22

Morphology and Thermo Mechanical Properties of Wood/Polypropylene Composites

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1. Introduction

Because of the future scarcity of fossil raw material and taking into account current environmental concerns, the development of eco-materials occupies a large number of research centers. Wood polymer composites (WPC) made from wood flour and polymer matrices, are part of this logic. In today's world, the growing needs of the population and the growing technological innovation are pushing industrial and researchers to move towards so-called new generation products such as wood polymer composites whose production increases considerably from year to year. In recent years, wood–fibers have gained significant interest as reinforcing material for commercial thermoplastics. They are now fast evolving as a potential alternative to inorganic fillers for various applications. These composites made from blends of thermoplastics and natural fibers have gained popularity in a variety of applications because they combine the desirable durability of plastics with the cost effectiveness of natural fibers as fillers or reinforcing agents and several advantages like low density, high specific properties, non-abrasive to processing equipment, low cost and most importantly biodegradability (Timmons et al., 1971). In tropical countries, fibrous plants are available in abundance; these fibers with high specific strength improve the mechanical properties of the polymer matrix. Wood is renewable, recyclable and biodegradable, characteristics well appreciated by environmentalists. For these reasons, combining the plastic timber produces a more accepted material. However, consumers want more and more natural materials. But in practice there are a lot of waste that can be exploited in combination with polymers to form composites that are resistant thermoplastic timber, recyclable and can be burned for energy recovery. The addition of wood wood flour, into the polymer matrix leads to an improvement in the stiffness of the composite and decreases in the abrasiveness on processing equipment and density of the product compared to mineral fillers. Because of these attributes, Wood/polypropylene composites (WPCs) are used in a variety of innovative applications. A composite material is a blend of at least two different elements. The new material thus formed, has properties that the elements alone do not possess. Wood polymer composite consists of a wooden frame

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called reinforcement (load) that provides the mechanical strength and protection called matrix that is the plastic (thermosetting or thermoplastic resin), which ensures the cohesion of the structure and transmission efforts towards the reinforcement while ensuring the cohesion of the material, gives it its final form and provides the interface with the mechanical environment and additives (accounting, anti-UV, antioxidants, fire retardants) which give the composite properties particular requirements for durability and performance of these materials for outdoor use. However the primary drawback of using wood–fibers for reinforcement is the poor interfacial adhesion between polar-hydrophilic wood–fibers and non polar-hydrophobic plastics (Diène et al., 2008). The WPC are used in four areas: Building materials account for 75% of production. The products concerned are mainly patios, fences, doors, windows and moldings decorative. The consumer and industrial products account for 10% of this market. In this domain, WPC are used in making furniture, cabinets, floor, pallet handling, brackets, boxes and containers. Motor vehicles occupy 8% of this sector. WPC are like interior components of vehicles such as door panels, components of trunk, empty-pockets, cargo cover and so on. Other applications include mainly municipal infrastructure, marine applications, etc... They account for 7% of the production. Among the products manufactured facilities parks, picnic tables, modules, games, etc... Interfacial interactions are very weak in wood/polymer composites , because the surface free energy of both the filler and the polymer is very small (Maldas & Kokta, 1993). As a consequence adhesion must be improved practically always to achieve acceptable properties. Various techniques are used or at least tried for the improvement of interfacial adhesion including the treatment of the wood with sodium hydroxide (Ichazo et al. 2001; Cantero et al. 2003), coupling with functional silanes (Ichazo et al. 2001), or the coating of wood flour with stearic acid (Stark N.M., 1999; Raj R.G. & Kokta B.V., 1991). However, polymers functionalized with maleic anhydride (Kazayawoko et al., 1999; Bledzki A. K. & Faruk O., 2002). The functional groups of these polymers were shown to interact strongly or even react chemically with the surface of wood (Lu et al., 2005; Kazayawoko et al. 1997), while the long alkyl chains diffuse into the matrix making stress transfer possible. The aim of this work is to develop composite materials from polyolefin (polypropylene) and wood flour with coupling agent. One of most popular methods to improve the durability of wood is chemical modification by some small chemical reagents. Among these reagents, acid anhydrides, inorganic acid esters, acid chlorides, aldehydes, lactones, reactive vinyl compounds, epoxides and isocyanates are most useful compounds. In this research, maleic anhydride was selected for its active ring-anhydride group, which is capable of easily reacting with hydroxyl groups on wood without reversed effect on environment and resultantly reducing amounts of hydroxyl groups. Consequently, it's a promising way to improve the wood durability. A first series of specimen was obtained by blending wood flour and polymeric material. In a second series, polypropylene grafted- maleic anhydride was added to the previous ingredients. The first key point for the production of acceptable WPC is the compatibility between wood and polymer host matrix. Wood is hydrophilic in nature (high surface tension), which lowers the compatibility with hydrophobic polymeric material (low surface tension) during composite preparation; this leads to WPCs with poor dispersions of wood fibers [Kazayawoko et al., 1999, 1997; Woodhams et al., 1984; Li Q. & Matuana LM., 2003). Scanning the literature, one can find different surface treatments that have been experienced to improve wood/polymer

