Effects of Screened Particle Sizes and Wood:Polypropylene Mixing Ratio on the Physical and Mechanical Properties of Rubberwood Plastic Composites

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ABSTRACT

Rubberwood sawdust is the main waste from furniture industries that has potential to be used as wood plastic composites (WPCs). Production of wood plastic composites might be the solution to decrease the wastes from furniture industries. The objectives of this research are to determine the physical and mechanical properties of wood plastic composite using polypropylene as matrix. The ratio of wood particles used in the study were 10%, 20% and 30%, while size of wood particle varied at 150μm, 180μm and 250μm. The strength properties were tested for bending and tensile test and the physical properties of water absorption rates and thickness swelling were based on ASTM standards. Smaller particles and 10% of wood ratio showed better physical and mechanical properties of wood plastic composite.

Keywords: *rubberwood sawdust, wood plastic composites (WPCs), polypropylene*

Introduction

Wood-plastic composite (WPC) is a composite material made by combining two or more materials to give a unique combination of properties. It is made of recycled plastic and wood wastes (Kim & Pal, 2010). WPC can also be referred to as natural fiber plastic composites or natural fiber reinforced plastics. Manufacturers claimed that wood-plastic composite is more environmentally friendly and requires less maintenance than the alternatives of solid wood treated with preservatives or solid wood of rot-resistant species (Anatole, 2007).

The present situation where the shortage of wood has become a problem in the furniture manufactured in Malaysia. To overcome this problem, the researchers need to find other sources to replace the solid wood which means that best practice is to develop wood plastic composite industry. Sawdust is composed of fine from wood particles. It is cutting lumber product with wood machine or saw, hence its name. It can present a hazard in manufacturing industries, especially in terms of its flammability and also waste. From wood waste, people can produce the wood-base products (wood plastic composite) which the properties of products are almost the same with the solid wood. The wood wastes from rubberwood, have potential to produce the wood-based products. Objectives of the study are to determine the physical and mechanical properties of the WPC produced from rubberwood sawdust in mixture with polypropylene as matrix. The effects of the screened particle sizes and mixing ratio were also studied.

Material and Methods

Field procedure and material preparation

The material used in this project is the sawdust of rubberwood from furniture industry at Kuantan. The rubberwood sawdust was used as a material for making wood plastic composite. The sawdust was dried using an oven to make sure the moisture content (MC) of sawdust is below 5%. The average moisture content of wood plastic composites used for the preparation of test specimens was determined as 5%. A temperature commonly used in the process of drying is 70-90°C and it takes about 1-2 days to dry completely. After all sawdust was dried, the sawdust was carried out to the grinder machine to produce the small dust. After grinding, the vibrator screener machine was used to separate the mesh according the required size 150μm, 180μm, and 250μm.

Manufacturing of Wood Plastic Composites

The screened particle sizes (150μm, 180μm, and 250μm) were mixed with polypropylene in a dispersion mixer at a mixing ratio of 10, 20 and 30% by weight of particles. After both plastic and sawdust are mixed together, the temperature was decreased until 150°C. Then, the mixture was pelletised with cooling temperature in the mixer. The granules were then put into mould for bending and tensile. Then the mould was placed into the hot press. The temperature that is needed in hot press making WPC is about 180°C. During hot press the pressure is 1000 kpa for 360 second for bending and 240 seconds for tensile. After hot press, the mould is sent to the cold press for five to six minutes. Then the board was cut according to the measurement provided for the testing process for bending test, tensile test, thickness swelling and water absorption test. Dimensions will be measured using a dial gauge and vernier calipers. The tensile testing was carried out by using ASTM Standards (D638) and for bending; testing was carried out by using ASTM Standard (D6272).

Results and Discussion

Physical Properties

Figure 1 showed the effect of particle size (PS) for thickness swelling (TS) and water absorption (WA). TS and WA were shown to be significantly affected by varying particle sizes used. Lower TS was at 150μm of PS and the highest TS are with PS of 250μm. The percentage increase in TS was about 46% while for WA it is about 305% when the PS changes from 150um to 250μm. Bigger particle size had more voids among the particles increasing the amount of water intake.

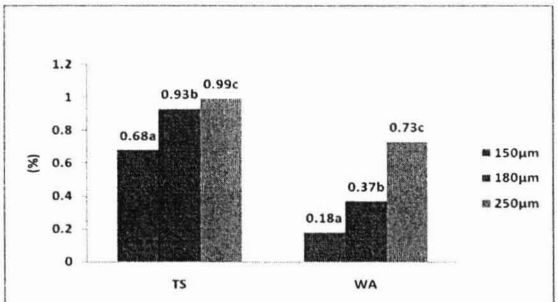

Figure 1: Effect of Particle Size for Thickness Swelling and Water Absorption

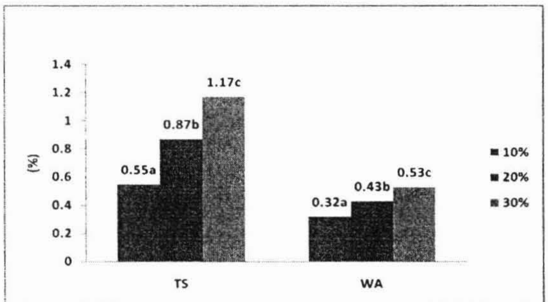

Figure 2: Effect of Filler Ratio for Thickness Swelling and Water Absorption

Figure 2 shows the effect of filler ratio on the thickness swelling and water absorption. Lower filler loading showed significantly better TS and WA properties. When the amount of filler was increase from 10% to 30% it was shown that TS value increased by about 113% while WA increased by about 66%. Higher TS and WA at higher filler loading were due to more wood available which is hygroscopic in nature.

