Comparative Study on the Effect of Manchurian Ash and Larch Wood Flour on Mechanical Property, Morphology, and Rheology of HDPE/Wood Flour Composites

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ABSTRACT: Effects of wood flour species and polyethylene grafted with maleic anhydride (MA-PE) on mechanical properties and morphology and torque rheology of high density polyethylene (HDPE)/wood flour composites have been comparatively investigated. The results demonstrated that without compatbilizer, wood flour species exhibited little influence on mechanical properties. In the presence of MA-PE, the mechanical properties were obviously increased. On the basis of the mechanical property data obtained from wood flour extracted by different methods, the extractant was an important factor affecting the mechanical properties. Manchurian ash and larch wood flours extracted by hot water presented almost the same mechanical properties, and larch wood flour was the most beneficial to enhance the mechanical properties. The scanning electron microscopy (SEM) and the atomic force microscopy (AFM) further confirmed that interfacial adhesion and dispersion of manchurian ash wood flour in composites were effectively improved by MA-PE. The torque results demonstrated that the chemical reactions of maleic anhydride groups on MA-PE with hydroxyl on cellulose in wood flour probably took place due to the increase of the equilibrium torque and the appearance of the torque peak, and larch wood flour was more beneficial to prepare the composites containing the higher wood flour content. © 2007 Wiley Periodicals, Inc. J Appl Polym Sci 107: 2520–2530, 2008

Key words: polyethylene/wood flour composites; manchurian ash; larch; MA-PE; mechanical property; morphology; rheology

INTRODUCTION

Polymer/wood composites has been rapidly developed and widely applied in building products such as decking, fencing, siding and decorative trim; infrastructure such as boardwalk and marinas; transportation such as interior automotive panels and truck floors, due to its good weatherability, low maintenance, and no cracking, warping or splintering.[1] Polyethylene and polypropylene are the primary thermoplastic resin matrixes. The composites is considered to be an environmental protection material because of using waste plastics and plant fibers (wood flours) as raw materials.

To gain the good mechanicial properties of the composites, many researchers have been paying attention to the interface modification between wood flour and polymer matrix, and the processing rheological behavior, because of different inherent polarity of wood flour and polymer matrix, and the high loading of wood flour.[2–12] Many modification methods have been adopted to improve poorly interfacial adhesion between the hydrophobic matrix (polymer) and the hydrophilic filler (wood flour). Firstly, polyolefin grafted with maleic anhydride are very effective compatibilizers to enhance the mechanical properties of the polymer/wood composites,[2–4,8–12] such as polyethylene grafted by maleic anhydride (MA-PE), polypropylene grafted by maleic anhydride (MA-PP), styrene-ethylene-butylene-styrene block copolymer (SEBS) grafted by maleic anhydride, polyethylene-SEBS blend grafted by maleic anhydride,[12] ethylene-propylene-dieneter polymers grafted by maleic anhydride (MA-EPDM), ethylene-caprylene polymers grafted by maleic anhydride (MA-POE) and so on. The experimental results have proved that their modifications are achieved by the chemical reactions of maleic anhydride groups on polyolefin with hydroxyl on wood flour. Secondly, silane coupling agents and fatty acids are used to modify the surface polarity of the wood flour for enhancing the wood flour-polymer

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matrix adhesion,[3,13,14] for example, Wu et al.[14] have studied the effect of fiber surface treatment with an acid-silane aqueous solution on the interfacial strength and mechanical properties of wood fiber/polypropylene composites.[13] They reported a considerable increment of tensile modulus and tensile strength of the composites.

The melt rheology is another technical issue of manufacturing polymer/wood composites due to application properties and high wood loading for economic consideration.[15–19] The melt rheological behavior of polymer/wood composite has been mainly studied by the high pressure capillary rheometric technique. The viscosity, extensional flow and viscosity-shear stress curves are obtained to understand the melt rheological behavior in the processing of the composites. Li and Wolcott[18] studied the rheology regarding steady state shear and extensional flow of HDPE/wood composites. The enhancing viscosity and shear thinning were reported for polyethylene/wood flour and polypropylene/wood flour composites and wood flour loading affected the viscosity. However, the investigations of torque rheology regarding polymer/wood composites have been rarely reported.

The fillers are also an important factor of affecting the mechanical properties of the polymer/wood (wood flour or wood fiber) composites. Plant, such as wood (wood flour or wood fiber), as a filler, is one of the natural polymeric materials with a complicated structure. Wood (wood flour or wood fiber) is consisted of cellulose, hemicellulose, lignin, and extractants. But its components and content are different due to different wood species, for example, hardwood such as manchurian ash and softwood such as larch. It is proved that manchurian ash contains more cellulose and hemicellulose, fewer extractants than larch. Hence, the effect of wood species on the composites is needed to be further studied.

In this contribution, we select two kinds of wood, such as manchurian ash and larch, as wood flour fillers. The mechanical properties, morphology, and torque rheology of HDPE/wood flour composites are comparatively investigated.

EXPERIMENTAL

Materials

High Density Polyethylene (HDPE) resin (HDPE-5000S, melting flow rate: 0.9 g/10 min (190°C, 216 kg)) used in this work was offered by Daqing Petrochemical Company (Daqing, China). Manchurian ash wood flour and larch wood flour(40–60 meshes) which were milled in the pulverizer and which shape approximates to sphericity, were produced by Xinglong Company (Xinglong, China), and pretreated at 105°C in an oven to constant weight. Polyethylene grafted with 0.8% maleic anhydride (MA-PE, melting flow rate 20 g/10 min (190°C, 216 kg)) was manufactured by Shanghai Rizisheng Hightech Corporation (Shanghai, China). Ethyl bis-stearamide (EBS) was purchased from Wuxi Henghui Chemical Limited Company (Wuxi, China). Polyethylene wax (CH-2A, mp: 102–103°C, molecular weight: 2500–3000) was manufactured by Jiangyin Guangda Plastic Fertilizer Factory (Jiangyin, China), and antioxodant 1010 by Yangzi Petrochemical Company (Nanjing, China).

Extraction of wood flour

Seven hundred milliliter of the solvent, such as water, benzene-ethanol (1 : 1 volume ratio) and petroleum ether, was added to a 1000-mL flask, and then 50 g of the dried wood flour was wrapped with the filter paper and added into Soxhlet apparatus. The volume of the Soxhlet apparatus was about 500 mL. The wood flour was extracted for 6 h, then dried at 105°C in an oven to constant weight. Hot water extracting wood flour, benzene-ethanol extracting wood flour and petroleum ether extracting wood flour were obtained.

