Optimization of mixing conditions for wood plastic composites fabrication process

M.N.A. Nordin[1,2 *], B.R. Mizah[1,2], A.A. Kamarolzaman[1,2] and R. Nadlene[1,2]

[1)] Fakulti Kejuruteraan Mekanikal, Universiti Teknikal Malaysia Melaka,
Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[2)] Centre for Advanced Research on Energy, Universiti Teknikal Malaysia Melaka,
Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

[*]Corresponding e-mail: mnazmi@utem.edu.my

Keywords: wood plastic composites; tensile properties; mixing conditions

ABSTRACT – This paper presents the optimization conditions of mixing process for wood plastic composites (WPC). The WPC specimens with 30 wt.% of wood fiber weight fraction were fabricated through an extrusion and injection molding processes under different mixing temperatures; 180 °C and 190 °C, and screw's speed of 5 rpm, 10 rpm, 20 rpm and 30 rpm, respectively. The extrusion process was done at single extrusion process before molded into a dumbbell shape via an injection molding machine at 200 °C. Tensile test was carried out for each type of WPC specimen. The tensile test results indicate the optimum tensile strength property obtained from the specimen at mixing temperature of 190°C and screw's speed of 20 rpm. Morphological study at the arbitrary cross-section of the WPC specimen was further studied and discussed.

1. INTRODUCTION

Appropriate amount of fillers and the compatibility of natural based reinforcement with the hydrophobic polymer matrix are among the issues that have been studied in order to improve the properties of natural fiber based composites. Other factors that may be related to the improvement of the properties of this materials includes the distribution, size and shape of the fillers.

Wood fiber has been used in many of commercialized composite materials, known as wood plastic composites (WPC). Although there are many natural based resources available, wood fiber is compatible as a filler for composite materials because of its ease of availability and low production cost. The combination of wood fiber with polymeric matrices brings a new sight in wood-based application, i.e. high durability and excellent mechanical properties such as high tensile strength and stiffness [1-3] and low density. A study by Leu et. al [4] offers an idea of optimization of wood fiber and other material composition in WPC that helps to achieve ideal properties of the material. It is stated that compounding up to 50 wt.% of wood fiber with the maximum value of coupling agent, maleic anhydride polypropylene (MAPP) at 3wt.% able to improve the mechanical properties of WPC.

In this study, WPC specimens at different mixing conditions; temperature and screw speed, were fabricated in order to investigate the effect of mixing condition on tensile properties of WPC. The cross-sectional area and the fracture surface were characterized by scanning electron microscope (SEM) and 3D laser microscope, respectively.

2. RESEARCH METHODOLOGY

2.1 Materials

In this study, WPC specimens with different weight fraction of wood flour were prepared by using *master-batch* pellets (CELBRID N, wood fiber length 150 µm; TOCLAS Corporation). The pellets were mixed with J107G type polypropylene (Homopolymer, MI=30; Prime Polymer Co.) by using a single screw extruder machine in order to gain desired weight fractions of wood flour.

2.2 Specimen fabrication

WPC specimens were fabricated through an extrusion and injection molding processes. The PP and *master-batch* pellets were first dried in a convection oven (MOV-112F; Sanyo Co.) at 120 °C for 5 h to reduce the moisture contents. Then, a desired amount of dried PP was added and mixed together with the dried *master-batch* pellets that caused a reduction of wood fiber weight fraction to a desired amount as mentioned above. The mixing process was done using a single screw extruder machine (Musashino Kikai Co. Ltd.). Here, the mixing conditions need to be set first in order to obtain material properties that produce maximum performance. For this purpose, first, the WPC specimens with 30 wt.% of wood fiber weight fraction were fabricated under different mixing temperatures; 180 °C and 190 °C, and screw's speed of 5 rpm, 10 rpm, 20 rpm and 30 rpm, respectively.

The extrusion process was done at single extrusion process before the extruded mixture was chopped into 5 mm length pellet, and molded into a dumbbell shape via an injection molding machine at 200 °C. The specimens were stored for at least 24 h before the static tensile test was carried out and the optimum mixing conditions were selected from the test results. As for the neat PP specimen, the dried PP pellets were directly added into the injection molding machine and molded under the same condition with WPCs specimens. The mixing conditions are summarized in Table 2.1.

2.3 Tensile test

A small-type tabletop testing machine (LSC-1/300; JT Tohsi INC.) was used to determine the tensile properties of each type of specimen. A strain amplifier (DPM-700B; Kyowa Electronic Instruments Co. Ltd.) and a strain gauge (KFG-2N-120-C1-11; Kyowa Electronic Instrument Co. Ltd.) were used for strain measurements during the tensile test. Tensile test was conducted at a crosshead speed of 10 mm/min up to

fracture at room temperature.

Table 2.1 Different mixing conditions of WPC specimens.

