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rHDPE/Wood Fiber Composites: Effect of Maleic Anhydride on Tensile Properties and Morphology Analysis

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Abstract – *The effect of maleic anhydride as a coupling agent on the tensile properties and morphology of recycled high density polyethylene/wood fiber (rHDPE/WF) composites was studied. rHDPE/WF composites with different wood fiber loading and the addition of maleic anhydride were prepared with Brabender Plasticorder at the temperature of 160°C and rotor speed of 50 rpm. The result indicated that rHDPE/WFM composites with maleic anhydride exhibited higher tensile strength and modulus of elasticity compared to rHDPE/WF composites. rHDPE/WFM with maleic anhydride composites gave a better interfacial adhesion between the matrix and the fiber than rHDPE/WF composites as evidenced using Scanning Electron Microscopy (SEM).*

Keywords: Recycled high density polyethylene, Wood fiber, Maleic anhydride

1.0 INTRODUCTION

Renewable natural organic fibers act as reinforcing materials that are biodegradable and eco-friendly for the use of glass or carbon fiber and inorganic fillers. These fibers have several advantages, which are high specific strength modulus, low cost, low density, renewable organic, nonhazardous, malleable, wide availability, and relatively no abrasiveness [1]. Yazid et al. [2] showed that the modulus of elasticity of rHDPE/NR/CFF composites increased with increasing fiber loading in the blends, but decreased the tensile strength and elongation at break. Through numerous studies and research, thermoplastic or natural fiber composites such as wood plastic composites (WPC) are proven to have high qualities in technical application fields, for example in load-bearing applications. Polyethylene, which is a type of polymer, has wide applications in our modern world. These polymers are frequently used in thermoplastics for the production of natural fiber to prepare composites compounded with natural minerals to improve their properties. The reason for this is due to its lower melting point and general availability [3].

In the United States, the commercial use of natural fibers in plastics has been limited to wood fiber because using this wood fiber as a filler in the composites increases stiffness and reduces toughness. The composites are brittle due to stress concentration at the fiber ends and poor interfacial adhesion between wood and synthetic polymer. Compatibilizer has been used to improve dispersion, adhesion and compatibility for the system containing filler and matrix in

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the composites [4]. Researches have been done in developing new coupling agents and compatibilizers [5], as well as to improve processing methods [6]. Supri et al. [7] demonstrated that polyaniline as a coupling agent has enhanced the interfacial adhesion between LDPE/NR blend and water hyacinth fiber, thus improving the compatibility of the composites as evidenced by the morphology study using SEM. Supri et al. [8] also proven that chicken feather fiber was more widely dispersed in the LDPE matrix with the addition of polyethylene grafted maleic anhydride as a coupling agent. This paper reports the effect of maleic anhydride on tensile properties, and the morphology analysis of rHDPE/WF composites were investigated.

2.0 SAMPLE PREPARATION METHOD

The formulation of recycled high density polyethylene/wood fiber (rHDPE/WF) composites with and without maleic anhydride is given in Table 1. The compounding of the composites was carried out by using the Brabender Plasticorder with the temperature of 160 °C and rotor speed of 50 rpm. Two types of composites were prepared; rHDPE/WF and rHDPE/WFM with maleic anhydride. rHDPE was then charged into Brabender Plasticorder to start the melt mixing. rHDPE was preheated for 2 min in the mixing chamber. Next, wood fiber with or without maleic anhydride was added to the soften rHDPE. The mixing process was carried out for another 8 min to obtain homogeneous composites. The composites were discharged from the mixing chamber and pressed to produce thick round pieces of composites. The discharged composites were then allowed to cool under ambient temperature.

Table 1: Formulations of rHDPE/WF and rHDPE/WFM composites at different fiber compositions

Blend composition	rHDPE [wt%]	Wood fiber [wt%]	Maleic anhydride [wt%]
rHDPE/WF	100	-	-
rHDPE/WF5	100	5	-
rHDPE/WF10	100	10	-
rHDPE/WF15	100	15	-
rHDPE/WF20	100	20	-
rHDPE/WF30	100	30	-
rHDPE/WF5$_M$	100	5	6
rHDPE/WF10$_M$	100	10	6
rHDPE/WF15$_M$	100	15	6
rHDPE/WF20$_M$	100	20	6
rHDPE/WF30$_M$	100	30	6