Preparation of the composites

HDPE, wood flour or extracted wood flour (manchurian ash and larch), MA-PE and other additives were mixed in a mixer (SHR mixer, 5 L, 2000 r/min, produced by Zhangjiagang Xinghuo Degradation Equipment Machine Factory (Zhangjiaguang, China)) for 5 min to obtain the mixtures, and then the mixtures were extruded from the co-rotating twin-screw extruder (TE-35, $L/D = 36$), and pressed on a curing machine at 150°C for 2 min to form sheets (thickness: 4 mm) for testing. The purpose of compounding with mixer first and then extrusion with twin-screw extruder makes the mixture mix better. After preparation of the composites, the composites were placed in the humidistat. The temperature of six processing zones in the extruder was 100, 165, 170, 180, 180, and 180°C, respectively. The components of the mixture consist of 20–80% wood flour, 20–80% HDPE, 0–25% MA-PE, 1.0% EBS, 1.0% polyethylene wax and 0.1% antioxidant 1010.

Mechanical property tests

Determination of tensile and flexural strength of all samples was performed by a RGD-20A material test machine (produced by Shenzhen Regear Instrument Cooperation (Shenzhen, China)), and Izod impact testing, such as notched and unnotched impact strength, was performed by using a XJC-25D impact test machine (produced by Chengde Precision Testing Machine Co. Ltd (Chengde, China)), according to ASTM D 638, ASTM D 790, and ASTM D 256, respectively. The testing temperature and relative humidity were 20°C and 50%. There are six specimens for each measurement. The thickness of the sheets for testing was 4 mm.

Scanning electron microscopy and Atomic force microscopy

The fractured surfaces of the composites obtained under liquid nitrogen were coated with gold to prevent electrical charging. The surfaces of the prepared samples were observed by the Japanese Rely S570 Scanning Electron Microscopy (SEM) at an acceleration voltage of 20 kV.

The sections of the samples were polished and the morphology of the composites was also examined using a Solver P47 atomic force microscope (AFM) made in Russia NT-MDT Corporation. All images were obtained in the noncontact mode at room temperature. The scanning scope was 4×4 μm^2. The AFM images were displayed with different shades of grey (dark grey indicating lower parts and light grey higher parts of the surface).

Torque rheological property of the composites

The torque rheological behavior was performed in a RM-200A torque rheometer. The mixtures that mean all the component after mixing in the mixer were added into the chamber of the torque rheometer, which was preheated to 160, 180, and 200°C, respectively, and the rotor was set a speed of 80 rpm. The content of every sample was kept at 60 g. Equilibrium torques and curves of torque versus time were recorded by a computer.

RESULT AND DISCUSSION

Comparison of mechanical properties of the composites

Figure 1 shows the curves of mechanical properties of both HDPE/manchurian ash wood flour and HDPE/larch wood flour composites without any compatilizer versus wood flour addition (20, 30, 40, 50, or 60 wt % by weight). It is clearly seen that tensile strength, flexural strength, unnotched Izod impact strength, and notched Izod impact strength steadily decreased with increasing wood flour addition. This result was in agreement with other literature.[2] In the comparison of manchurian ash wood flour and larch wood flour, tensile strength and flexural strength of HDPE/manchurian ash wood flour composites were slightly higher than those of HDPE/larch wood flour composites, while Izod impact strengths of them were nearly the same. For instance, the tensile strength and flexural strength of the composites containing 60 wt % wood flour were 10.8, 17.6 MPa for manchurian ash wood flour and 9.1, 16.9 MPa for larch wood flour, respectively, while unnotched Izod impact strength and notched Izod impact strength of the composites were 4.0, 2.4 kJ m^{-2} for manchurian ash wood flour and 4.1, 2.4 kJ m^{-2} for larch wood flour, respectively. Compared with the tensile and flexural strength of control sample (polyethylene and additive without wood flour), addition of wood flour lead to decrease of the tensile and flexural strength. This was probably due to the fact that wood flour and HDPE are immiscible system.

Figure 2 gives the curves of the mechanical properties of both HDPE/manchurian ash wood flour and HDPE/larch wood flour composites versus wood flour addition, which contained 5 wt % MA-PE compatilizer based upon the composite weight. To study the effect of different wood flour contents on the mechanical properties of the composites, we set one MA-PE system. So we choose 5 wt % MA-PE for comparison. According to Figures 1 and 2, 5 wt % MA-PE obviously enhanced the mechanical properties of the composites compared with those of the composites without any compatibilizer, and the changing tendency of the tensile strength and flexural strength of the composites was contrary. The tensile strength and flexural strength of the composites containing 5 wt % MA-PE increased with the increase of wood flour addition, while unnotched Izod impact strength and notched Izod impact strength of them were reduced. From Figure 2, it is seen that mechanical properties of HDPE/manchurian ash wood flour composites were clearly higher than these of HDPE/larch wood flour composites, for instance, the mechanical properties of the composites containing 60 wt % wood flour and 5 wt % MA-PE were 26.7 MPa of tensile strength, 40.3 MPa of flexural strength, 13.0 kJ m^{-2} of unnotched Izod impact strength and 3.7 kJ m^{-2} of notched Izod impact strength for HDPE/manchurian ash wood flour composite, respectively, and 21.9 MPa of tensile strength, 33.3 MPa of flexural strength, 9.4 kJ m^{-2} of unnotched Izod impact strength and 3.1 kJ m^{-2} of notched Izod impact strength for HDPE/larch wood flour composite, respectively. These results demonstrated that MA-PE was more effective in improving interfacial interaction between manchurian ash wood flour and HDPE than larch wood flour and HDPE. This is probably explained that different wood flours contain different extractants, which is considered to be an important

