Mechanical and Physical Properties of *Araucaria* Fibre-Polypropylene Composite

Jamaludin Kasim
Wan Nazri Wan Abd Rahman
Suriana Husin

ABSTRACT

Araucaria hunsteneii fibres were used as fillers in the manufacturing of wood fibre-polypropylene composite. Fibre content of 5, 10, 15 and 20% and a MAPP addition of 3% were used in the study. The results indicate that fibre content significantly affected the mechanical and water absorption properties while with MAPP addition no significant improvement was observed. Araucaria hunsteneii fibres could be used as fillers in the manufacturing of thermoplastic composite.

Keywords: *Araucaria hunsteneii, fibres-polypropylene composite, fibre content, MAPP*

Introduction

Work on lignocellulosics fibres/fillers for plastic composites have concentrated on wood-based flour and have been reported by many researchers (Woodhams et al., 1984; Myers et al., 1993; Sanadi et al., 1994a). The use of annual growth lignocellulosics fibres suggests that these fibres have the potential for use as reinforcing fillers in thermoplastics (Sanadi et al., 1994b). As compared to wood fillers/fibres, they have the advantage of being low cost, low density and the less abrasive nature (allowing high filling levels), thereby, resulting in significant cost-saving material.

This paper discusses the suitability of *araucaria* fibres as reinforcing fillers in polypropylene composite. The effects of fibre content and maleated polypropylene (MAPP) addition on the properties are also discussed.

Materials and Methods

The used polypropylene (PP) 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, the coupling agent for improving the compatibility and adhesion between the particles and plastic matrix. The *araucaria* fibres in the study were first produced in a pressurised refiner. The *araucaria* fibres were first dried in an oven at 60°C for 48 hours. The study was designed to determine the effects of fibre to plastic ratio and MAPP addition on the composite properties. *Araucaria* fibres used at 5, 10, 15 and 20%, while MAPP addition was at 0 and 3% of the total composite weight. The compounding of the fibres into the PP was accomplished using a Dispersion mixer D1-5 with a capacity of 1 kg of each batch. The mixer was first heated to the working temperature of 185°C, the PP was melted down in about 10 minutes and the MAPP added followed by the fibres. The compounded admixture was, then, rolled into thin sheets and fed into a crusher to be pelletised. Tensile and water absorption samples were produced using a chrome-plated mould with a dimension of 150 × 150 × 2 mm. About 70 g (giving a density of about 1000 kg m^{-3} of the pelltised 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 × 25 × 6 mm. A total of 4 to 8 boards and 6 to 12 bending samples were produced at each blending condition depending upon the amount of compounded admixture available. All the test specimens were prepared and conditioned in accordance to the British Standard 2872: Part 0: 1992 (BSI, 1992) for tropical countries. The test specimens were tested for their mechanical properties using a Testometric Testing Machine Model Micro-500.

Results and Discussions

Mechanical and Physical Properties

The physical and mechanical properties of *araucaria*-polypropylene composite according to fibre content and MAPP addition are shown in Table 1. The analysis of variance and Duncan Multiple Range T-tests are given in Tables 2 and 3, respectively.

Table 1: Properties of *Araucaria* Fibres-polypropylene Composite

Fiber content (%)	MAPP (%)	Density (kg/m^3)	FMOR (N/mm^2)	FMOE (N/mm^2)	TMOR (N/mm^2)	TMOE (N/mm^2)	Elong (%)	WA (%)
5		895	47.46	1498	32.28	2331	12.68	1.29
10		919	45.52	1474	30.89	2586	10.01	1.50
15	3	921	38.34	1721	28.23	2717	8.94	1.90
20		922	41.47	1860	26.97	2782	7.32	2.06
5		878	44.37	1348	36.99	2795	13.85	1.41
10		876	42.99	1465	30.27	2511	11.32	1.73
15	0	908	45.10	1762	27.55	2741	9.59	1.76
20		925	41.40	1801	25.48	2852	6.60	2.12

Note; FMOR - Flexural modulus of rupture, FMOE - flexural modulus of elasticity, TMOR - tensile modulus of rupture, TMOE - tensile modulus of elasticity, Elong - elongation at break and WA - water absorption

Table 1 shows that, composite manufacture with 5% fibre content and 3% MAPP has the highest value for FMOR (47.46 N/mm^2) and lowest WA of 1.29%. For TMOR and Elong, composite made with 5% fibre content and without any MAPP shows the highest value of 1860 N/mm^2 and 13.85%, respectively. Composite with 20% fibres and 3% MAPP shows the highest FMOE (1860 N/mm^2) while composite made at 20% fibre without MAPP has the highest TMOE value of 2852 N/mm^2.

Table 2 shows the analysis of variance on the composite properties. Fibre content has significant effects on all the composite properties while MAPP has no effects at all. However, their interaction shows significant effects on FMOR, TMOR, TMOE and WA.