adhesion in composites. Remind that the level of adhesion and/or the dispersion state of wood are the key points for the improvement of mechanical properties of the composites. Indeed, the wood particles which have high strength and modulus – with good adhesion and uniform dispersion – can impart better mechanical properties to the host polymer in order to obtain a composite with better properties than those of the unfilled polymer. Substantial research has been carried out on the surface modification of wood fibers with coupling agents to improve the strength properties of WPCs (Woodhams et al., 1984; Li Q. & Matuana L. M., 2003), among these, the addition of maleated polypropylene (MAPP) in polypropylene (PP)-based WPCs has been shown to appreciably improve the dispersion of fibers in the matrix and the mechanical properties of WPCs because of the formation of linkages between the OH groups of wood and maleic anhydride. Many authors (Kazayawoko et al., 1999; Woodhams et al., 1984) in-depth studies have elucidated the mechanisms of adhesion between MAPP treated wood fibers and the PP matrix that cause the improvement. In our study the effects of the incorporation of wood particles with and without a compatibilizing agent on the processing and properties of WPC and the effects of wood flour concentrations on the mechanical properties of the composites were investigated and the results are discussed.

2. Experimental

2.1 Materials

The wood flour particles of 425 microns (40-mesh) in size were kindly donated by American Wood fibers (Schofield, WI) and are constituted predominantly with ponderosa pine, maple, oak, spruce, southern yellow pine, cedar. The wood was oven dried at 100°C for 24 h before processing to remove moisture. The isotactic polypropylene matrix (PP) has a density of 0.9 g/cm^3 and a melt flow index of 2.5 g/10 min, it was provided by Solvay Co. Polypropylene grafted with maleic anhydride (MAPP) with an approximate maleic anhydride (MA) content of 3 wt. % was purchased from Aldrich Chemical Company, Inc. (Milwaukee, WI). All ingredients were used as received.

2.2 Compounding and processing

Before compounding, the wood flour was dried in an oven for at least 48 h at 105°C to a moisture content of less than 1%. The dried wood flours were stored in a sealed plastic container to prevent the absorption of water vapor. The PP matrix, dried wood flour, MAPP, were added to a high-intensity mixer (Papenmeier, TGAHK20, Germany) and dry-blended at room temperature for 10 min. After blending, the compounded materials were stored in a sealed plastic container. Several formulations were produced with various contents of wood flour, PP and MAPP (table 1). For the mechanical property experiments, test specimens were molded in a 33-Cincinnati Milacron reciprocating screw-injection molder (Batavia, OH). The nozzle temperature was set to 204°C. The extrudate, in the form of strands, was cooled in the air and pelletized. The resulting pellets were dried at 105°C for 24 h before they were injection-molded into the ASTM test specimens for flexural, tensile (Type I, ASTM D 638), and Izod impact strength testing. The dimensions of the specimens for the flexural tests were 120x 3x 12 mm^3 (Length x Thickness x Width). The different samples and their code are listed in table 1.

2.3 Electron and optical microscopy

The state of dispersion of the wood inside the polymeric matrix was analyzed using optical microscopy on samples of 100–200 lm thick. Scanning electron microscopy (SEM) was used to obtain microphotographs of the fracture surfaces of the wood composites. These fractures have been performed in liquid nitrogen to avoid any deformation. SEM has been performed using a FEI Quanta 400 microscope working at 30 kV. The polymer surface was examined with LEICA optical microscope working in a transmission mode. Samples were thin enough that no special preparation of the samples was needed for their observations with the optical microscope.

