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Thermal and Mechanical Properties of Wood-Plastic Composites from Iron Wood Flour and Recycled Polypropylene Foam

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Abstract

In this work some of the important properties of experimentally manufactured wood-plastic composites (WPC) were determined. Specimen having 30% particle of Iron wood (Xylia Xylocarpa) was mixed with recycled polypropylene foam (RPPF) and two different additives, glycerol as a plasticizer and maleic anhydride grafted polypropylene homopolymer (MAPP) which is a compatibilizer. The thermal and mechanical properties of the composites were analyzed and compared with those of non-additive composites. Compared with RPPF, Iron wood/RPPF composites had higher melting and crystallization temperature, but much lower crystallinity level. Their thermal stability was lower than RPPF due to the degradation of the wood flour. The experimental results revealed that addition of the wood flour increased the tensile modulus, but decreased the values of the tensile strength and elongation at break of the composites. The uses of plasticizer and compatibilizer have been shown to influence on the thermal and mechanical properties of the composites. The results indicate that both glycerol and MAPP improved the compatibility of the Iron wood flour and RPPF in the composites, lead to the good properties determined for these materials.

Key words : Iron wood flour ; Recycled polypropylene foam ; Wood-plastic composites

Introduction

Wood-plastic composites have received considerable attention from industry in recent years. Much work has been done on wood flour and virgin thermoplastic composites, which succeed in wood composite industry. However, work done on wood flour/recycled plastic systems is still limited. Polypropylene foam is widely used in packaging applications and transportations, and can be collected to recycling process. Thus, recycled PP foam is an alternative source of raw material. Most of the physical and mechanical properties of the wood-plastic composites depend mainly on the interaction between the wood and the thermoplastic material. One way to improve this interaction is incorporating the compatibilizer. Several studies showed that using PP modified with maleic anhydride as a compatibilizer in the wood-plastic composites significantly increased interfacial bonding between the wood flours and the plastics.(1,2) However, the wood-plastic composites also have problems because of characteristic of the wood flour, such as the thermal degradation and the dispersion of the wood flour during a compounding. On the other hand, the use of a plasticizer may be one way to reduce the thermal degradation and the dispersion of the wood flour. Therefore, the main objective of this work is to investigate the effect of plasticizer and compatibilizer on the thermal and mechanical properties of the wood flour and the recycled PP foam composites.

Materials and Experimental Procedures

Materials

Recycled polypropylene foam (RPPF) was provided as the plastic pellets by S. Pinya recycle Co., Ltd. Its melting temperature was 109°C and melt flow index was 9.9 g/10min at 230°C, 2.16 kg load. Its density at room temperature was 0.889 g/cm^3. Four types of the wood flours were analyzed by TGA to assess the thermal stability. The results are summarized in Table 1. The degradation temperature of the Iron wood flour listed in Table 1 was the highest, and then used as filler in this work at 30% by weight. The Iron wood flour was sieved with a 500-mesh screen. Before use, it was also oven-dried at 80°C for 24 h and its moisture content was controlled at lower than 2%. Mixing of the Iron wood flour and the RPPF plastic along with a commercial glycerol

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content of 3% by weight, play as a plasticizer. Maleic anhydride grafted polypropylene homopolymer (COMPOLINE CO/PP H60) was used as a compatibilizer, in the content of 5% by weight, supplied by Behn Meyer Chemical (Thailand) Co., Ltd. The melt flow index of 60g/10 min at 230°C/2.16 kg, a graft level of 0.25-0.5%, and the melting temperature of 165°C.

Table 1. Thermal stability of the different wood flours with thermogravimetric analyzer.

Wood Flours	Degradation Temperature (°C)
Para rubber (general)	328
Para rubber (dark)	333
Para rubber (light)	310
Iron wood	356

Methods

The raw materials were first dry blended with a high speed mixer and then fed into a 20 mm laboratory co-rotating twin screw extruder. The barrel, screw and die temperatures were held constant between 180-220°C, with the screw speed of 150 rpm. Thermogravimetric analysis was used to study the thermal stability of the wood flours and the resultant composites with a thermogravimetric analyzer (Mettler Toledo TGA/SDTA 851e), under air at a scan rate of 20°C/min from 30-600°C. Experiments on the thermal behavior of the composites were carried out on a Mettler Toledo DSC 822e differential scanning calorimeter. The sample size was about 5 mg with a heating rate of 10°C/min. The specimens (specific dumbbell shape W=10 mm, L=100 mm, D=3 mm) of the composites were prepared by injection moulding at the melting temperature profiles of 150-170°C and the injection speed of 20 mm/s. At least five specimens were measured for the tensile properties, using an Universal Testing Machine (INSTRON Model 55R4502) with a crosshead speed of 50.0 mm/min.