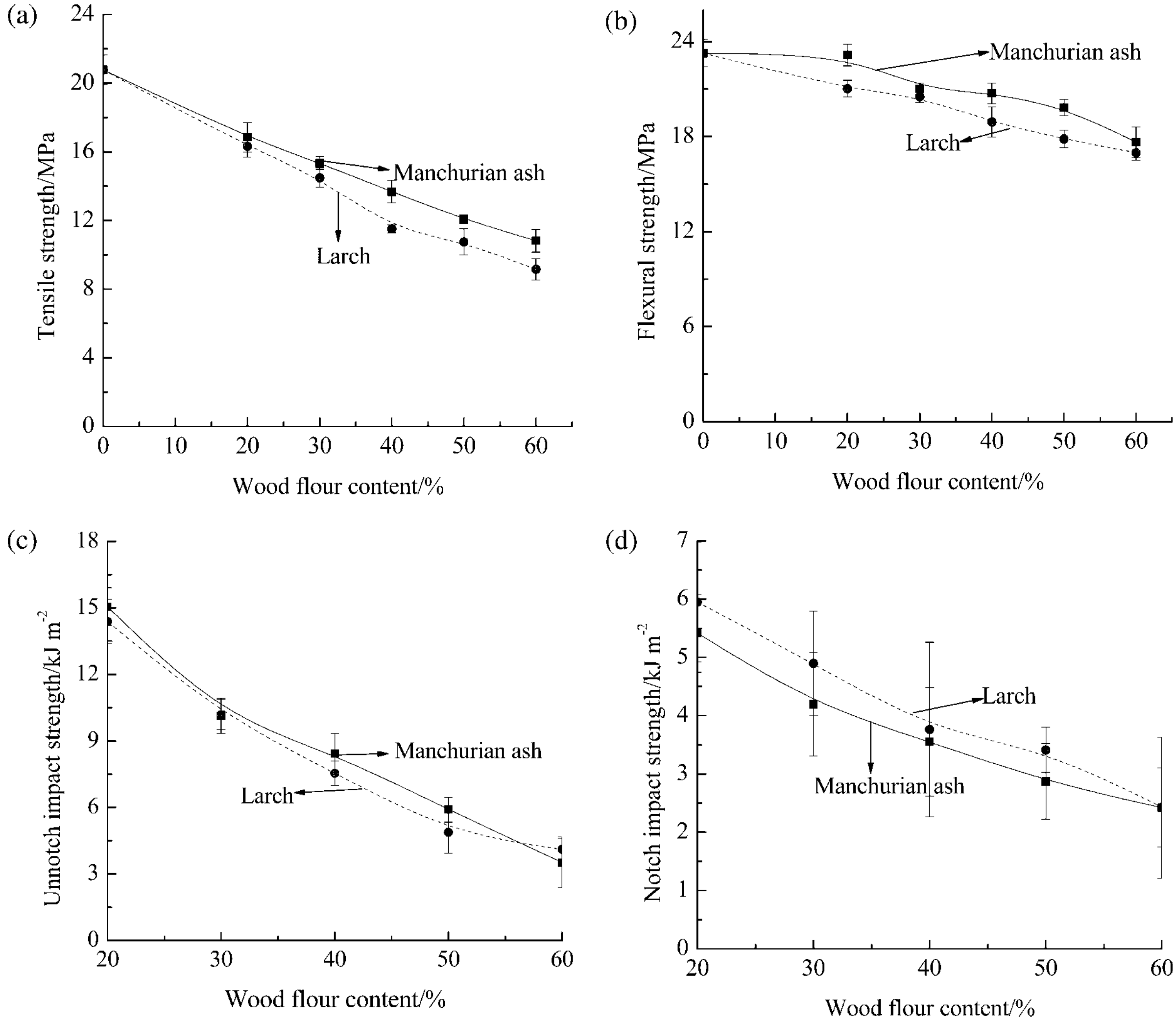

Figure 1 Effect of wood flour content on mechanical properties of the composites without MA-PE, (a) tensile strength, (b) flexural strength, (c) unnotched impact strength, (d) notched impact strength.

component of affecting interfacial modification of MA-PE on wood flour and HDPE, seen the section of the effect of extracted wood flour on mechanical properties of the composites. Compared with the tensile and flexural strength of control sample (polyethylene, MA-PE and additive without wood flour), addition of wood flour lead to increase of the tensile and flexural strength. This can be explained that MA-PE act as compatibilizer and it could connect wood flour to HDPE effectively. Wood flour act as a filler, so the tensile and flexural strength increased.

Figure 3 shows that the effect of MA-PE on mechanical properties of the composites with 60 wt % wood flour. Addition of MA-PE had a positive effect on the mechanical properties of the composites, the properties increased with the increase of MA-PE addition. When the addition of MA-PE was 10 wt % based on the composite weight, the mechanical properties of the composites reached the maximum level. However, when the addition of MA-PE was more than 10 wt %, the mechanical properties of the composites slightly decreased with the increase of MA-PE addition. These results are attributed to the esterification reactions between hydroxyl on the wood flour surface and anhydride on MA-PE, and better interfacial interaction between HDPE matrix and long chain on MA-PE, which was discussed by some researches,[20,21] however, the melting flow rate of MA-PE (20 g/10 min) is much higher than that of HDPE (1.3 g/10 min), hence, higher addition of MA-PE resulted in reducing mechanical properties of the composites.

Figure 4 shows that the effect of different MA-PE contents on tensile and flexural strength of HDPE. It can be see that tensile and flexural strength of HDPE decreased with increase of MA-PE contents. Because MA-PE has a low molecular weight and high melt

