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 were studied. rHDPE/WF composites with different wood fiber loading and the addition of maleic anhydride were prepared with Brabender Plasticorder at temperature of 160°C and rotor speed of 50 rpm. The result indicated that rHDPE/WF composites with maleic anhydride exhibit higher tensile strength and modulus of elasticity than rHDPE/WF composites. rHDPE/WF composites with maleic anhydride composites gave a better interfacial adhesion between the matrix and the fiber than rHDPE/WF composites as evidence using Scanning electron microscopy (SEM).

Introduction

A renewable natural organic fibers act as reinforcing materials which are biodegradable and ecofriendly for the use of glass or carbon fiber and inorganic fillers. These fibers have 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 studies and research, thermoplastic or natural fibers composites like wood plastic composites (WPC) are proven to have high qualities in technical application fields, for example in load-bearing applications. Polyethylene which is a polymer has wide applications in our modern world. These polymers are frequently used thermoplastic for the production of natural fiber to prepare composites and compounded with natural minerals so as to improve their properties. This is due to its lower melting point, and general availability [3].

In America, the commercial use of natural fibers in plastics has been limited to wood fiber because the use of this wood fiber as filler in the composites increases stiffness and reduces toughness. The composites are brittle due to stress concentrations at fiber ends and poor interfacial adhesion between wood and synthetic polymer. Compatibilizer has been used to improved dispersion, adhesion and compatibility for system containing filler and the matrix in the composites [4]. Researchers have been done in developing new coupling agents, compatibilizers [5] and to improve processing methods [6]. Supri et al. [7] presented that polyaniline as a coupling agent have enhanced the interfacial adhesion between LDPE/NR blend and water hyacinth fiber improving compatibility of the composites, as evidenced by the morphology study using SEM. Supri et al. [8] also approved that chicken feather fiber more widely dispersed in the LDPE matrix with addition of polyethylene grafted maleic anhydride as a coupling agent. This paper reports the effect of maleic anhydride on tensile properties and morphology analysis of rHDPE/WF composites are investigated.
Methods

Sample Preparation. 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 were carried out by using the brabender plastocorder with temperature 160 °C and rotor speed of 50 rpm. Two types of composites were prepared, rHDPE/WF and rHDPE/WF with maleic anhydride. rHDPE was then charged into brabender plastocorder to start the melt mixing. rHDPE was preheated for 2 minutes in the mixing chamber. Next, wood fiber with or without maleic anhydride were added to the soften rHDPE. The mixing process was allowed for another 8 minutes to obtain homogeneous composites. The composites was discharged from the mixing chamber and pressed into thick round pieces. The discharged composites were then allowed to cool under ambient temperature.

Table 1: Formulations of rHDPE/WF and rHDPE/WF_M composites at different fiber loading.

<table>
<thead>
<tr>
<th>Blend composition</th>
<th>rHDPE (wt%)</th>
<th>Wood fiber (wt%)</th>
<th>Maleic anhydride (wt%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>rHDPE/WF</td>
<td>100</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>rHDPE/WF5</td>
<td>100</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>rHDPE/WF10</td>
<td>100</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>rHDPE/WF15</td>
<td>100</td>
<td>15</td>
<td>-</td>
</tr>
<tr>
<td>rHDPE/WF20</td>
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<td>20</td>
<td>-</td>
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<tr>
<td>rHDPE/WF30</td>
<td>100</td>
<td>30</td>
<td>-</td>
</tr>
<tr>
<td>rHDPE/WF5_M</td>
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<td>5</td>
<td>6</td>
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<tr>
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<td>6</td>
</tr>
<tr>
<td>rHDPE/WF15_M</td>
<td>100</td>
<td>15</td>
<td>6</td>
</tr>
<tr>
<td>rHDPE/WF20_M</td>
<td>100</td>
<td>20</td>
<td>6</td>
</tr>
<tr>
<td>rHDPE/WF30_M</td>
<td>100</td>
<td>30</td>
<td>6</td>
</tr>
</tbody>
</table>

Results and Discussion

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

![Fig. 1. Tensile strength vs. fiber loading on tensile of rHDPE/WF and rHDPE/WF_M composites.](image-url)
The effect of fiber loading on modulus of elasticity of rHDPE/WF composites and rHDPE/WF$_M$ composites with maleic anhydride is shown in Fig. 2. The modulus of elasticity of rHDPE/WF and rHDPE/WF$_M$ composites tend to increase as filler loading increased. This was due to the presence of the fibers that provide the strength and stiffness in the composites. This result agrees with the finding of Yazid et al. [2]. This indicated that the presence of fibers has reduced ductility of the rHDPE/WF composite and increased stiffness. It can be observed that the modulus of elasticity of rHDPE/WF$_M$ composite exhibit higher modulus of elasticity than rHDPE/WF composite. Again this was due to better interfacial adhesion between rHDPE and wood fiber with the presence of maleic anhydride as a coupling agent.

![Graph showing Modulus of Elasticity vs. fiber loading of rHDPE/WF and rHDPE/WF$_M$ composites.](image)

**Fig. 2. Modulus of Elasticity vs. fiber loading of rHDPE/WF and rHDPE/WF$_M$ composites.**

**Morphology Properties.** The influence of the wood fiber loading on the morphology of rHDPE/WF composites and rHDPE/WF$_M$ with maleic anhydride composites were observed in Fig. 2(a-d). As the filler loading increases, the micrographs show poor interaction between fiber and the matrix. The lower filler loading show less pull out of filler from matrix compared to the higher filler loading. It can be seen that, Fig. 3 (c), and (d) rHDPE/WF$_M$ composites indicated a rough and good dispersion of wood fibers in the rHDPE/WF$_M$ phases compared to Fig. (a) and (b) rHDPE/WF composites. This was due to the presence of maleic anhydride which acted as coupling agent that enhanced the interfacial adhesion between the fibers and the matrix.

![Images showing poor and good interfacial adhesion](image)

(a) rHDPE/WF$_5$  (c) rHDPE/WF$_5M$

![Images showing poor and good interfacial adhesion](image)

(a) rHDPE/WF$_5$  (c) rHDPE/WF$_5M$
Figs. 2 (a)-(d): SEM morphology of the tensile fracture of rHDPE/WF and rHDPE/WFM composites at different fiber loading.

**Conclusion**

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

**References**