3.0 RESULTS AND DISCUSSION

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3.1 Tensile Properties

The effect of fiber loading on the tensile strength of rHDPE/WF composites with and without maleic anhydride is shown in Fig. 1. The result showed that as the loading of fiber increased, the tensile strength of rHDPE/WF composites decreased due to the incompatibility of rHDPE and wood fiber. This incompatibility reduced the tensile strength because fracture would be initiated from the weak interface of the composites due to their poor interfacial adhesion. In a previous study [9], it was found that the strength of rHDPE was similar to those of virgin HDPE or PP. At a similar fiber loading, rHDPE/WFM composites with maleic anhydride exhibited higher tensile strength compared to rHDPE/WF composites. This indicates that the presence of MAH has reduced the possibility of interfacial debonding and leads to improvement of tensile strength as shown in the morphology study. This result agrees with the finding of Jie Ren et al. [10].

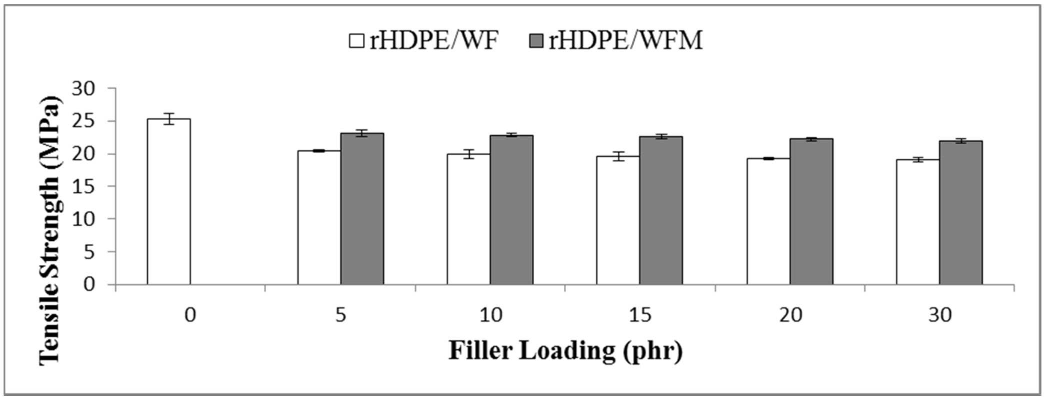

Figure 1: Tensile strength versus filler loading for rHDPE/WF and rHDPE/WFM composites.

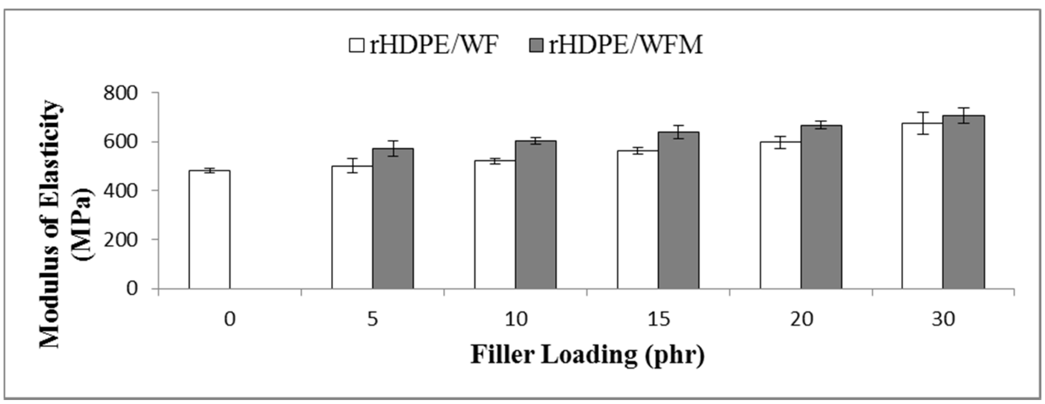

Figure 2: Modulus of elasticity versus filler loading for rHDPE/WF and rHDPE/WFM composites.

