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EFFECT OF PHTHALIC ANHYDRIDE ON TENSILE PROPERTIES AND THERMAL STABILITY OF RECYCLED HIGH DENSITY POLYETHYLENE / WOOD FIBER COMPOSITES

M. P. M. Hanif[a*], Supri A. G.[b], Firuz Zainuddin[a]

[a]School of Materials Engineering, Universiti Malaysia Perlis (UniMAP), Kompleks Taman Muhibah, Jejawi 2, 02600, Perlis, Malaysia
[b]Faculty of Engineering, Universiti Malaysia Perlis (UniMAP), Kampus Utama, Pauh Putra, 02600, Perlis, Malaysia

*Corresponding author
anepisal@gmail.com

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Abstract

The effect of phthalic anhydride as a coupling agent on the tensile properties and thermal stability of recycled high density polyethylene/wood fiber (rHDPE/WF) composites were studied. Both composites rHDPE/WF and rHDPE/WF/PAH (modified with phthalic anhydride) were prepared using Brabender Plasticorder at a temperature of 160°C and rotor speed of 50 rpm. The result indicated that rHDPE/WF/PAH composites exhibit higher tensile strength and modulus of elasticity than rHDPE/WF composites. It was also found that the addition of phthalic anhydride offers better thermal stability in rHDPE/WF/PAH composites than that of rHDPE/WF composites.

Keywords: Recycled high density polyethylene, wood fiber, phthalic anhydride

Abstrak

Kesan phthalic anhidrida sebagai ejen gandingan pada sifat-sifat tegangan dan kestabilan haba daripada serat polietilena ketumpatan tinggi yang dikitar semula / kayu (rHDPE/WF) komposit akan dikaji. Kedua-dua komposit rHDPE/WF dan rHDPE/WF /PAH (diubah suai dengan anhidrida phthalic) telah disediakan dengan menggunakan Brabender Plasticorder pada suhu 160°C dan kelajuan pemutar 50 rpm. Hasilnya menunjukkan bahawa rHDPE/WF/PAH komposit pameran kekuatan tegangan dan modulus keanjalan lebih tinggi daripada komposit rHDPE/WF. Kajian juga mendapati bahawa penambahan anhidrida phthalic menawarkan kestabilan yang lebih baik haba dalam rencam rHDPE/WF/ PAH daripada komposit rHDPE/WF.

Kata kunci: Polietilena ketumpatan tinggi yang dikitar semula, serat kayu, phthalic anhidrida

1.0 INTRODUCTION

Renewable natural organic fibers act as reinforcing materials or inorganic fillers for glass or carbon fibers, which are biodegradable and ecofriendly and inorganic fillers. These fibers have advantages including high specific strength modulus, low cost, low density, renewable organic, nonhazardous, malleable, wide availability and relatively no abrasiveness [1]. Aina *et al*. [2] reported that the different types of wood species (funtumia elastic, brachystegia kennedy and milica excels) in rHDPE matrices at different ratios of fiber will not only reduce the tensile strength but improves the modulus of elasticity of the composites. Through studies and research, thermoplastics or natural fiber composites like wood plastic composites (WPC) have been proven to have high qualities in technical applications, for example, load-bearing. Polyethylene is a polymer that has wide applications in this modern world. These polymers are frequently used thermoplastics for the production of natural fibers to prepare composites and often compounded with natural minerals, 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 wood fibers as fillers in the composites tend to increase stiffness and reduce toughness. The composites are brittle due to stress concentrations at the fiber ends and have poor interfacial adhesion between the wood and synthetic polymers. Researches have been conducted in developing new coupling agents i.e. compatibilizers [4] to improve processing methods [5]. Supri *et al*. [6] presented that vinyl alcohol-phthalic anhydride, as a coupling agent, could enhance the interfacial adhesion between Low Density Polyethylene (LDPE) and tyre dust thus improving compatibility of the composites, as evidenced by its thermal stability using X-ray Diffraction (XRD). Supri *et al*. [7] also approved of the more widely dispersed chicken feather fiber with addition of polyethylene grafted maleic anhydride—in the LDPE matrix—as a coupling agent. This paper reports the effect of phthalic anhydride on tensile properties and thermal degradation of rHDPE/WF composites.

2.0 METHODOLOGY

Materials. The recycled high density polyethylene (rHDPE) with a melt flow index of 0.7 g/min at 190 °C, density of 939.9 kg/m^3, glass transition temperature of -80 °C, melting temperature of 126 °C and water absorption content less than 0.01 % has been supplied by Mega Makmur Sdn. Bhd., Penang, Malaysia. The wood fibers with the size of 199 µm and type Pulverised Wood Fiber with grade mix wood was obtained from Titan Petchem (M) Sdn. Bhd., Pasir Gudang, Johor, Malaysia. PAH (C6H4(CO)2O with molar mass=148.12 g/mol was used as coupling agents and obtained from AR Alatan Sdn. Bhd., Alor Setar, Kedah, Malaysia.

