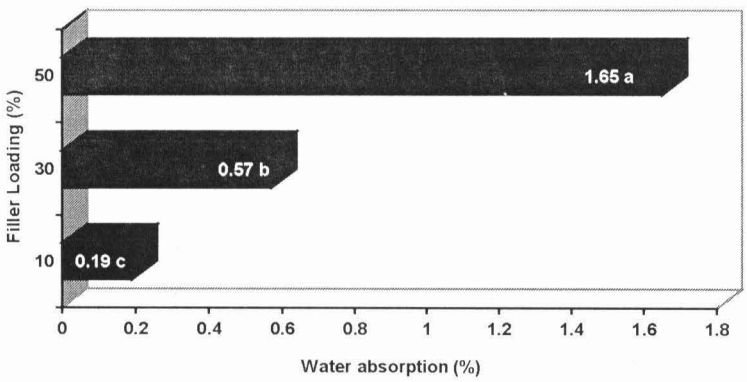

Figure 4. Effects of Filler Loading on the Water Absorption Property

Effect of MAPP

The dispersion and adhesion between nonpolar polypropylene matrix dan the polar lignocellulosic materials are critical factors in determing the properties of the composite. Composites without coupling agent results in poor adhesion of particles to the plastic polymer and weak interfacial regions imply that the transfer of stress from the polymer matrix to the filler would be innefficient. According to Hancock et al. (1980); Chacko et al. (1983) and Davies et al. (1985) a drop in strength properties is

expected and is a common phenomenon with thermoplastic composites filled with particulate fillers.

MAPP has been reported to function efficiently as compatibilizer in lignocellulosic - PP systems (Sanadi et al,.1993; Felix et al., 1993). Oksman (1996) stated that the compatibilizer reduced the interfacial energy between the wood particles and the plastic matrix, therefore improving the dispersion of the filler thus improving the strength properties. The effects of MAPP on the thermoplastic properties are shown in Figure 5. Addition of 3% MAPP during composite manufacture significantly improved the TEN by about 17%, TMOE (31%) and MOR (6%) compared to those without MAPP. Similar observations of the effects of MAPP on the mechanical properties have been reported by other researchers (Dalvag et al. 1985, Maldas and Kokta 1991, Krzysik and Youngquist 1991, Gatenholm et al. 1992, Meyers et al.1993 and Sanadi et al. 1995). The correlation coefficients in Table 3 further showed that MAPP addition caused the properties of TEN ($r = 0.37$) and TMOE ($r = 0.38$) to increase significantly while Elong ($r = - 0.16$) and MOE ($r = - 0.22$) decrease insignificantly. However, MOR ($r = 0.11$) tended to increase with MAPP addition.

The increase in TEN, TMOE and MOR values are probably due to the better adhesion occurring between the components. Gatenholm et al. (1992) stated that the anhydride groups present in MAPP could covalently bond to the hydroxyl groups on the bamboo filler surface. The improved interaction and adhesion between the bamboo fillers and matrix could be either through covalent bonding or acid-base interaction (H-bonding), or combination of both, leading to better matrix to fiber stress transfer. Figure 5 further shows that MAPP decreases the Elong and MOE significantly. The reduction in Elong and MOE values are due to the matrix being severely restricted by interfacial bonding which in fact increase the tensile (Ferrigno 1978).

Depending upon the end use of the product, the dimensional stability in water, especially the water absorption, could be a major problem in composites with high percentages of wood fillers. The WA showed a significant decrease of about 42% with 3% MAPP addition (Figure 5), while the correlation analysis (Table 1) showed that WA ($r = - 0.29$) decreased significantly with MAPP addition. The better resistance to water penetration could be due to the existence of better bonding between the fillers and the matrix. Krzysik and Youngquist (1991) also reported similar trends in the WA property with MAPP addition.

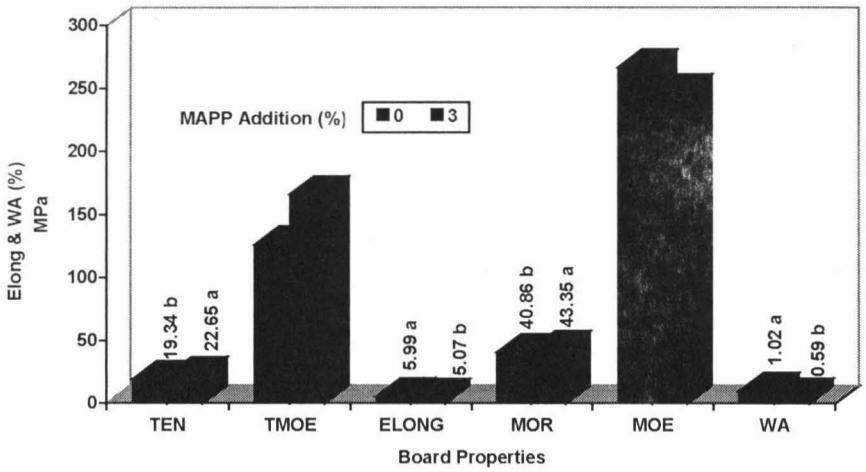

Figure 5: Effects of MAPP Addition on the Board Properties

CONCLUSION

The mechanical and water absorption properties of bamboo plastic composite were shown to be significantly affected by particle size, filler loading and MAPP addition. With higher filler addition the water absorption and mechanical properties decrease except for tensile and flexural modulus. An increase in particle size decreases the mechanical properties and the resistance to peneration of water. Addition of MAPP was found to reduce the interfacial energy and improved the filler dispersion leading to better mechanical and water absorption properties.