The effect of fiber loading on the modulus of elasticity of rHDPE/WF composites and rHDPE/WFM composites with maleic anhydride is shown in Fig. 2. The modulus of elasticity of rHDPE/WF and rHDPE/WFM composites tend to increase as filler loading increased. This

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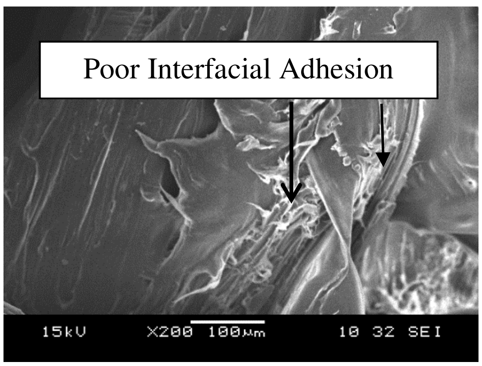
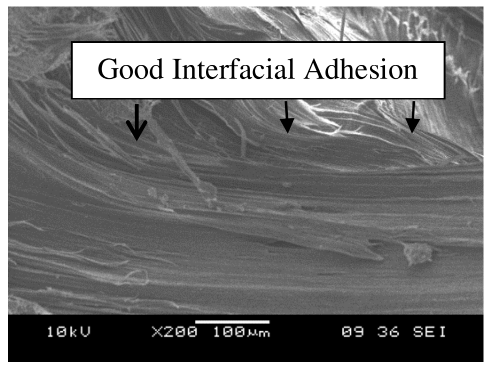
was due to the presence of fibers that provided the strength and stiffness in the composites. This result agrees with the finding of Yazid et al. [2]. This indicates that the presence of fibers has reduced the ductility of rHDPE/WF composites and increased its stiffness. It can be observed that the modulus of elasticity of rHDPE/WFM composites exhibits higher modulus of elasticity than rHDPE/WF composites. This can again be attributed to better interfacial adhesion between rHDPE and wood fiber with the presence of maleic anhydride as a coupling agent.

3.2 Morphology Properties

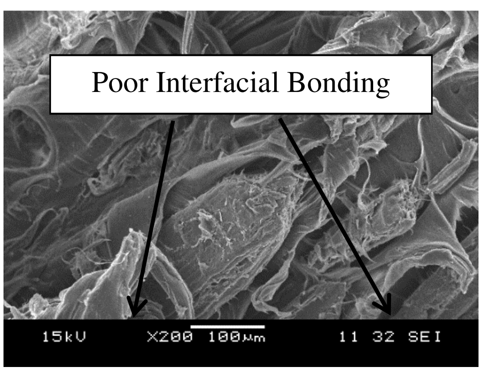
The influence of the wood fiber loading on the morphology of rHDPE/WF composites and rHDPE/WFM with maleic anhydride composites can be observed in Fig. 3 (a-d). As the filler loading increased, the micrographs showed poor interaction between fiber and the matrix.



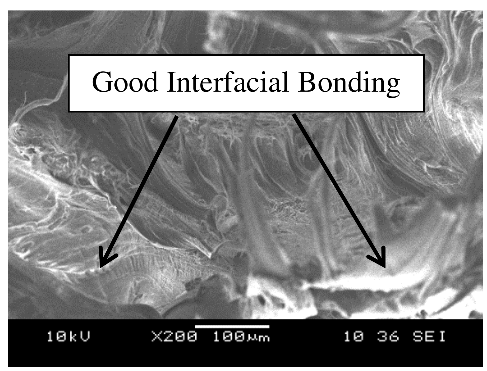
(a) rHDPE/WF5



(c) rHDPE/WF5M



(b) rHDPE/WF15



(d) rHDPE/WF15M

Figure 3: (a)-(d) SEM morphology of the tensile fracture of rHDPE/WF and rHDPE/WFM composites at different fiber loadings.

The lower filler loading showed less filler movement out from the matrix compared to the higher filler loading. It can be seen from Fig. 3 (c) and (d) that rHDPE/WFM composites indicated a rough and good dispersion of wood fibers in the rHDPE/WFM phases compared to Fig. 3 (a) and (b) of rHDPE/WF composites. This was due to the presence of maleic anhydride

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which acted as a coupling agent that enhanced the interfacial adhesion between the fibers and the matrix.

4.0 CONCLUSION

The addition of maleic anhydride as a coupling agent in the mechanical properties and morphology of rHDPE/WF composites was evaluated. rHDPE/WFM composites showed higher tensile strength and modulus of elasticity compared to rHDPE/WF composites. The morphology study indicated the compatibility between fiber and rHDPE matrix was also enhanced by maleic anhydride.

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