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

Compression Molding. Samples of rHDPE/WF and rHDPE/WF/PAH with phthalic anhydride composites were compressed via an electrically heated hydraulic press to produce the composites in plate form. The hot and cool press was set at a temperature of 160°C for both top and bottom platen. Then, the composites were put into the mold, preheated for 6 minutes and followed by compression for 2 minutes at the same temperature and subsequently cooled under pressure for 4 minutes.

Characterization and Measurements. Tensile tests were conducted based on ASTM D638 by using Instron 5569 with crosshead speed of 10 mm/min. Dumbbell shaped specimens were conditioned at ambient temperature (25±3) °C and relative humidity (30±2) % before conducting the test. Five dumbbell shaped samples were used for each blend composition. The tensile strength and modulus of elasticity of each composition were obtained from the test. Thermogravimetry analysis of rHDPE/WF composites with and without phthalic anhydride was done by using a Perkin Elmer Pyris 6 TGA analyzer. Samples of about 10 mg were scanned from 30 to 650°C with a heating rate of 10°C/min by using constant nitrogen gas flow of 50 ml/min to prevent thermal oxidation process of the polymer sample. The temperature at 50 % weight loss (T-50%WT), final decomposition temperature (FDT) and the residual mass of TG curve were calculated.

Table 1 Formulations of rHDPE/WF with and without phthalic anhydride at different fiber loading

Codes	rHDPE (phr)	Wood Fiber (phr)	Phthalic Anhydride (phr)
rHDPE/WF0	100	-	-
rHDPE/WF5	100	5	-
rHDPE/WF10	100	10	-
rHDPE/WF15	100	15	-
rHDPE/WF20	100	20	-
rHDPE/WF30	100	30	-
rHDPE/WF5/PAH	100	5	6
rHDPE/WF10/PAH	100	10	6
rHDPE/WF15/PAH	100	15	6
rHDPE/WF20/PAH	100	20	6
rHDPE/WF30/PAH	100	30	6

3.0 RESULTS AND DISCUSSION

Tensile Properties. The effect of fiber loading on tensile strength of rHDPE/WF composites with and without phthalic anhydride is shown in Figure 1. The result shows that as the loading for the fiber increases, tensile strength of rHDPE/WF composites decreases due to incompatibility between the rHDPE and wood fiber. This incompatibility reduces the tensile strength because fractures would be initiated from the weak interface of the composites due to poor interfacial adhesion [8]. In the previous study, it was found that the strength of rHDPE that is used here is similar to those of virgin HDPE [9]. At a similar fiber loading, rHDPE/WF/PAH composites exhibits higher tensile strength compared to rHDPE/WF composites. This is due to the presence of PAH that help enhance the interaction between the rHDPE and the wood fibers, which also affects the stress transfer, hence reducing the chance of interfacial de-bonding that leads to improvements on their properties [6].

The effect of fiber loading on modulus of elasticity of rHDPE/WF composites and rHDPE/WF/PAH composites with phthalic anhydride is shown in Figure 2. The modulus of elasticity of rHDPE/WF and rHDPE/WF/PAH composites tend to increase as filler loading is increased. This is due to the presence of fibers that provide strength and stiffness in the composites. This result agrees with the findings of Supri *et al*. [7]. They have indicated that the presence of fibers reduces the ductility of the rHDPE/WF composite and increases stiffness. It can be observed that the rHDPE/WF/PAH composites exhibit a higher modulus of elasticity than rHDPE/WF composites. Again this is due to better interfacial adhesion between rHDPE and wood fibers with the presence of phthalic anhydride as a coupling agent [10].