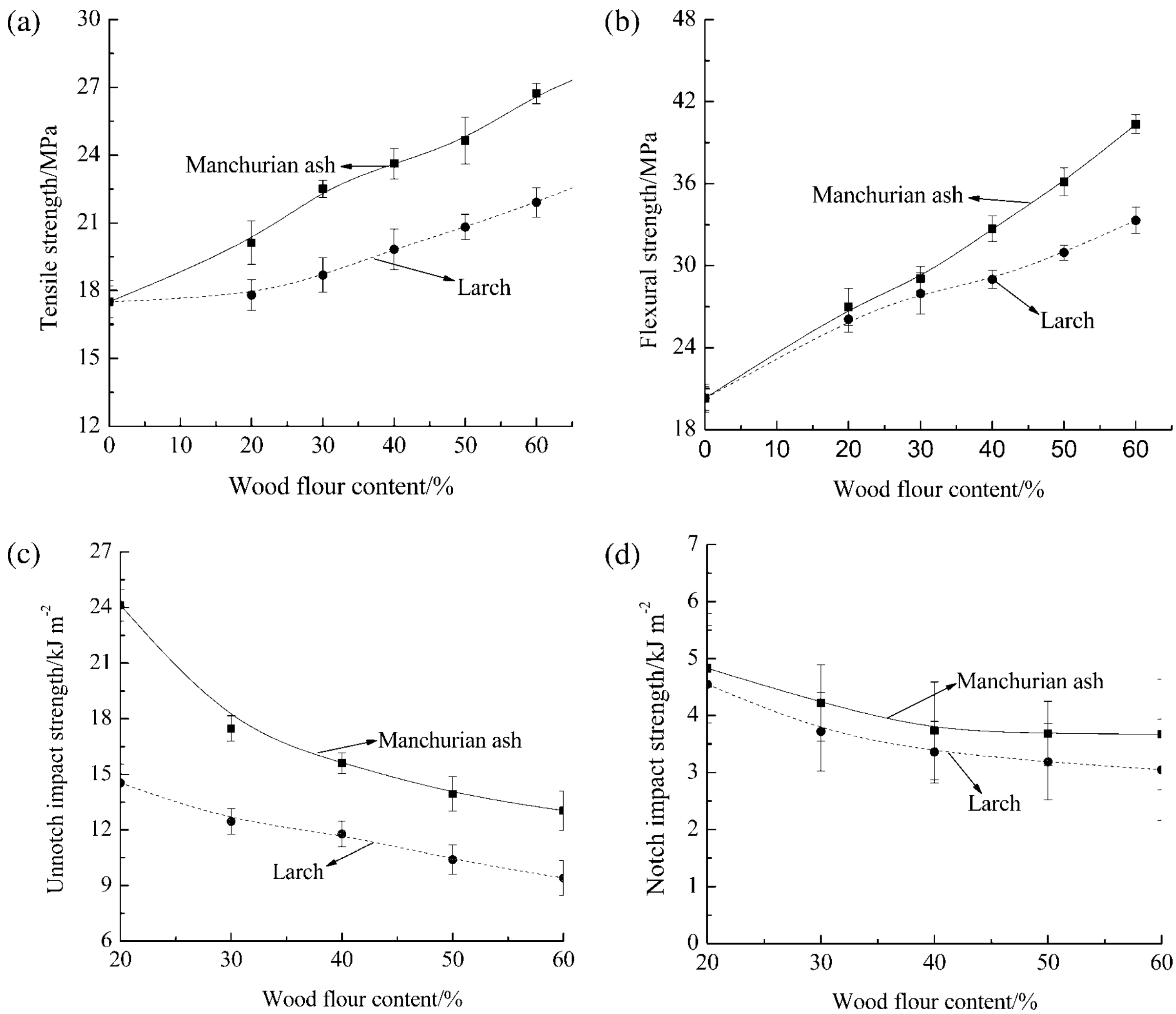

Figure 2 Effect of wood flour content on mechanical properties of the composites with 5 wt % MA-PE, (a) tensile strength, (b) flexural strength, (c) unnotched impact strength, (d) notched impact strength.

flow index, it acted as plasticizer when it was added to HDPE.

Effect of extracted wood flour on mechanical properties of the composites

From above experimental results, the extractant in wood flour is an important factor of influencing the interfacial interaction of MA-PE and wood flour. Therefore, in order to investigate the effect of wood flour extractants on the mechanical properties of the composites, the wood flour was treated with different solvents, and hot water extracting wood flour, benzene-ethanol extracting wood flour and petroleum ether extracting wood flour were obtained in this contribution to be used for the preparation of the composites. Table I gives the content of extractants in the wood flour by different extracting methods. As it can be seen, the content of extractants in larch wood flour was more than that in manchurian ash wood flour, and the content of hot water extractants was the highest, followed by benzene-ethanol extractants and petroleum ether extractants. It is well known that the chemical components of wood flour extractants are different based on different extracting methods.[22] The components of the extractants are mainly consisted of sugar, tannin and inorganic salts in hot water, resin, tannin, fat, wax and fatty acid in benzene-ethanol, and resin, wax, fat and fatty acid in petroleum ether, respectively.

Table II shows the mechanical properties of HDPE/extracted wood flour composites without any compatibilizer. Compared with the composites of unextracted wood flour, the mechanical properties of HDPE/extracted wood flour composites were improved. This is because low molecule weight extractants are extracted from wood flour surface to reduce the influence of the extractants on the interfacial adhesion. However, manchurian ash and larch wood flour presented little effect on the mechanical

