Effect of Blending Process Condition on Morphology and Properties of Oil Palm Trunk based Wood Plastic Composite

Bahruddin[1],, R. Efrizal[1], Zulfansyah[1], S. P. Utami[1]*

[1]Chemical Engineering Department, Engineering Faculty, Riau University, Riau, Indonesia; bahruddin@unri.ac.id

Abstract. Blending process conditions in making polymer composite influence the quality of the composite. This study aimed to evaluate the effect of blending process condition on morphology and properties of oil palm trunk based wood plastic composite (WPC). The blending condition evaluated in this study were blending temperature (170°C, 175°C and 180°C) and blending time (10 and 15 minutes). The making of WPC samples were conducted by using an internal mixer, labo plastomill type, with rotor speed 80 rpm and mass ratio of oil palm trunk powder (OPTP) and polypropylene (PP) 50/50 (w/w). Paraffin 2% and maleic anhydride polypropylene 5% were used as plasticizer and compatibilizer, respectively. The samples were prepared using hot press for measurement of tensile strength according to ASTM D638 standard, morphology and physical properties. The results showed that the temperature and blending time influence morphology and properties of WPC significantly. The best properties of WPC was obtained at temperature 170°C and blending time 15 minutes, which reached tensile strength 24.8 MPa, density 0.99 g/cm^3 and water absorption 1.1%.

Keyword: Blending time; blending temperature; morphology; oil palm trunk; tensile strength; wood plastic composite

Introduction

Indonesia is the world largest palm oil plantations country, which is about 13.5 million hectares. Palm trunks are usually productive in the range 25-30 years and produce a lot of waste when replanting. Today's technology has not covered the utilization of the waste and usually left to rot in plantations . This is because the palm oil trunk is considered only as a low quality wood and possesses a fragile and susceptible to fungal attack. Therefore, we need a technology to make it becomes applicable as construction materials or furniture. One of the potential technology was the utilization of the waste (trunk) as reinforcement material in Wood Plastic Composite.

Wood plastic composite (WPC) is a polymeric composite that is made from a mixture of thermoplastic and wood dust [1]. In the mixture, polypropylene serves as a thermoplastic

© 2015 Published by IPST2013

matrix, whereas sawdust serves as a filler. The use of WPC as a substitute for natural wood is growing rapidly, especially in countries of Europe, America and Japan. Compared to conventional wood, WPC material is durable, high dimensional stability, and resist to weather, termite and fungus, and also low maintenance costs [2].

WPC quality is determined by several factors, including the condition of the mixing process of thermoplastic and wood (such as temperature, shear stress and mixing time) [3,4], type of thermoplastic (virgin and recycled) [5], and the type of filler and compatibilizer [4,6]. Although the type of filler used can be derived from synthetic fiber, natural fiber use will be more popular in the future because it is more environmentally friendly. In this study, the authors studied the effect of the mixing process conditions (temperature, rotor speed and time) on the properties and morphology of WPC products based on palm oil trunks, as one of the natural filler.

Experimental

Raw Material

Palm oil trunk as raw material was obtained from local palm oil plantation in Riau, Indonesia. Polypropylene (PP), PF1000 was produced from PT. Pertamina Plaju, Indonesia. MAPP as compatibilizer, Epolene G-3003 and paraffin plastisizer were obtained from local distribution.

Preparation of Palm Oil Trunk

Palm oil trunk that entered replanting phase (aged around 30 years) was shaved until become a fiber. The fiber was then immersed in the water at room temperature for 3 days with replacing water every 24 hours. The treated fiber was then dried until reach 5-10% water content and then sieved to 100 meshes.

Preparation of WPC Compounds

The POTP-PP with 50/50 of mass ratio, paraffin with amount of 2% w/w and MAPP with amount of 5% w/w were blended using internal mixer (Toyo-Seiki Labo-Plastomill LPM 18-125 type). The blending temperature and time were varied at 170°C, 175°C, and 180°C and 10 minutes and 15 minutes, respectively. Rotor speed was settled for 80 rpm.

Samples Testing

The testing included tensile properties test by using Universal Testing Machine (UTM) according to ASTM D-678 standard, physical properties and morphology by using Scanning Electron Microscope (SEM).