2.4 Differential scanning calorymeter (DSC)

Wood, natural and synthetic polymers are subject to a degradation of the mechanical properties under the influence of increased temperatures (Munker M., 1998). It is very important to have knowledge about the effect of the processing temperatures in relation to the processing duration because there is always thermal stress during the manufacturing of WPC. Important properties concerning the thermal stability of the WPC are obtained from the differential scanning calorimetric (DSC). DSC is widely used to characterize the thermal properties of WPCs. DSC can measure important thermoplastic properties, including the melting temperature (Tm), heat of melting, degree of crystallinity [x(%)] crystallization, and presence of recyclates/ regrinds, nucleating agents, plasticizers, and polymer blends (the presence, composition, and compatibility). Thermal analysis of the WPC samples was carried out on a differential scanning calorimeter (PerkinElmer Instruments, Pyris Diamond DSC, Shelton, Connecticut) with the temperature calibrated with indium. All DSC measurements were performed with powdered samples of about (8–10)±0.5mg under a nitrogen atmosphere with a flow rate of 20 ml/min. Three replicates were run for each specimen. All samples were subjected to the same thermal history with the following thermal protocol, which was slightly modified from the one reported by (Valentini L. et al., 2003):

First, the samples were heated from 40 to 180°C at a heating rate of 20°C/min to erase the thermal history.

Second, the samples were cooled from 180 to 40.00°C at a cooling rate of 10°C/min to detect the crystallization temperature (Tc).

Finally, the samples were heated from 40 to 180°C at a heating rate of 10°C/min to determine Tm. Tm and the heat of fusion (ΔH_m) were calculated from the thermograms obtained during the second heating. The values of (ΔH_m) were used to estimate x(%), which was adjusted for each sample.

2.5 Mechanical tests

Tensile tests (tensile strength and tensile strain) and three-point flexural tests (flexural strength) were carried out on an Instron 5585H testing machine (Norwood, MA) with crosshead rates of 12.5 and 1.35 mm/min according to the procedures outlined in ASTM standards D 638 and D 790, respectively eight replicates were conducted to obtain an average value for each formulation. Before each test, the films were conditioned in a 50% relative humidity chamber at 23°C for 48 h. The Izod impact strength was measured with an

Instron impact pendulum tester (model PW5) according to ASTM D 256 with acutely notched specimens (notch depth = 2 mm) at room temperature. Each mean value represented an average of eight tests. The impact strength is defined as the ability of a material to resist the fracture under stress applied at a high speed. The impact properties of composite materials are directly related to their overall toughness. In the Izod standard test, the only measured variable is the total energy required to break a notched sample. Specimens for the test had the following dimensions 50 x 12.7 x 3.2 mm^3. Eight replicates for each composition were tested for impact strength.

Sample	PP (%)	Wood (%)
WPPC0	100	0
WPPC1	95	5
WPPC3	75	25
WPPC4	50	50

(a)

Sample	PP (%)	Wood (%)	MAPP (%)
WPPC0*	95	0	5
WPPC1*	90	5	5
WPPC3*	70	25	5
WPPC4*	45	50	5

(b)

Table 1. Composition and code of the wood/polymer composites (percentage is in weight). The star (*) denotes a composite with Wood/PP and 5% wt MAPP.

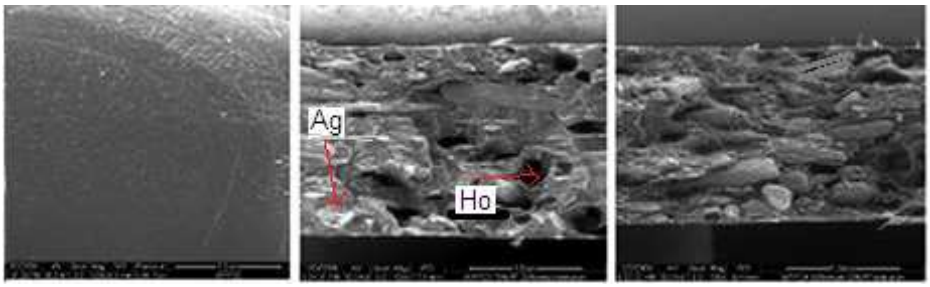
3. Results and discussions

The results are discussed in several sub-sections in accordance with the goals of the study.