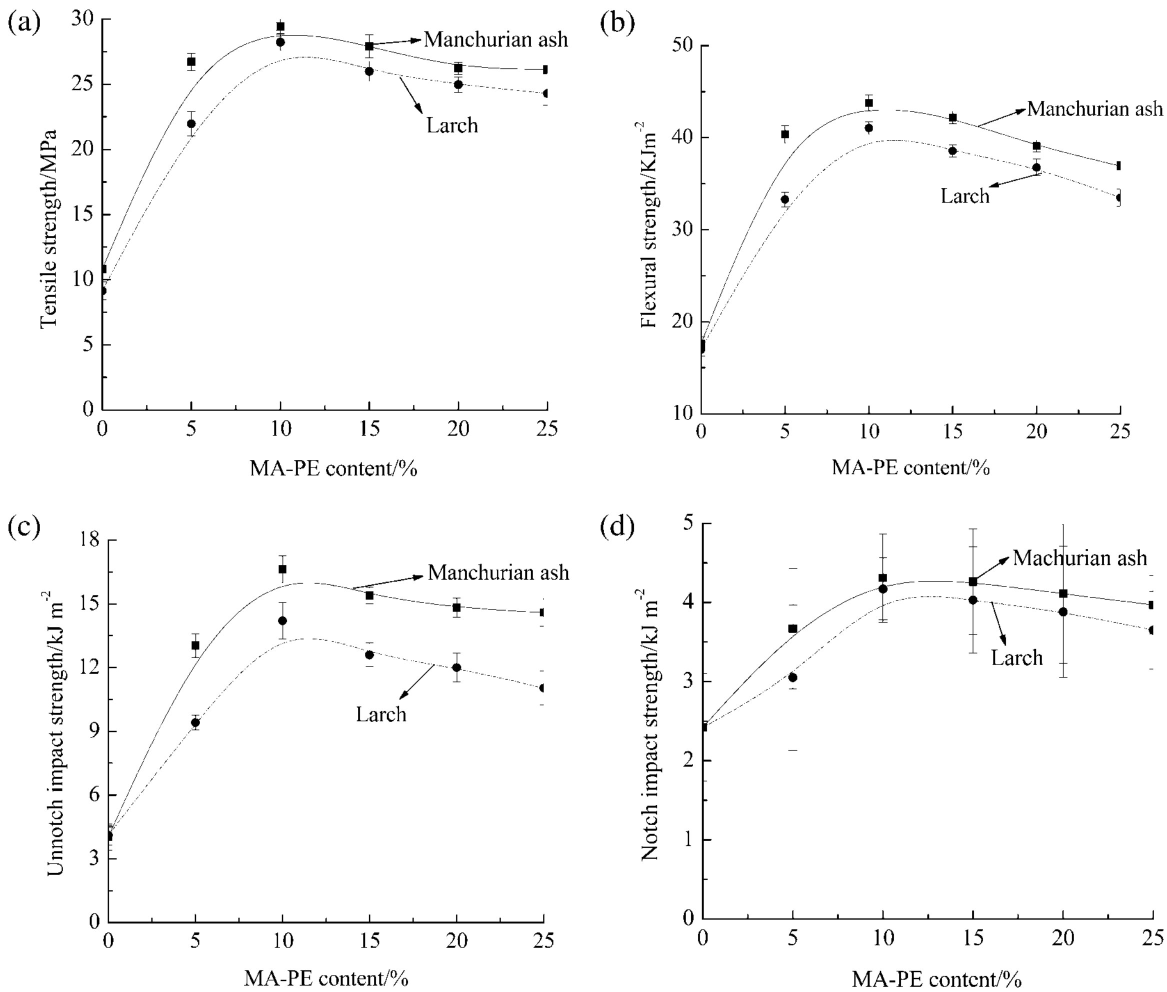

Figure 3 Effect of MA-PE content on mechanical properties of the composites, (a) tensile strength, (b) flexural strength, (c) unnotched impact strength, (d) notched impact strength.

properties of the composites based on the mechanical properties of the composites of differently extracted wood flour, seen in Table II. Table III gives the mechanical properties of HDPE/extracted wood flour composites with 5 wt % MA-PE. It was found that the mechanical properties of HDPE/wood flour composites modified with 5 wt % MA-PE were much higher than those of HDPE/wood flour

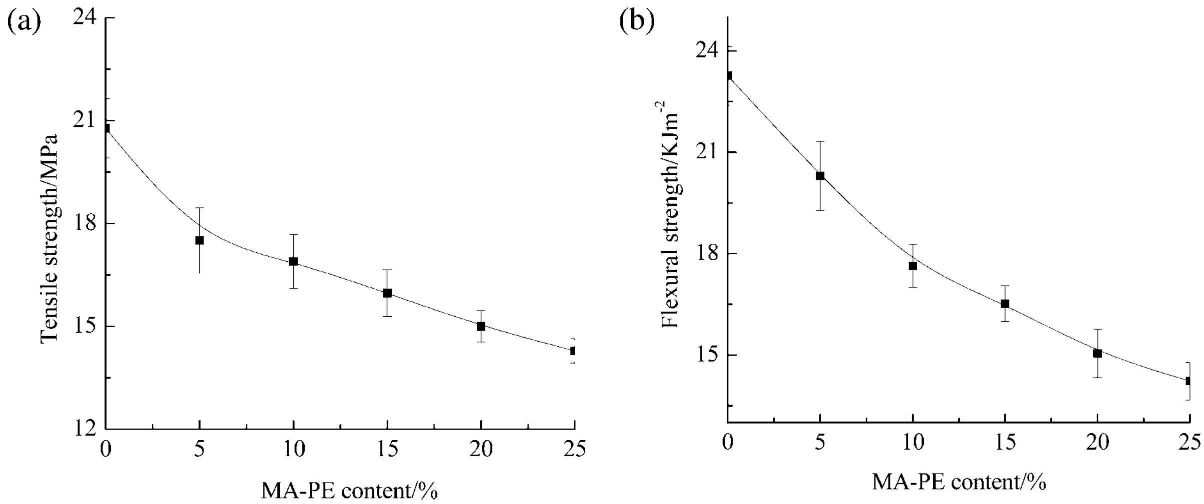

Figure 4 Effect of MA-PE content on mechanical properties of HDPE, (a) tensile strength, (b) flexural strength.

TABLE I
The Extract Content of Wood Flour by Different Extracting Methods

Extracting methods	Extractant content/%	
	Manchurian ash	Larch
Hot water	3.52	5.75
Benzene-ethanol	2.94	3.93
Petroleum ether	1.17	2.15

composites without MA-PE, whether unextracted wood flour or extracted wood flour, compared with the data in Table I. It is of interest that the manchurian ash and larch wood flour extracted by hot water made the mechanical properties of the composites become the same nearly, while the extracted wood flour obtained by benzene-ethanol or petroleum ether method presented different mechanical properties of the composites based upon different wood flours. These results are probably attributed to the fact that hot water can effectively extract polyhydroxyl compounds, such as low molecular weight sugars, to weaken the effect of them on the interfacial interaction between hydroxyl on surface of cellulose in wood flour and maleic anhydride groups on MA-PE. A similar result is reported in our previous work,[7] while the ability that benzene-ethanol or petroleum ether extracted low molecular weight sugars became weak.

Morphological structure of the composites

SEM patterns of the fractured surfaces of the composites can provide information about the interfacial compatibility between the wood flour and HDPE matrix. Figure 5 shows the morphological structures of HDPE/manchurian ash wood flour composites and HDPE/larch wood flour composites. From Figure 5(a,b), it is clearly observed that many empty spaces existed on the surface of wood flour in the composites without MA-PE, and the agglomerated wood flours in the composites. This result indicated that the interfacial adhesion between wood flour and HDPE and the dispersion of the wood flour in the composites were poor, hence, resulting in low mechanical properties.

MA-PE is considered to be one of the most effective compatilizers of polymer/wood composites. In order to improve the interfacial interaction between HDPE and wood flour to enhance the mechanical properties, MA-PE was added to the HDPE/wood flour composites. From Figure 5(c,d), it was difficult to differentiate wood flour from the matrix, the wood flour was embeded in HDPE matrix phase and well dispersed in the composites. Good adhesion between wood flours and HDPE were obtained. Therefore, this result produces a positive effect on the tensile, flexural and Izod impact strength, which means that loads can be transferred from HDPE matrix to the wood flour.