Temperature [°C]	Screw speed [rpm]	Number of specimens
180	5	5
	10	7
	15	9
	20	9
190	5	7
	10	9
	15	9
	20	5

2.4 Fracture surface observation

In order to understand the morphological structure of the wood filled polypropylene composite specimens at fracture area, the fracture surface of composite specimens from fatigue test was observed using the scanning electron microscope (SEM). The fracture surface sample was prepared by cutting the fractured specimens into 5 mm in length and the golden vapor deposition was conducted at appropriate thickness for each sample using micro-ion weld slag equipment. On the other hand, the wood flour distribution was observed from the arbitrary cross-sectional area of the specimen. The cross-sectional sample was prepared by embedded the specimen, that has been cut and polished at any cross-section area, into an epoxy-hardener solution in a silicon-case and hardened for 24 h at room temperature. Then, the observation surface was ground by using a grinding machine before it was polished. Finally, before the SEM observation, the golden vapor deposition was applied at the observation surface of the sample stage.

3. RESULTS AND DISCUSSION

3.1 Tensile properties

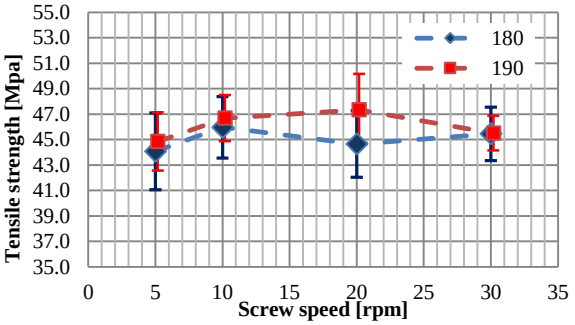

Figure 3.1 Average tensile strength of each specimen.

Figure 3.1 illustrated the average tensile strength of each specimen according to the predefined mixing conditions. Here, it is understanding that the tensile strength was slightly increased for specimens that were fabricated at 190 °C compared to that of with 180 °C as the mixing temperature. For specimens with mixing temperature of 190 °C, the tensile strength was slightly improved for specimens with screw's speed of 10 to 20 rpm, however, to some extent decreased at 5 rpm and 30 rpm. At higher screw's speed, the mixing time become shorter where sufficient kneading cannot be obtained, meanwhile the mixing time become longer at low screw's speed; result in thermal degradation of WPC material. In another words, it is considered that the improper kneading that leads to the poor distribution of wood fiber and thermal degradation of the material contribute to the declination of the tensile strength. Thus, in this study, the optimal mixing condition was at 190 °C and screw's speed of 20 rpm, and this condition is applicable for the fabrication process of WPC specimen.

3.3 Morphological analysis

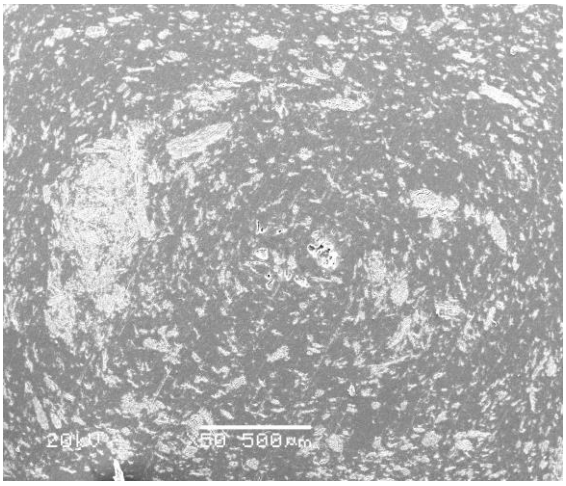

Figure 3.2 Observation of cross-section of WPC specimen.

Figure 3.2 shows an arbitrary cross-sectional area of WPC specimens at single extrusion process. The clustered wood fiber are clearly seen, of which the largest cluster size is approximately 600µm in length. When high amount of PP was added to the highly dense wood-PP pellets (CELBRID N; *master-batch* pellet contains approximately 70 wt.% of wood fiber), it is hard for the pellets to disband and scatter uniformly through the PP matrix in a short time. That is to say, the duration of single extrusion to mix the materials is considerably short, resulting in the formation of clustered wood fiber as mentioned in section 4.3.1.

4. SUMMARY

This study was examined the effect of temperature and screw speed on mixing process of wood fiber with PP in order to fabricate WPC specimens. As the result, the optimal mixing condition regarding to tensile test result was at 20 rpm of screw speed at 190 °C.

REFERENCES

[1] L. Danyadi, T. Janecska, Z. Szabo, G. Nagy, J. Moczo, B. Pukanszky (2007). Wood Flour Filled Composites: Compatibilization and Adhesion, *J Comp Sci Tech*, 67, 2838-2846.

[2] V.N. Hristov, M.Krumova, St. Vasileva, G. H. Michler (2004). Modified Polypropylene Wood Composites. II. Fracture, Deformation, and Mechanical Properties, *J Apply Polym Sci,* 92, 1286-1292.

[3] E. Perez, L. Fama, S.G. Pardo, M.J. Abad, C. Bernal (2012). Tensile and Fracture Behavior of

PP/Wood Flour Composites, *J Composites B,* 43, 2795-2800.

[4] S.Y Leu, T.H Yang, S.F Lo, T.H Yang (2012). Optimized material composition to improve the physical and mechanical properties of extruded wood-plastic composites (WPCs), *J cons build mat*, 29, 120-127.