3.1 Structure and morphology (SEM)

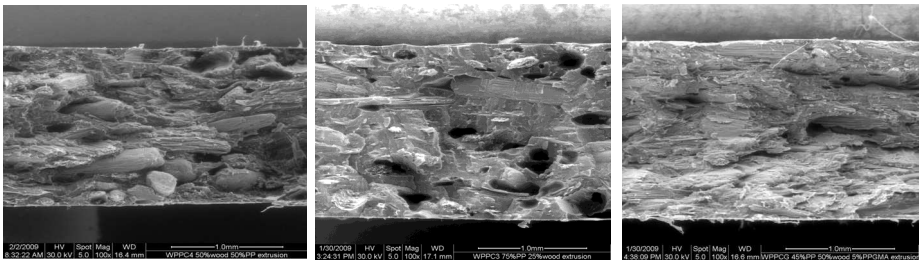
Figure 1 and figure 2 show the micrographs of WPCs. It is well known that the properties of wood polymer composites are highly dependent on the wood dispersion and adhesion with the polymer matrix. Figure 1a shows the SEM image of the pure PP fracture surface which was smooth and featureless. As for the WPC, the wood's particles are detected as white dots in figure 1b, 2a and 2b. These figures reveal more separate wood chips and polymer areas for the non compatibilized system. The micrograph in Fig.1c and fig.2c, show that with MAPP there is better dispersion and less voids than without MAPP in fig.1b, fig.2a and fig.2b. On the other hand, between the fig.2a and 2b, it is visible that the dispersion is better in figure 2b; where there's less wood, these two figures show that dispersion decrease with wood loading. When the wood content was enough higher, the particles were uniformly distributed in the PP matrix. They exhibited many single disperse particles and aggregates integrated with particles. The matrix is not enough to encapsulate the solid micro particles of wood. However, large aggregates were found, and the aggregate size increased substantially in these micrographs with higher with higher wood loading wood. The copolymers in the blends can act as a compatibilizer decreasing the interfacial tension between the blend components of the mixture while enhancing the dispersion of dispersed phase in the matrix (Moon H.S., 1994). MAPP improves interfacial adhesion and prevents the debonding of even very large particles. Interfacial interactions and the strength of adhesion determine micromechanical deformation processes and the failure mode of the composites (Renner et al., 2009). The SEM micrographs taken from the surface of broken specimens provide indirect information about the failure mode and interfacial adhesion. Fig.1c

and fig.2c present the fracture surface of specimens prepared with MAPP. The coverage of the wood with the polymer and the relatively small number of holes related to debonding or fiber pull out indicate good adhesion. On the other hand, the opposite is observed in composites prepared without MAPP. The number of debonded particles is quite large, the contours of particles remaining on the surface are sharp, and adhesion seems to be poor, at least compared to MAPP modification.



(a) (b) (c)

Fig. 1. SEM micrographs of (a) pure PP and composites containing (b) wood/PP (25/75) and (c) wood/PP/MAPP (25/70/5). Ho seems holes and Ag seems aggregate.



(a) (b) (c)

Fig. 2. SEM micrographs (a) Wood/PP (50/50), (b) Wood/PP (25/75) and (c) Wood/PP /MAPP (25/70/5).

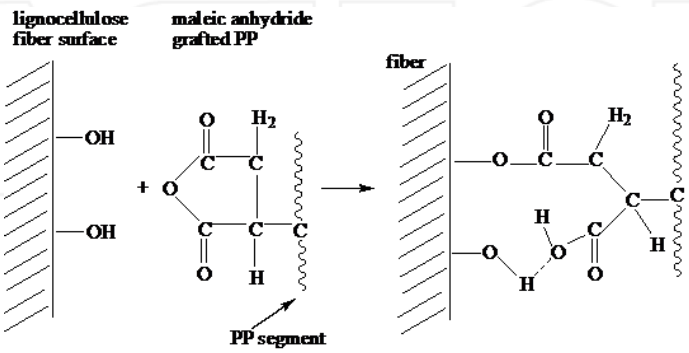


Fig. 3. Schematic description of the grafting of maleic anhydride with wood (Gauthier et al., 1999).

Figure 3 shows the summary of the grafting reaction of MAPP with wood.

3.2 Thermal and crystallization behavior

In this work, the thermal stability, the process of crystallization and melting of PP in its composites with wood (red pine) are studied by SEM analysis and differential scanning calorimetry, respectively, as a function of the wood content and coupling agent.