Results and Discussion

Thermal Properties

When the 30% Iron wood flour was added to RPPF, both melting temperature (T_m) and the crystallization temperature (T_c) were significantly increased whereas decreased the crystallinity level (attributed to enthalpy of melting and crystallization on DSC thermogram) as shown in Figure 1. The wood flour particles could act as a nucleating agent during the nucleation stage to increased the crystallization temperature of the composites. However, it could also act as an interfering agent during the growth stage to decreased in the overall crystallinity level of the composites. Adding only the plasticizer or compatibilizer did not obviously influence the crystallinity level, whereas severely changed when they were added together. The lowered crystallinity level with introducing both plasticizer and compatibilizer suggested that the compatibility between the Iron wood flour and RPPF matrix was improved.(3)

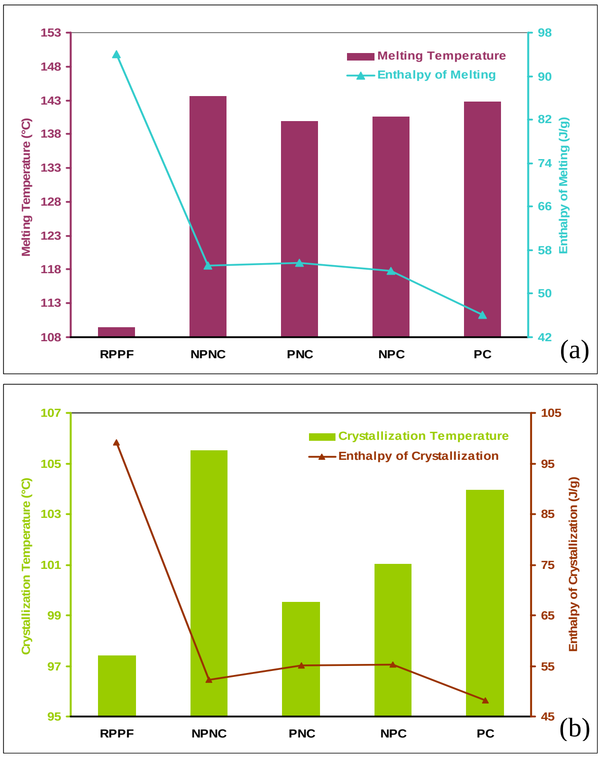

Figure 1. Thermal properties of the Iron wood/RPPF (30/70 w/w) composites (a) melting temperature and enthalpy of melting; and (b) crystallization temperature and enthalpy of crystallization (RPPF : recycled polypropylene foam, P : plasticizer, C: compatibilizer, NP : no plasticizer, and NC: no compatibilizer).

The TGA and DTG (is the first derivative of the TGA) curves of RPPF and composites under air are represented in Figure 2 and 3. The thermogravimetric analys is of RPPF showed a single-mass loss step with maximum degradation rate at 433°C indicated the degradation of saturated and unsaturated carbon atoms in polypropylene. All the composites showed multi-stepped degradation due to the various species present. An initial transition around 100°C due to moisture evaporation. The first degradation peak around 380°C could derive from the degradation of cellulosic components. The next degradation peak around 430°C was due to the degradation of the polymer matrix in the composites. Above 450°C the composite showed some peaks of degradation are probably related to further breakage of degradation products formed during the thermal analysis.

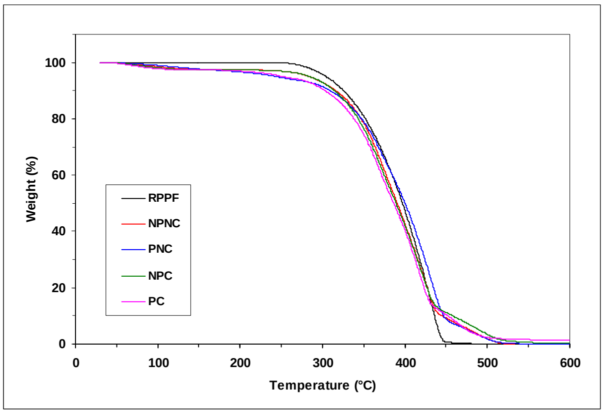

Figure 2. TGA curves of the Iron wood/RPPF (30/70 w/w) composites.

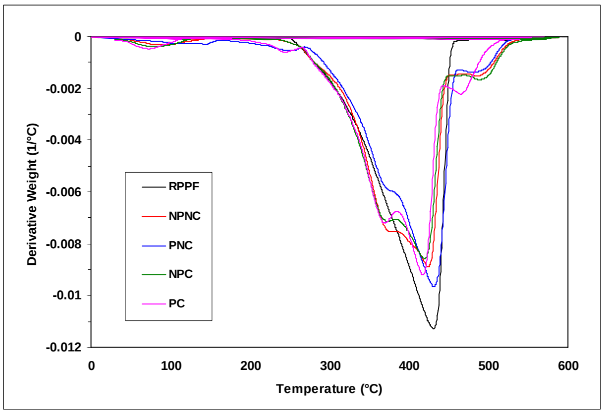

Figure 3 DTG curves of the Iron wood/RPPF (30/70 w/w) composites.