Figure 6 show the atomic force micrographs of HDPE/manchurian ash wood flour composites. It is also observed that gaps existed in interface between wood flour phase and HDPE phase in the composites without MA-PE, and the gap was about 200 nm based on AFM micrograph, whereas in the presence of 5 wt % MA-PE, the gap is disappeared, seen in Figure 6(b). This result further indicated that MA-PE effectively improved the interfacial interaction between HDPE and wood flour. AFM results are in agreement with SEM results.

SEM and AFM micrographs of other HDPE/wood flour composites are not presented here due to the same character of them.

Torque rheological behavior of the composites

Figures 7 and 8 show the torque versus time curves of HDPE/wood flour composites obtained at 180°C in torque rheometer. Figure 7(a,b) gives the effect of wood flour loading and species on the torque rheological behavior of the composites without MA-PE. It is found that the processing torque was clearly influenced by wood flour loading and species. At 60 wt % loading of manchurian ash, the torque of HDPE/manchurian ash wood flour composites presented the peak value in the melting process, while the torque of HDPE/larch wood flour composites

TABLE II
Effect of Extracted Wood Flour on Mechanical Properties of the Composites Without MA-PE

Mechanical Properties	Unextracted		Hot water		Benzene-ethanol		Petroleum ether	
	MWF[a]	LWF[b]	MWF	LWF	MWF	LWF	MWF	LWF
Tensile strength (MPa)	10.8	9.1	14.4	13.2	15.5	14.5	12.9	11.2
Flexural strength (MPa)	17.6	16.9	23.6	21.7	25.1	24.2	20.4	20.0
Unnotched impact strength (kJ m^{-2})	4.0	4.1	4.5	4.0	4.3	4.2	4.4	3.4
Notched impact strength (kJ m^{-2})	2.4	2.4	2.7	2.7	2.8	2.8	2.7	2.6

HDPE: wood flour = 40 : 60.
[a] MWF: manchurian ash wood flour.
[b] LWF: larch wood flour.

TABLE III
Effect of Extracted Wood Flour on Mechanical Properties of the Composites with 5 wt % MA-PE

	Unextracted		Hot water		Benzene-ethanol		Petroleum ether	
Mechanical Properties	MWF[a]	LWF[b]	MWF	LWF	MWF	LWF	MWF	LWF
Tensile strength (MPa)	26.7	21.9	29.8	29.8	30.7	26.7	30.1	25.0
Flexural strength (MPa)	40.3	33.3	46.1	41.2	45.5	38.4	44.5	35.3
Unnotched impact strength (kJ m^{-2})	13.0	9.4	14.7	13.5	16.0	9.6	16.0	9.9
Notched impact strength (kJ m^{-2})	3.7	3.1	4.1	4.1	4.4	3.4	4.3	3.4

HDPE: wood flour = 40 : 60.
[a] MWF: manchurian ash wood flour.
[b] LWF: larch wood flour.

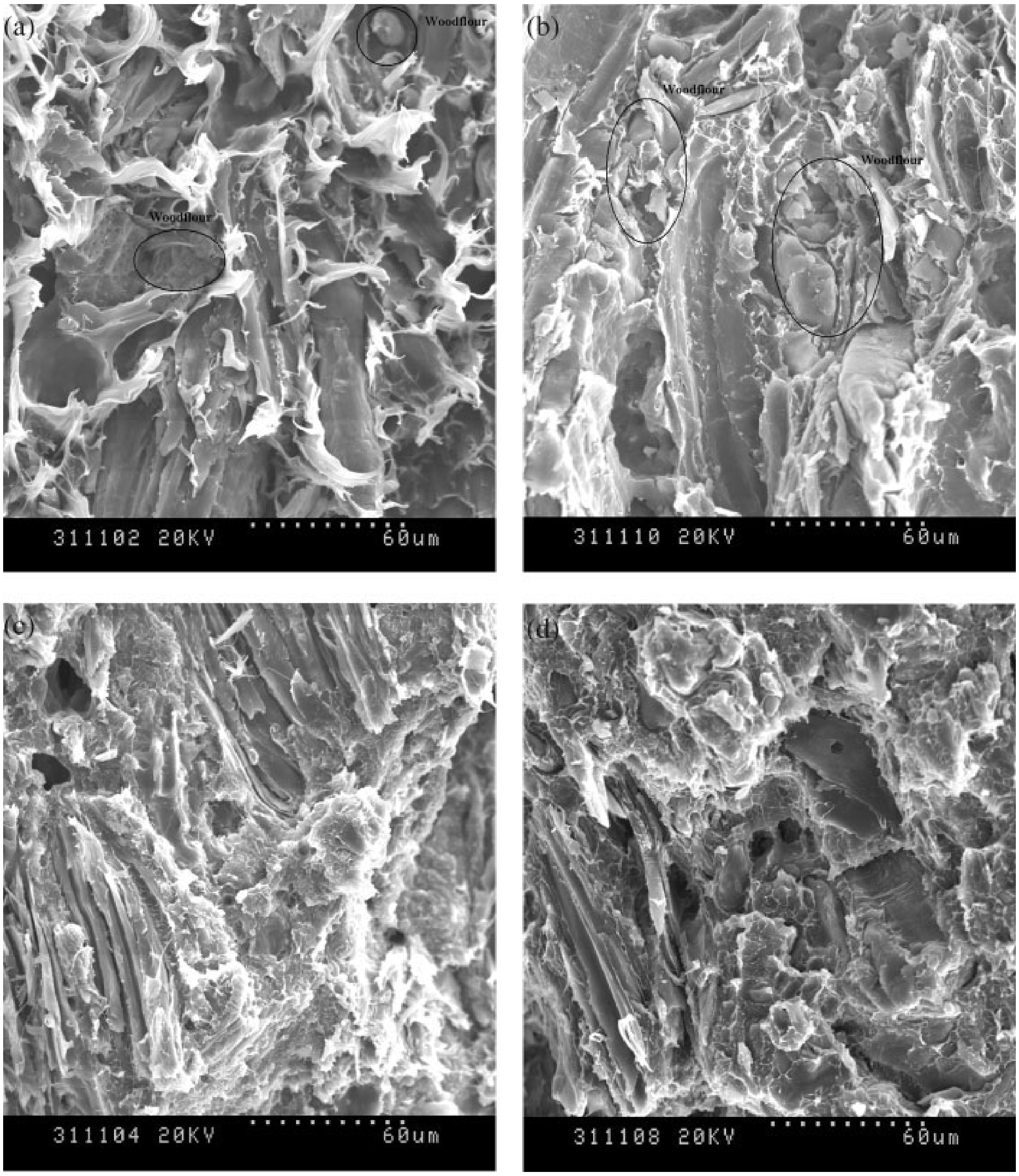

Figure 5 SEM micrograph of room-temperature fractured surface of the composites, ×500 (a) HDPE/manchurian ash woodflour composite, (b) HDPE/larch woodflour composite, (c) HDPE/manchurian ash woodflour with 5 wt % MA-PE, (d) HDPE/larch woodflour composite with 5 wt % MA-PE.