The physical properties of the WPC could be significantly affected by the crystallization characteristics of PP. Table 2 summarizes the results obtained from this heating run for all of the samples. The measurements were performed immediately after the melt-quenching thermal and crystallization behavior. The physical properties of the WPC could be significantly affected by the crystallization characteristics of PP. The measurements were performed immediately after the melt-quenching scans, so the samples had the same thermal history without an aging cycle. The curves revealed the following thermal events with increasing temperature: the cold crystallization process characterized by T_c and the cold crystallization enthalpy ΔH_c, and the melting process with following characteristics melting temperature (T_m) and melting enthalpy (ΔH_m). Comparing the thermograms and calorimetric parameters collected in table 2, one can see that with a filling of wood, as shown in this table, neat PP represented a tiny broad exothermic peak at 120°C, which indicated a rather low cold crystallization capability. However, in the case of WPC, this peak was sharper and appeared at much higher temperature, and the crystallization enthalpies increased correspondingly.

Sample code	Tc(°C)	$-\Delta H_c$ (J/g)	Tm(°C)	ΔH_m (J/g)	χ(%)	χ_{corr} (%)
WPPC0	120.8	87.9	160.1	89.2	37.9	37.9
WPPC1	123.4	94.9	160.8	95.7	34.3	38.2
WPPC3	124.7	92.7	162.5	93.0	30.1	40.1
WPPC4	125.1	89.0	162.7	90.7	20.6	41.2

Table 2. Thermal and Crystalline Properties of the neat PP and WPCs

The double endothermic melting peaks are visible on the thermograms, as shown in fig.4. Due to the reorganization during heating; the composite appears to slide to a more stable phase that melts at a higher temperature. We know that for pure PP one endothermic peak of melting occurs at 160°C corresponding to melting of its crystalline phase. On the thermograms of samples with a rate of wood more than 25%, we notice a slight peak at 110°C after the main crystallization peak around 120°C (cooled from the melt) and another small peak at 145°C (heating) before the main melting peak of the composite which arrived at 160°C. This corroborates the heterogeneity of the material. Scanning the literature, some authors have noticed these very specific peaks. Maillard and co-author (Maillard et al., 2008) observed these peaks at the same temperatures. Some authors (Quilin et al., 1993) believe that this is not a real effect, but simply a result in heat capacities between the samples of pure PP and those impregnated wood, causing an apparent shift in temperature

measurement. According to the data listed in table 2, the Tc values of all the WPC were greatly increased compared to that of neat PP.

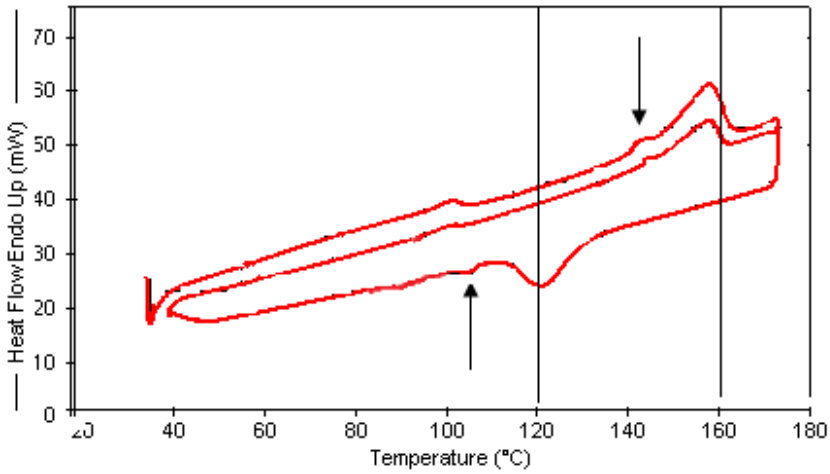


Fig. 4. DSC curve of heating and cooling of WPPC3

In the meantime, ΔH_c were decreased gradually with increasing the rate the rate of wood incorporated. This phenomenon between reinforcing material and polymer matrix has been reported in many other articles (Nam et al., 2001; Sinha et al., 2002). Generally, with the addition of lower content of wood, the polymer in the WPC, formed crystals much more easily because of the nucleation effect of the wood particles. However, when it reached certain content, the appearance of some aggregates restricted the crystallization behavior of PP. These results suggested that the incorporation of wood enhanced the cold crystalline ability of PP. The crystallization arrives sooner in WPC than in pure PP; this phenomenon was ascribed to a nucleating effect of the wood, which accelerated the crystallization speed of PP. The addition of wood flour had the effect of shifting Tm to higher temperatures. This increase was accompanied by an increased of crystallinity $x(\%)$. We corrected the degree of crystallinity of the composites $x_{cor}(\%)$ in the equation (1) by taking into account the wood-flour concentration:

$$x_{cor}(\%) = \frac{\Delta H_m}{(1\text{-MF}).\Delta H_o} \tag{1}$$

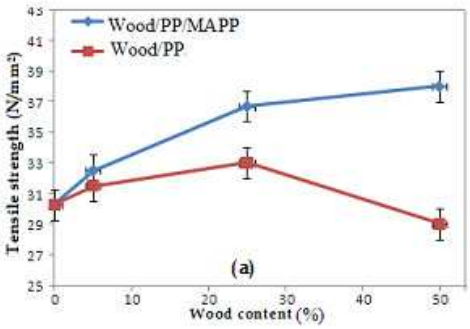
where ΔH_m and ΔH_o are respectively the melting enthalpies of the composite and polymer with 100% crystallinity and MF is the mass fraction of the wood in the composite.

This result can be explained by the agglomeration of the wood's particles. More wood's particles were added, and more aggregates were formed. In general, larger aggregates contributed to the crystallization of PP. This significantly conformed by the gradually decrease of ΔH_c that corresponded to the increase in wood content. With wood loading, the T_m increases for all WPC; this was ascribed to the poor thermal conductivity of wood. In

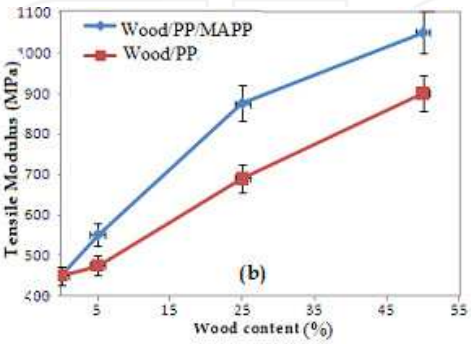
the composite, wood flour acted as an insulating material, hindering the heat conductivity. As a result, the WPC compounds needed more heat to melt. Similar findings were previously reported by Matuana and co-author (Matuana L. M. & Kim J.W., 2007) for PVC based wood–plastic composites. They found that the addition of wood flour to the PVC resin caused significant significant increase in the temperature and energy at which fusion between the particles started. The delayed fusion time observed in rigid PVC/wood flour composites was attributed to the poor thermal conductivity of the wood flour; this decreased the transfer of heat and shear throughout the PVC grains. These phenomena were consistent with the results of this study.

3.3 Mechanical properties

Tensile strength, flexural strength, module of elasticity (MOE) and elongation at break provide an excellent measure of the degree of reinforcement provided by the fiber to the composite (Mueller D.H. & Krobjilowski A., 2003). It can be seen from fig.5a and fig.5b respectively that the tensile strength and the tensile modulus increase with wood content.



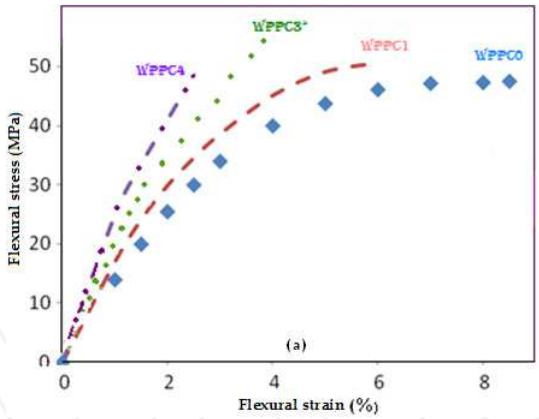
(a)



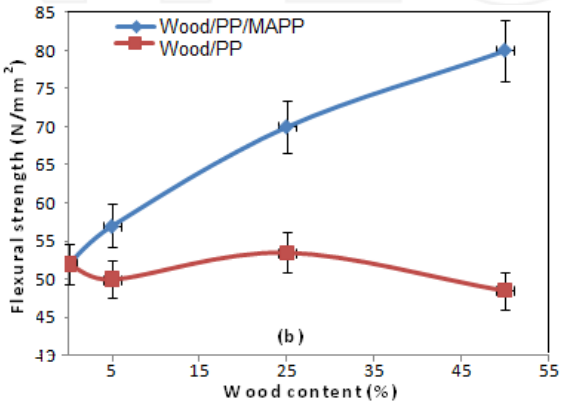
(b)

Fig. 5. Tensile strength and tensile modulus respectively in (a) and (b) versus wood content.