Table 2: Summary of the Analysis of Variance on the Composite Properties

SOV	DF	FMOR	FMOE	TMOR	TMOE	Elong	WA
Fiber ratio (FC)	3	6.41*	15.93*	93.48*	5.08*	22.56*	5.38*
MAPP(M)	1	0.02 ns	1.09ns	1.47ns	4.46ns	0.95ns	0.24ns
FC X M	3	7.05*	0.85ns	13.30*	4.12*	0.64ns	0.37*

* - F values are significant at $P < 0.05$ probability level, ns – not significant

Effects of Fibre Content

Fillers are added to modify various properties of the polymers and according to Zaini et al. (1996), the incorporation of fillers may increase or decrease the tensile and bending strength of the resulting composite. Fibre type fillers normally improve the tensile strength, while irregularly shaped fillers decrease the tensile due to its inability to support stresses transferred from the polymer matrix.

Figure 1 shows the effects of fibre content on the FMOR and TMOR. Composite with 5% fibres shows better strength for both FMOR and TMOR compared with other fibre content. However, from the figure, both FMOR and TMOR were observed to decline with increase in fibre content. The correlation analysis further reveals that both TMOR (r = -0.87) and FMOR (r = -0.46) decreases with higher fibre content. This decrease is probably due to the decreased deformability of a rigid interphase between the fibre and matrix material (Zaini et al., 1996).

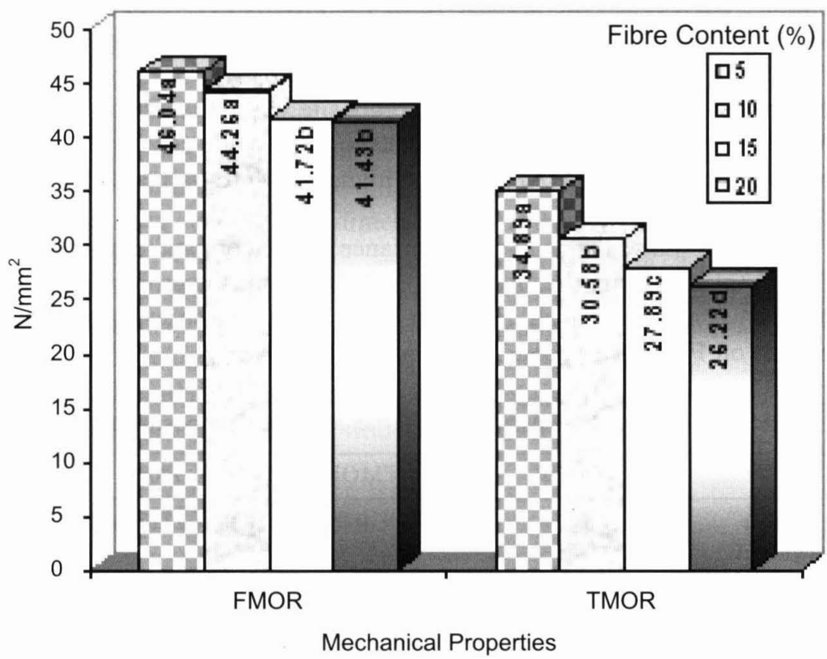

Figure 1: Effects of Fibre Content on the Flexural Strength and Tensile Strength

The primary intention of fibre incorporation is to increase the stiffness of the composite. Figure 2 shows that by increasing the fibre content from 5% to 20% resulted in a significant increase in FMOE (28.0%) and TMOE (9.4%). It is further revealed in Table 3 that the FMOE (r = 0.70) and TMOE (r = 0.40) show positive correlation with fibre content. The increase in modulus with an increase in fibre content according to Fuad et al. (1995) is a common phenomenon.

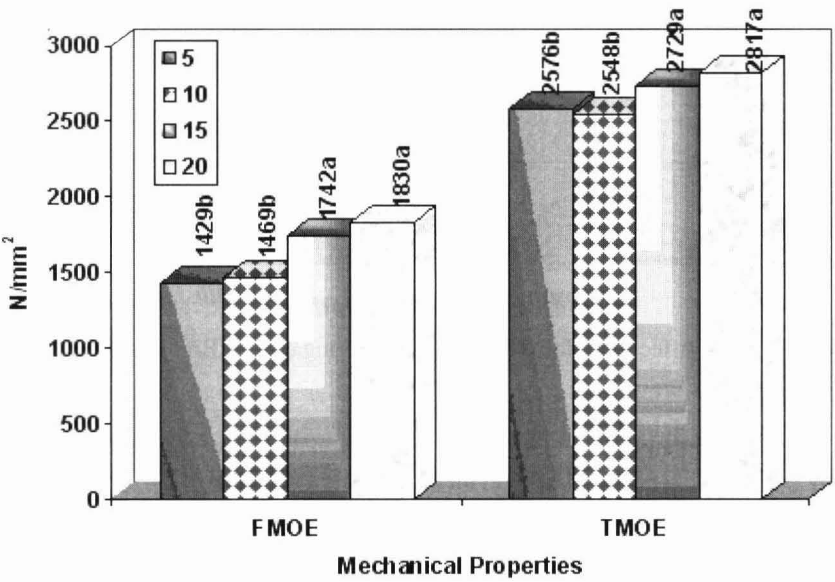

Figure 2: Effects of Fibre Content on the Flexural and Tensile Modulus of Elasticity