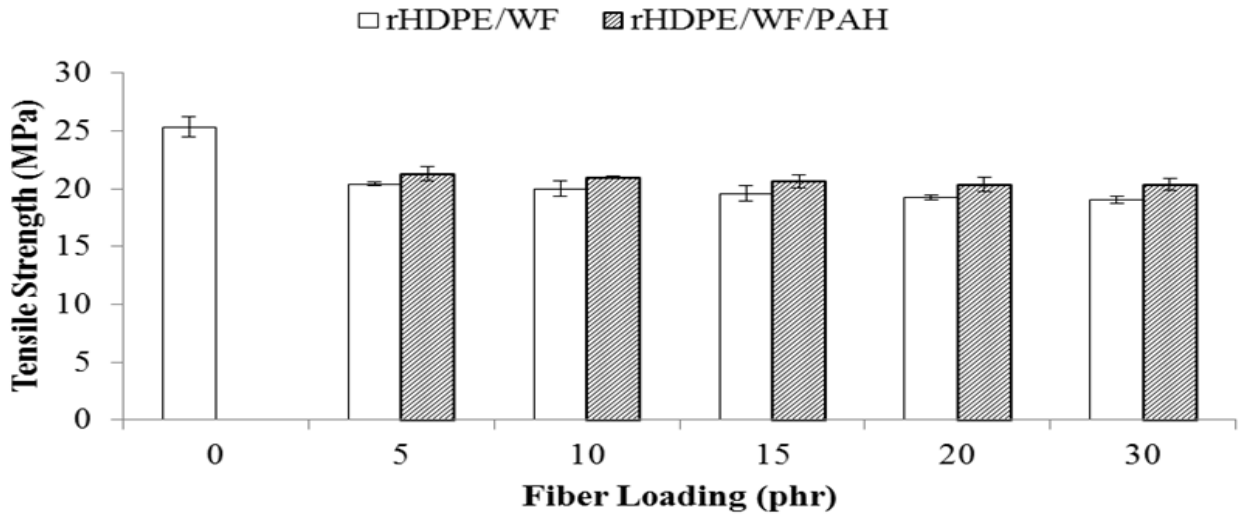

Figure 1 Tensile strength versus fiber loading of rHDPE/WF and rHDPE/WF/PAH composites

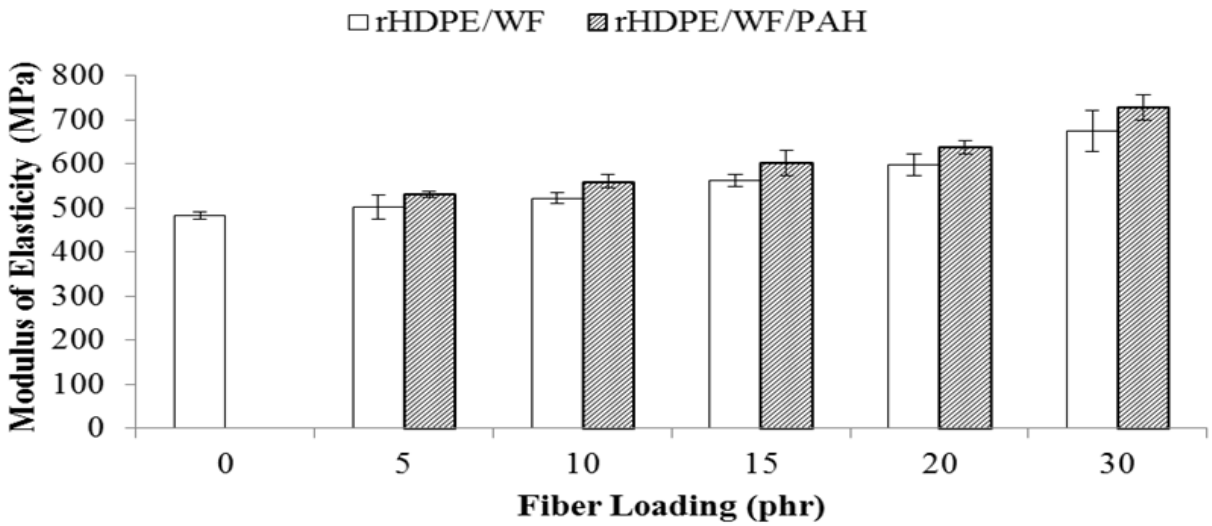

Figure 2 Modulus of elasticity versus filler loading of rHDPE/WF and rHDPE/WF/PAH composites

Thermal Degradation. Figures 3 and 4 show the typical thermal degradation curves for the effect of PAH on rHDPE/WF composites at different fiber loadings. Table 2 shows that the temperature of 50 % weight loss (T-50%wt) decreases with increasing fiber loading for both composites. This was due to lower degradation temperature at T-50%wt weight loss than the rHDPE matrix due to the degradation of WF at lower temperature that causes the reduction of thermal stability [11]. However, FDT and residual mass of both composites increases with increasing of WF loadings, which indicated that the residue mainly consists of decomposition products of the fiber reinforcement [12]. By comparing both sets of the composites with the same fiber loading, rHDPE/WF/PAH composites showed lower value of T-50%wt and FDT due to less thermal resistance of the wood fiber modified with PAH. However, higher residual mass indicated enhanced thermal stability of rHDPE/WF/PAH composites compared to rHDPE/WF composites. In addition, the PAH might be due to the presence of good interfacial adhesion between fiber and matrix as a result of uniform dispersion of fiber throughout the matrix. This indicates that the presence of acrylic anhydride (RCO-O-COR) group as the coupling agent has increased the thermal stability of rHDPE/WF composites. According to Reddy *et al*. [13], these results clearly illustrate that the thermal stability of the extracted cellulose microfibrils was higher than that of the raw fibers. This is attributed to the removal of hemicellulose and lignin from the raw fibers on several chemical treatments.