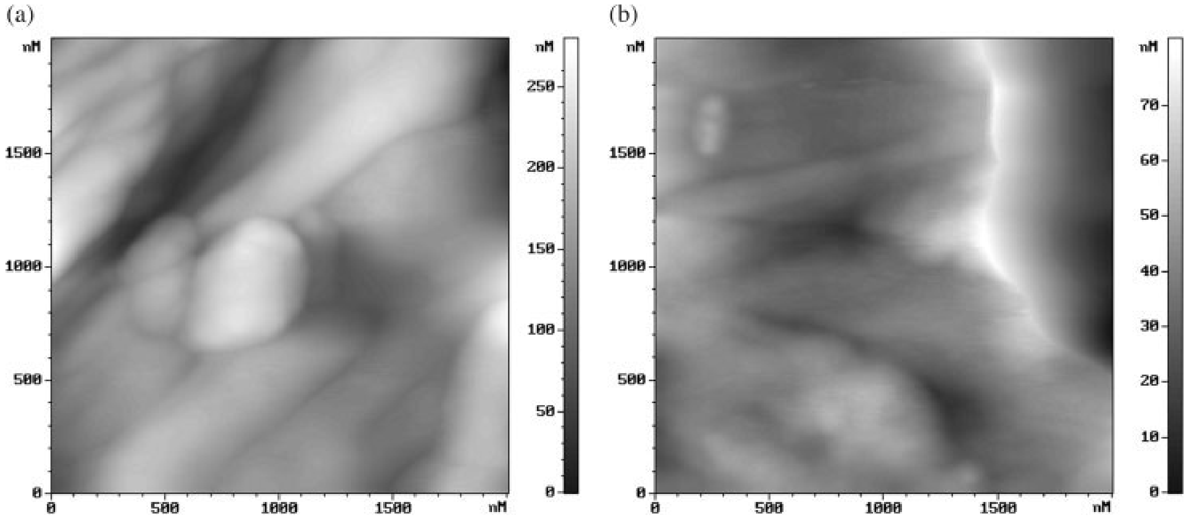

Figure 6 AFM micrograph of the composite transect, (a) HDPE/manchurian ash woodflour composite, (b) HDPE/manchurian ash woodflour composite with MA-PE.

presented the peak value at 60–70 wt % loading of larch. The torque peak presented that larch wood flour was beneficial to obtain the higher loading composites due to the higher content of extractants in larch wood flour as lubricants. This result demonstrated that larch wood flour was beneficial to obtain the composites with high loading of wood flour. In the presence of 5 wt % MA-PE, seen in

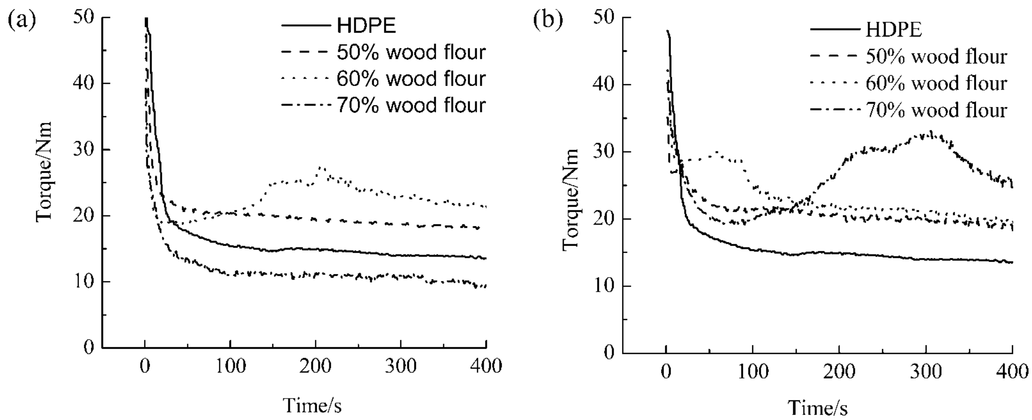

Figure 7 Torque curves of the composites. (a) HDPE/manchurian ash flour composite, (b) HDPE/larch flour composite.

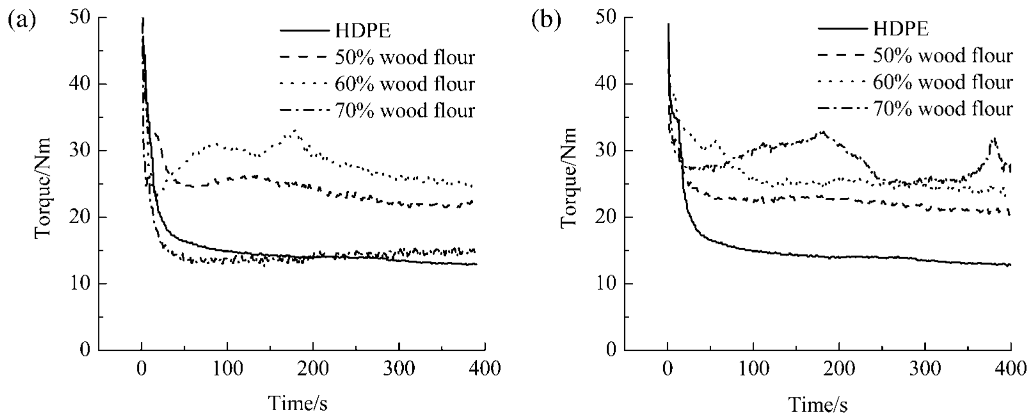

Figure 8 Torque curves of the composites with 5 wt % MA-PE. (a) HDPE/manchurian ash flour composite, (b) HDPE/larch flour composite.