REFERENCES

Anonymous, 1992. BS 2782:Part 0: Methods of Testing plastics. British Standards Instituition. Pp. 5.

Abd. Latif, M. 1987. Guidelines on blinds and satay stick production. *FRIM Technical Information* 2. FRIM, Kepong 8 pp.

Bigg,D.M. 1987. Mechanical properties of particulate filled polymers. *Polymer Composites* 8: 115-122.

Chacko,V.P., Farris,R.J. and Karasz, F.E. 1983. Tensile properties of calciyum carbonate-filled polyethylenes. *Journal Applied Polymer Science* 28: 2701-2713.

Dalvag, H., Klason, C and Stromvall, H.E. 1985. The efficiency of cellulosic fillers in common thermoplastics Part II: Filling with processing aids and coupling agents. *International Journal Polymeric Materials* 11: 9-38.

Davies,L.C.B., Hodd,K.A. and Sothern, G.R. 1985. Pulverised fuel ash, its use as filler for polyolefin Part 2: Coupling agents and a comparison with Ballotini. *Plastic Rubber Processing Applications* 5(1): 9-14.

Felix, J. M., Gatenholm, P. and Schreiber, H.P. 1993. Controlled interactions in cellulose-polymer composites I: Effect on mechanical properties. *Polymer Composites* 14: 449.

Ferrigno, T.H. 1978. Principles of filler selection and use. In Katz, H and Milewski, J.V. eds. Handbook of fillers and reinforcements. Van Nostrand Reinhold Company, New York. PP. 11-66

Fuad, A.M.Y., Ismail,Z., Ishak, Z.A.M. and Omar, A.K.M. 1995. Application of rice husk ash as fillers in polypropylene: Effect of titanate, zirconate and silane coupling agents. *European Polymer Journal* 31(9):885-893.

Gatenholm, P., Felix,J., Klason, C. and Kubat, J. 1992. Cellulose-polymer composites with improved properties. In Salamone, J.C. and Riffle, J. eds., Contemporary Topics in Polymer Science, Vol 7. Plenum, New York. Pp. 75-82

Hancock ,M., Tremayne,P and Rosevar, J.1980. Filler in polypropylene. *Journal of Applied Polymer Science* 18:3211-3217.

Kline, C. H. 1980. Reinforcements and Fillers for 1980. Pp. 1166 in Woodhams, R. T., Thomas, G and Rodgers, D. K. Wood Fillers as reinforcing fillers for polyolefins. *Polymer Engineering and Science*, Vol. 24: 15.

Kokta, B.V., Chen, R., Daneault, C. and Valade, J. L. 1983. Improvement of the mechanical properties of composites from polystyrenes. *Polymer Composites* 4(4): 229.

Kokta, B.V., Maldas, D., Daneault,C. and Beland, P. 1990. Composites of Poly(vinyl chloride) and wood fibres Part II: Effect of chemical treatment. *Polymer Composites* 11(2): 84-89.

Krzysik, A.M. and Youngquist, J.A. 1991. Bonding of air-formed wood fibre/polypropylene fibre composites. *International Journal of Adhesion and Adhesives* 11(4): 235-240.

Maldas, D., Kokta,B. V., Raj, R.G. and Daneault, C. 1988. Improvement of the mechanical properties of sawdust wood fiber-polystyrene composites by chemical treatment. *Polymer* 29(7): 1255-1265.

Maldas, D. and Kokta, B.V. 1991. Influence of maleic anhydride as a coupling agent on the performance of wood fibre-polystyrene composites. *Polymer Engineering and Science* 31:1351-1357.

Myers, G.E., Chahyadi, I.S., Gonzalez, C. and Coberly, C.A. 1993. Wood flour and polypropylene or high density polyethylene composites: Influence of maleated polypropylene contration and extrusion temperature on properties. Pp. 49-56 in *Proceedings of 1st Wood-Fiber Composite Conference : Wood-Fiber/Polymer Composites : Fundamental Concepts, Processess and Materials Options.* Madison, WI: Forest Products Society.

Nielsen, L.E. 1974. Mechanical properties of polymer and composites Vol. 2. Marcel Dekker, New York. 431 pp.

Oksman, K. 1996. Improved interaction between wood and synthetic polymers in wood/polymer composites. *Wood Science and Technology* 30: 197-205.

Sanadi A.R., Young, R.A., Clemons, C. and Rowell, R.M. 1994a. Recycled newspaper fibers as reinforcing fillers in thermoplastics: Analysis of tensile and impact properties in polypropylene. *Journal Reinforced Plastics Composites* 13: 54.

Sanadi, A. R., Caulfield, D.F., and Rowell, R. M. 1994b. Reinforcing Polypropylene with Natural Fibers. *Plastic Engineering,* April, 27.

Sanadi, A.R., Caulfield, D.F., Jacobson, R.E. and Rowell,R.M. 1995. Renewable agricultural fibers as reinforcing fillers in plastics: Mechanical properties of kenaf fiber-polypropylene composites. *Industrial Engineering Chemical Research* 34(5): 1889-1896.

Woodhams, R.T., Thomas, G. and Rodgers, D.K. 1984. Wood fibers as reinforcing fillers for polyolefins. *Polymer Engineering Science* 24(15): 1166-1171.

Zaini, M. J., Fuad, M.Y. A., Ismail, Z., Mansor, M. S. and Mustafah, J. 1996. The effect of filler content and size on the mechanical properties of polypropylene/oil palm wood flour composites. *Polymer International* 40: 51-55.