© 2015 Published by IPST2013

Result and Discussion

Tensile Strength

Effect of temperature on the tensile strength on mixing time variation as 10 minutes and 15 minutes is shown in Fig. 1.

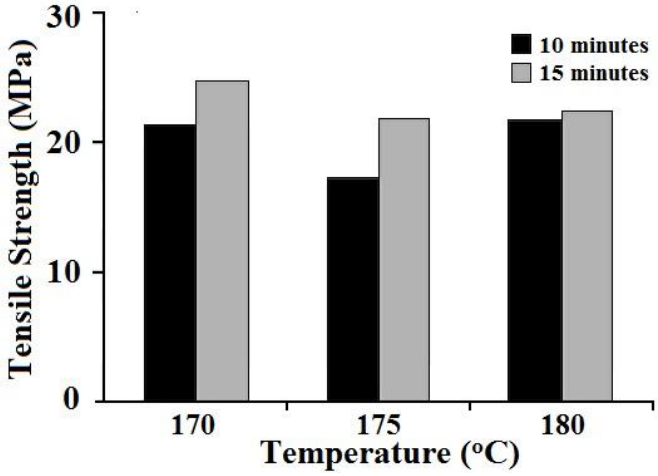

Figure 1. Effect of temperature and mixing time on the tensile strength.

The tendency of the effect of mixing temperature (above the melting temperature of the PP phase) was similar for tensile strength properties at a longer mixing time (15 min) and shorter time (10 min). However, a longer mixing time resulted in higher tensile strength, rotor speed (80 rpm) resulted in a greater tensile strength. At 60 rpm rotor speed, the highest tensile strength of 21.1 MPa was obtained at temperature of 175°C and lowest of 15.8 MPa at a temperature of 170°C. At a speed of 80 rpm resulted in the highest tensile strength of 21.8 MPa at 180°C and lowest of 17.4 MPa at a temperature of 175°C. Even at temperature of 170ºC, tensile strength ~~can~~ could reach 24.8 MPa for 80 rpm rotor speed.

Longer mixing time caused a decrease in the filler structure. Contacting filler with a screw stirrer caused the decrease in fiber length but diameters did not change so that the filler becomes shorter. In addition, the mixing time facilitating the distribution and dissemination of the filler into the matrix [7] . Good spreading of filler producesd solid WPC structure resulting in higher tensile strength. Shorter mixing time requiresd high temperatures and vice versa. Higher temperature cause~~s~~d the low viscosity of the PP matrix causes the process of mixing and distribution POTP become more uniform and produce~~s~~d good tensile strength.

Tensile strength of composite is affected by the spreading of the particles in the matrix [8]. A good spreading can be obtained with the right rotor [9-11]. Higher rotor speed and

© 2015 Published by IPST2013

mixing temperatures produced good tensile strength and vice versa. At higher rotor speed, the length of the filler will be reduced, making it easier in distribution of the PP matrix and increases the tensile strength [7]. But the mixing process at a relatively high temperature for a long time can cause degradation in the composite polymer components, thereby decreasing the mechanical properties of the composites.

Density

Effect of temperature and mixing time on the density of the WPC are shown in Table 1.

Table 1. Effect of temperature and mixing time on the density of the WPC.

Sample number	Mixing temperature (°C)	Mixing time (min)	Density (gr/cm^3)
1	170	10	0,970
2	170	15	0,989
3	175	10	0,989
4	175	15	0,980
5	180	10	0,976
6	180	15	1,000

Process conditions (temperature, rotor speed and mixing time) did not give the significant effect on density WPC. However, there ~~is~~was a slight tendency that the greater density of WPC resulted in higher tensile strength. Greater density caused the distribution of the filler in the matrix PP POTP more uniform. Longer mixing time (15 min) gave the longer duration of the filler POTP to contact with the PP that can be distributed more, resulting in a better density. Low density indicated that the pores in PP matrix were unfilled by filler POTP. The pores will be a source of the WPC oxidation [2]. The lower the density of WPC, the easier composite to oxidize and damage.

Water Absorption

Effect of temperature and mixing time on the water absorption of WPC products are shown in Table 2.

© 2015 Published by IPST2013

Table 2. Effect of temperature and mixing time on the water absorption.