The WA influences composite product usage and poses a big problem in composites with high fibre content. Fibre content is shown to significantly affect WA (Figure 3). WA increased by 54.8% when the fibre content increased from 5% to 20%. The correlation analysis (Table 3) reveals that WA (r = 0.54) was positively correlated with fibre content. Elong decreases by 92.9% when the fibre content increases from 5% to 20%. The decrease in Elong is similar to the trends exhibited by TMOR and FMOR.

An addition of 3% MAPP increases all the mechanical properties (Figure 4). The correlation analysis, however, reveals that addition of MAPP causes FMOR (r = 0.04), TMOR (r = 0.08), FMOE (r = 0.12) and TMOE (r = 0.23) to increase insignificantly. The improvement in the

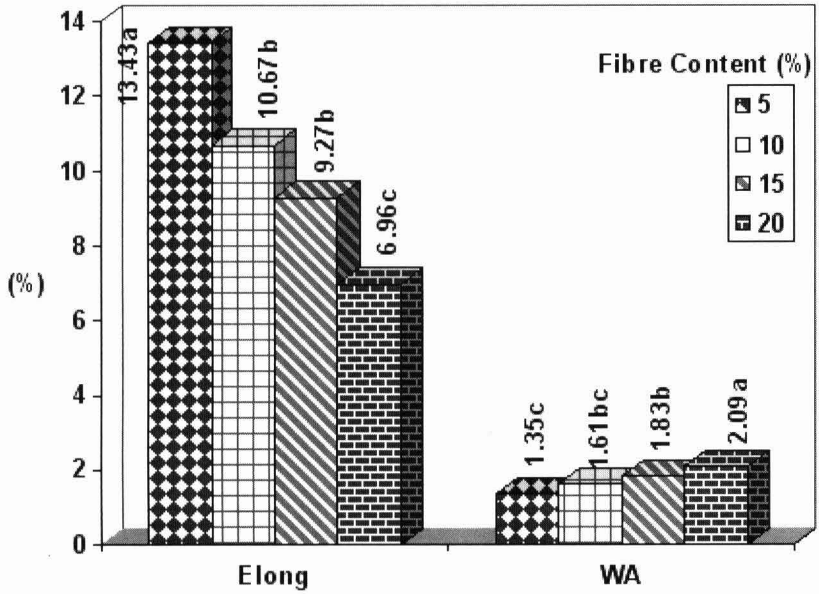

Figure 3: Effects of Fibre Content on the Elongation at Break and Water Absorption

Table 3: Summary of the Correlation Analysis on the Effects of Fibre Content and MAPP on the Composite Properties

SOV	FMOR	TMOR	FMOE	TMOE	Elong	WA
Fiber Content	-0.464*	-0.87*	0.70*	0.41*	-0.78*	0.54*
MAPP	0.04ns	0.08ns	0.12ns	0.23ns	-0.12ns	-0.08ns

*- significant at $p < 0.05$, ns - not significant

mechanical properties is probably due to the better adhesion occurring between the components. Gatenholm et al. (1992) stated that the presence of anhydride groups in MAPP could covalently bond to the hydroxyl groups on the fibre surface leading to better matrix to fibre stress transfer.

Figure 5 shows the effects of MAPP on the Elong and WA. An addition of 3% MAPP decreases the Elong by 6.6% while WA decreases by 4.6%. Correlation analysis further reveals that the Elong (r = -0.12) and WA (r = -0.08) decreases insignificantly. The reduction in Elong is due to the matrix being restricted by interfacial bonding. The better resistance to water penetration could be due to the existence of better bonding between the fibres and the matrix.