Mechanical properties

The effect of particle size on bending strength (BMOR), bending modulus (BMOE), tensile strength (TMOR) and tensile modulus (TMOE) is shown in Figure 3. The properties for BMOR and TMOR were significantly affected by the particle size. BMOR decrease by about 27% when PS of 150μm was replaced by PS of 250μm. The higher TMOR of 25.86 MPa is with PS of 150μm and it decreases by about 12% when the PS of 250μm was used. TMOE also showed a similar trend. However for BMOE the opposite trend was exhibited. Biggest 250μm particles showed a significantly higher value when compared to other particles.

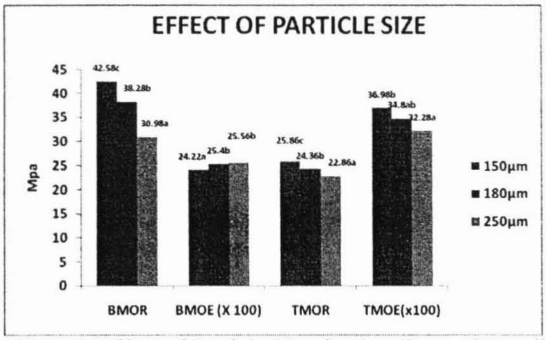

Figure 3: Effect of Particle Size for Bending and Tensil

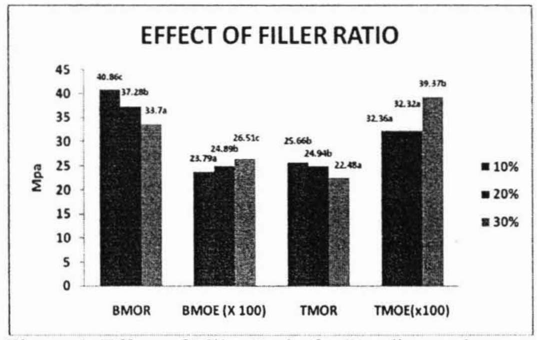

Figure 4: Effect of Filler Ratio for Bending and Tensil

Figure 4 shows the effect of filler ratio on the bending and tensile properties of WPC. Bending and tensile strength properties were all significantly affected by varying the fillaer loading. BMOR and TMOR their value decreases with higher filler loading while foe BMOE and TMOE their values increased. This phenomenon may be due to the presence of wood fillers that are too high in the composite causing disruption to the crystalline structure of PP matrix. This situation was lead to the increase in the amorphous polymer composites which was result in weak, brittle and easily broken (Myers *et al*, 1991). By increasing the filler ratio from 10 % to 30 %, BMOR decrease by about 7.16 %, TMOR by 3.18 % and BMOE increase by 2.72%, TMOE by 7.01%.

Statistical significance

Table1 shows the summaries of the analysis of Variance of the effects of particle size and filler loading on the properties of WPC from rubberwood. Particle size and filler loading shows the significant effects on all the physical and mechanical properties. Their interaction showed insignificant effects on only MOR, MOE and TMOR.

Table 1: Analysis of Variance on the Particle Size and Filler Loading

SOV	df	MOR	MOE	TMOR	TMOE	WA	TS
FILLER LOADING	2	33.08^{xx}	21.28^{xx}	25.18^{xx}	14.19^{xx}	170.33^{xx}	522.47^{xx}
PARTICLE SIZE	2	88.69^{xx}	6.08^{xx}	20.4^{xx}	4.77^{x}	1192.11^{xx}	153.53^{xx}
FILLER * PARTICLE	4	3.15^{x}	0.79^{ns}	1.7^{ns}	2.89^{x}	20.3^{xx}	19.45^{xx}

Note: ^{ns} for not significant, $p > 0.05$, ^{x} for significant, $p < 0.05$;
^{xx} highly significant, $p < 0.01$

Conclusions

The mechanical and physical properties of the composites were investigated and compared with different wood ratio and different sizes of particles. From this study, the conclusion that can be summarized is that composites with smaller particle size as 150µm displayed higher in bending strength, tensile strength, and tensile modulus compared to the larger ones as 180µm and 250µm. But for the bending modulus, the larger of particle size as 250µm has better strength than the smaller particle such as 180µm and 150µm. It is believed that better filler dispersion is the main factor responsible for the observed trends. Increased of wood ratio, from 10% to 30%, displayed decreased flexural strength, but increased flexural modulus. The higher wood ratio can increase the rate of water absorption and thickness swelling. The larger size particle also increases the rate of water absorption and thickness swelling.

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