Sample number	Mixing temperature (°C)	Mixing time (minute)	Density (gr/cm^3)
3	170	10	2,788
4	170	15	1,091
7	175	10	1,449
8	175	15	1,308
11	180	10	2,305
12	180	15	0,877

Process conditions (temperature, rotor speed and mixing time) relatively influenced the water absorption of WPC. Shorter mixing time (10 min) produced greater water absorption on WPC. This was due to the greater porosity of the WPC, so the water ~~is~~ was easy to entered the WPC and tied to POPT phase. The use of MAPP as compatibilizer improved interaction POTP-PP in WPC products. In addition, the higher rotor speed (80 rpm) also result~~s~~ed in a better spread of POPT so most of POTP entered the pores of PP and disguised by the PP. Such a mechanism would minimize voids in the structure of WPC and will increase the density of WPC, so that the water absorption is lower [2].

Morphology

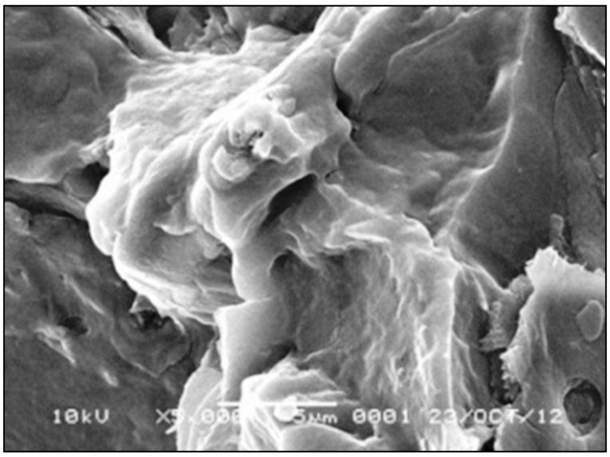

Figure 2. Micrograph SEM wood plastic composite.

Fig. 2 showed the function of MAPP in improving the bond between the filler and matrix PP POTP. The interaction between the filler and matrix PP POTP was compact but there was still a section that has not been filled by POTP filler. Empty pore due to the hydrogen bonds formed section and POTP surface polarity difference between POTP/PP led to

© 2015 Published by IPST2013

POTP tend to clot. This suggests that the strength of WPC could be enhanced if the cavity in the structure of WPC was minimal.

Conclusion

The use of palm oil trunk particles (POPT) as a filler producesd tensile and physical properties of the WPC (POTP/PP 50/50) were quite good and a relatively homogeneous morphology. The mixing process condition (temperature, rotor speed and blending time) influencesd morphology and properties of the composite. The best properties of the WPC were obtained at 170ºC, 80 rpm of rotor speed and 15 min of blending time, which reached tensile strength of 24.8 MPa, density of 0.99 gr/cm3 and water absorption of 1.1%. These results indicated that POTP had a potential for being used in the wood plastic composite.

Acknowledgments

Authors thank to DP2M-DIKTI that has funded this research. The authors are also grateful to Nyoman Kurniawan, Lili Saktiani, Reni Oktaviani and Rikawati, bachelor students of Chemical Engineering Department-Riau University, who have supported the experiment for the research.

[1] C. M. Clemons, *Forest Products Journal*. **2002**, 6(52), 10.
[2] A. Klyosove, “*Wood Plastic Composite*“, John Wiley & Sons, Inc, New Jersey 2007, p.5.
[3] C. M. Clemons, R. E. Ibach, *Forest Products Journal*, **2004**, 54(4), 50.
[4] P. Wang, J. Liu, W. Yu, C. Zou, *Polym. Bull*., **2011**, 66, 683.
[5] S. K. Najafi, M. Tajvidi, E. Hamidina, *Holz. Roh. Werkst*, **2007**, 65, 377.
[6] J. Girones, G. Pardini, F. Vilaseca, M. A. Pelach, P. Mutje, *J. Polym Environ*, **2010**, 18, 407.
[7] N. C. Das, *Carbon*, **2002**, 40, 807.
[8] B. K. Deka, T.K. Maji, *Polym. Bull*., **2012**, 87, 54.
[9] G. Jiang, H. Huang, *J. Matter Sci*, **2008**, 43, 5305.
[10] S. C. Zunjarrao, *J. Matter Sci*, **2006**, 41, 2219.
[11] K. T. S. Kong, *Polym. Bull*., **2012**, 69, 937.

© 2015 Published by IPST2013