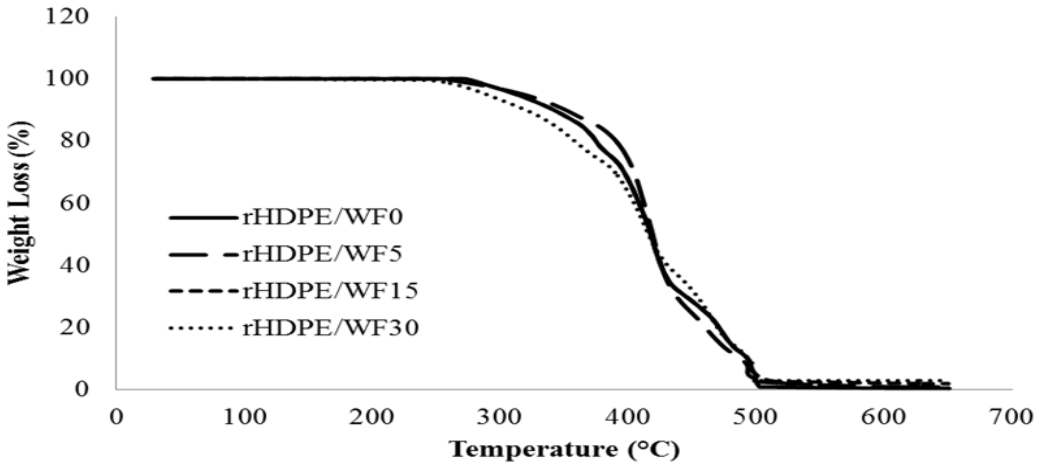

Figure 3 Thermogravimetric curves of rHDPE/WF composites at different fiber loadings

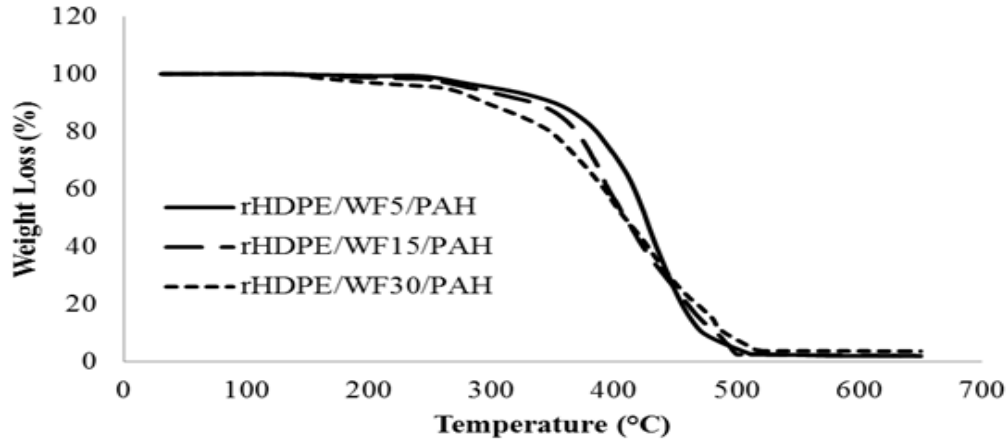

Figure 4 Thermogravimetric curves of rHDPE/WF/PAH composites at different fiber loadings

Table 2 Temperature of 50% weight loss ($T_{-50\%\ wt}$), final decomposition temperature and residual mass for rHDPE/WF with and without modified phthalic anhydride composites at different fiber loadings

Codes	T_{50} %wt (°C)	FDT (°C)	Residual mass (%wt)
rHDPE/WF	434.52	520.34	0.269
rHDPE/WF5	419.17	522.38	0.284
rHDPE/WF15	417.59	529.46	0.604
rHDPE/WF30	415.86	530.96	1.063
rHDPE/WF5/PAH	424.87	530.53	1.435
rHDPE/WF15/PAH	420.28	539.85	1.688
rHDPE/WF30/PAH	419.90	548.14	2.417

4.0 CONCLUSION

The addition of phthalic anhydride as a coupling agent against the tensile properties and thermal degradation has been evaluated. Recycled high density polyethylene, rHDPE modified wood fiber (rHDPE/WF/PAH) showed higher tensile strength, modulus of elasticity and thermal stability compared to rHDPE/WF composites.

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