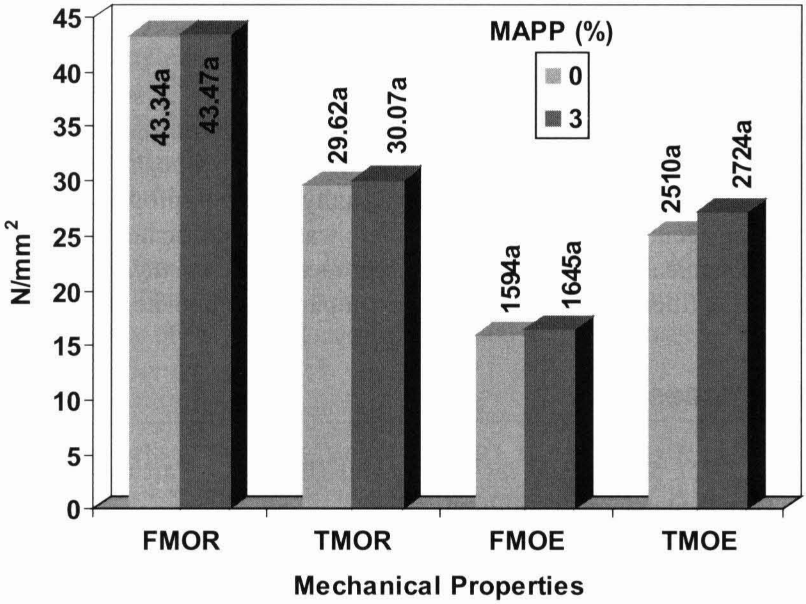

Figure 4: Effects of MAPP on Mechanical Properties

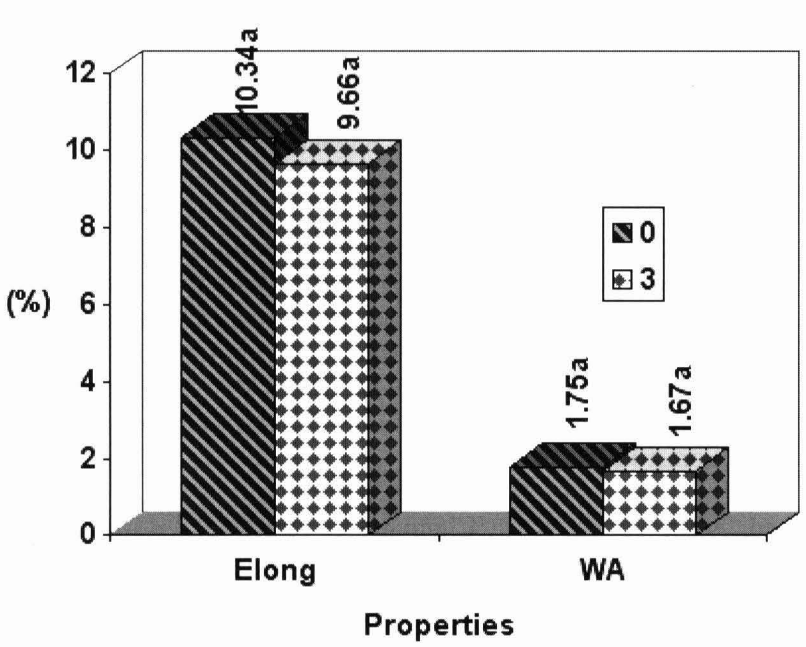

Figure 5: Effects of MAPP on Elong and WA

Conclusion

Polypropylene composite with *araucaria* fibres was successfully manufactured. Fibre content was shown to significantly affect all the mechanical and water absorption properties of the composite produced. However, with the addition of maleated anhydride polypropylene as the coupling agent to improve bonding there was no significant increase in the mechanical and water absorption properties. *Araucaria* fibres can be used as fillers in polypropylene thermoplastic composite.

References

BSI. (1992). *Methods of testing plastics* (BS 2782: Part 0). London: British Standards Instituition.

Fuad, A.M.Y., Ismail, Z., Ishak, Z.A.M. & 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. & Kubat, J. (1992). Cellulose-polymer composites with improved properties. In J.C. Salamone & J. Riffle (Eds.), *Contemporary topics in polymer science*, *7* (pp. 75-82). New York: Plenum.

Myers, G.E., Chahyadi, I.S., Gonzalez, C. & Coberly, C.A. (1993). *Wood flour and polypropylene or high density polyethylene composites: Influence of maleated polypropylene contration and extrusion temperature on properties.* Paper presented at 1st Wood-Fiber Composite Conference: Wood-Fiber/Polymer Composites: Fundamental Concepts, Processes and Materials Options, Madison, WI. Forest Products Society.

Sanadi A.R., Young, R.A., Clemons, C. & 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. & Rowell, R.M. (1994b). Reinforcing polypropylene with natural fibers. *Plastic Engineering, 27*, 27-28.

Woodhams, R.T., Thomas, G. & 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. & 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.

JAMALUDIN KASIM & WAN NAZRI WAN ABD RAHMAN, Department of Wood Industries, UiTM, Pahang, 26400 Jengka, Pahang Darul Makmur. djamal@pahang.uitm.edu.my

SURIANA HUSIN, Department of Applied Chemistry, Faculty of Applied Sciences, UiTM, 40450 Shah Alam, Selangor Darul Ehsan.