Moreover, the DTG curve of the composites with the plasticizer addition showed the degradation of the glycerol around 250°C.(2,3)

For the Iron wood/RPPF composites, it was verified that the maximum degradation rate was shifted to a lower temperature. This is indicated that the present of the wood flour lowered the thermal stability of the materials. However, the degradation temperature of the wood flour increased about 20°C in comparison to the neat wood flour which might derive from RPPF coating around the wood flour. The plasticizer and compatibilizer seemed to have different influence on the thermal degradation of the composites. The glycerol showed better heat degrading inhibition than that of MAPP compatibilizer. However, the addition of both plasticizer and compatibilizer together lowered the degradation temperature of the materials. It was recommended that maleic anhydride, in the presence of moisture from wood, could convert to maleic acid which stimulated to degradation of the composites.(4)

Mechanical Properties

Figure 4. Showed the tensile strength, tensile modulus and elongation at break of the composites. It can be clearly observed that introducing the Iron wood flour increased the tensile modulus, but decreased the values of the tensile strength and elongation at break, when compared to those of recycled PP foam. It is interesting to note that the tensile modulus progressively increased with addition of the wood flours, probably caused by the fact that the wood flour is more rigid than the plastic. However, the decreases in tensile strength and elongation at break were probably caused by a number of reasons, as suggested by Sombatsompop et al.(5)

Figure 4. Also showed the effect of the plasticizer and compatibilizer on the mechanical properties of the Iron wood/RPPF composites. In general, it was observed for all compatibilizers that tensile strength and tensile modulus of the composites were found to increase, accompanied by a decrease in elongation at break, with introducing MAPP compatibilizer. The decrease in elongation at break was expected since the composites with MAPP compatibilizer now were stiffer and had higher strength. Surprisingly, introduction of glycerol as the plasticizer resulted in increasing tensile strength and elongation at break. It seems act as another compatibilizer in this wood/plastic system. The addition of both plasticizer and compatibilizer simultaneously showed the positive effect to enhance the tensile

strength, whereas showed the negative effect to reduce tensile modulus and elongation at break of the composites.

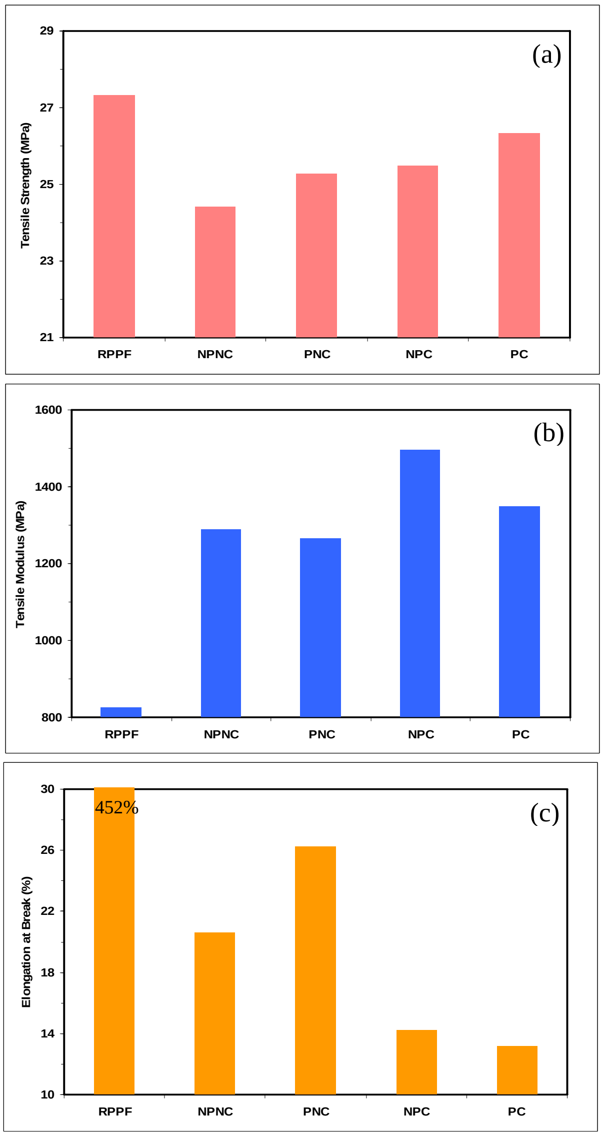

Figure 4. Mechanical properties of the Iron wood/RPPF (30/70 w/w) composites (a) tensile strength; (b) tensile modulus; and (c) elongation at break.

Conclusions

The experimental results indicated the increase of the melting and crystallization temperature, accompanied with the decrease of the crystallinity level, thermal stability, the tensile strength and elongation at break of the Iron wood/RPPF composites with the presence of the Iron wood flour, as it was expected. However, the addition of the polymeric compatibilizer produced composites with better performance, since the tensile strength was increased. This behavior can be attributed to the enhanced chemical compatibility between the components. Moreover, we have observed the positive effect of glycerol on the maleic anhydride compatibilizer. Thus, to more effectively improve the thermal and mechanical properties of the composites, glycerol as plasticizer and a MAPP compatibilizer should be selected.

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