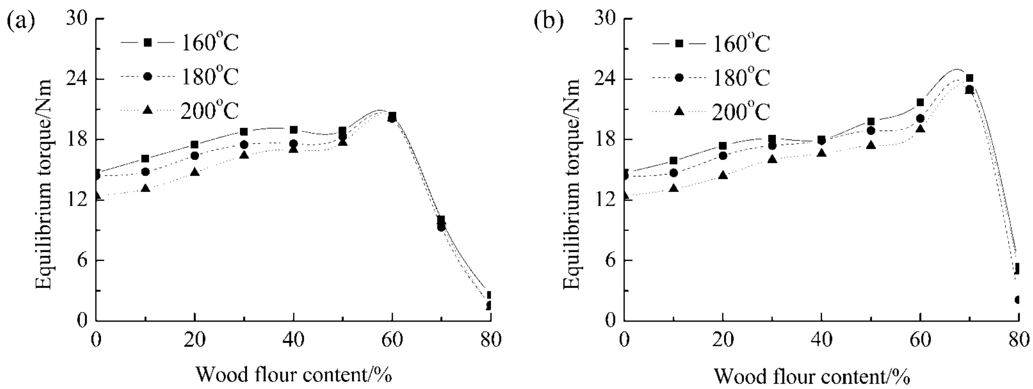

Figure 9 Effect of wood flour content on equilibrium torque of the composites without MA-PE. (a) HDPE/manchurian ash flour composite, (b) HDPE/larch flour composite.

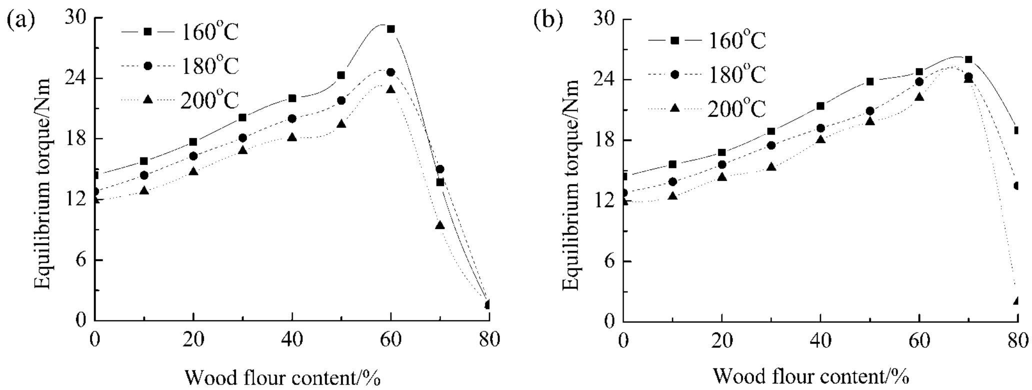

Figure 10 Effect of wood flour content on equilibrium torque of the composites with 5 wt % MA-PE. (a) HDPE/manchurian ash flour composite, (b) HDPE/larch flour composite.

Figure 8(a,b), the torque peaks appeared early at 60 wt % loading of mancurian ash wood flour, and 60 and 70 wt % loading of larch wood flour compared with the composites without MA-PE. When the loading of wood flour is 50 wt %, it is clearly observed that MA-PE made the torque-time curves appear the weak torque peak in both HDPE/manchurian ash wood flour composite and HDPE/larch wood flour composite. It is probably because maleic anhydride groups on MA-PE reacted with hydroxyl on the surface of cellulose in wood flour, consequently resulting in increasing the processing torque.

Figures 9 and 10 show the curves of the equilibrium torque versus the wood flour content at different temperatures, such as 160, 180, and 200°C. From Figure 8, at the same temperature, the equilibrium torque increased with the increase of the wood flour loading. When the loading of manchurian ash wood flour reached 60 wt %, and the loading of larch wood flour reached 70 wt % based on the composite, the equilibrium torque was maximal. However, after the maximal point, the equilibrium torque obviously decreased with the increase of the wood flour loading, and the plasticization effect was poor.

Figure 11 shows that the effect of MA-PE content on the equilibrium torques of the composites. It is found that the addition of MA-PE clearly enhanced the equilibrium torque of the composites, compared with the composites without MA-PE. However,

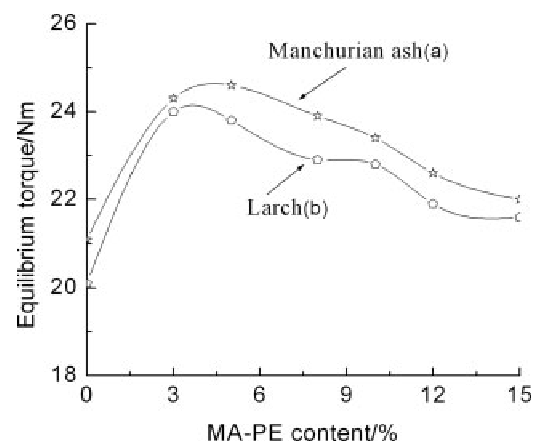

Figure 11 Effect of MA-PE content on equilibrium torque of the composites with 60 wt % wood flour. (a) HDPE/manchurian ash flour composite, (b) HDPE/larch flour composite.

when the loading level is more than 5 wt % based on the composite, the equilibrium torque of the composites lowered with the increase of wood flour content.

CONCLUSIONS

Two species of wood flours, such as machurian ash and larch, were used to prepare HDPE/wood flour composites in this contribution. The influence of wood flour species, wood flour content and MA-PE content on the mechanical properties, morphology, and rheology of the composites were investigated. The following conclusion can be drawn:

Without any compatbilizer, wood flour species, such as machurian ash and larch, presented little influence on the mechanical properties of the composites, and the mechanical properties of the composites decreased with the increase of wood flour content. However, in the presence of MA-PE, as a compatibilizer, the mechanical properties of the composites were obviously enhanced, and the tensile and flexural strength of the composites increased with the increase of wood flour content. These results demonstrated that MA-PE presented a strong ability of improving the interfacial compatibility of wood flour and HDPE. However, manchurian ash wood flour and larch wood flour showed different influences that MA-PE enhanced mechanical properties of the composites, due to different extractants in them. This result was proved by the mechanical properties of the composites obtained from extracted wood flour by different extraction methods. Microstructures of the interface between wood flour and HDPE matrix obtained by SEM and AFM micrographs further proved that MA-PE effectively improved the interfacial compatibility of the composites. The experimental results obtained by a torque rheometer demonstrated that the reactions of maleic anhydride groups on MA-PE with hydroxyl on cellulose in wood flour took place based upon the increase of equilibrium torque and the appearance of the torque peak, and larch wood flour was more beneficial to obtain the composites containing the higher wood flour content.

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