Tensile strength increases over WPC. Whereas, without compatibilizer, the tensiles strength of the composites are in the range of 33.5–28.5 N/mm^2 at wood loading from 5% to 50%, suggesting that, there is little stress transfer from the matrix to the fibers irrespective of the amount of wood present. When MAPP was incorporated into the WPC, the wood was relatively well dispersed and the interaction has occurred between the wood and matrix that was corresponding to the improved tensile strength. The use of MAPP improves interaction and adhesion between the fibers and matrix leading to better matrix to stress transfer. Similar observations were reported by Felix and Gatenholm (Felix J. M. & Gatenholm P., 1991) where tensile strength of the composites increased linearly with fiber content when MAPP treated fibers were used instead of untreated fibers. Myers et al. (Myers et al., 1993) reported 21% increase in tensile strength for a 50:50 wood flour polypropylene composites when MAPP was used as a compatibilizer. Stark and Rowlands (Stark N. M. & Rowlands R. E., 2003) also reported a 27% increase in tensile strength of composite prepared with 40% wood–fiber and 3% MAPP. At lower filler content the tensile modulus does not seem to be affected by improved adhesion (Felix J. M. & Gatenholm P., 1991). However at higher filler loading the tensile modulus of the composites with compatibilizer was much superior to that of the composites without compatibilizer. Compatibilizers can change the molecular morphology of the polymer chains near the fiber–polymer interphase. Yin et al. (Yin et al., 1999) reported that the addition of coupling agent (MAPP) even at low levels (1–2%) increases the nucleation capacity of wood– fibers for polypropylene, and dramatically alters the crystal morphology of polypropylene around the fiber. When MAPP is added, surface crystallization dominates over bulk crystallization and a transcrystalline layer can be formed around the wood–fibers. Crystallites have much higher moduli as compared to the amorphous regions and can increase the modulus contribution of the polymer matrix to the composite modulus (Sinha et al., 2002). The elongation at break (Fig.6) decreases steadily with the wood–fiber content. There is no significant difference in elongation at break for composites with and without compatibilizer so we have only represented the stress versus strain for only WPC without coupling agent. The steep decline in elongation immediately on filler addition is obvious, because wood–fibers have low elongation at break and restrict the polymer molecules flowing past one another. This behavior is typical of reinforced thermoplastics in general and has been reported by many researchers (Felix J.M. & Gatenholm P., 1991). Adding a suitable interface modifier will promote the stability of the morphology in wood plastic composite (Snijder M.H.B. & Bos H.L., 2000). The crystallinity results can help to explain the results from the mechanical testing. The strength and modulus are increasing with wood content in WPC at the same time, in the DSC curves (not represented here), the degree of crystallinity of these samples increases. Introducing wood filler modifies the mechanical behavior by making the material stiffer, which is characterized by the significantly decreased failure strain. The addition of wood decreases the compatibility between the hydrophilic wood material and hydrophobic matrices (binders) and entanglement between the PP and its molecules. This results in poor interphase properties and a lower strain to failure of the composite. The percentage elongation of all the composites with wood decreased with wood loading until 50% as compared to neat polymer. From the stress–strain curve of the composites with different wood loading (fig.6a), it is found that the stress–strain curve of pure polypropylene is similar to that of brittle materials. The behavior is perfectly elastic, the stress increases linearly with strain. However, addition of wood makes the matrix more ductile. This is evident from the elongation at break values of the composites. The flexural strength (fig.6b) increase with wood loading and the coupling agent make this phenomenon more pronounced.



(a)



(b)

Fig. 6. Curves of: (a) Flexural stress/strain and (b) flexural strength function of wood content.

Figure 7 exhibits the curves of Izod impact strength function of wood incorporated. It is important to note that the impact test machine used in this study did not provide enough energy to break the neat PP because of the high flexibility of the PP matrix. By contrast, all of the composites with and without MAPP broke completely. For the impact property testing, composites with high wood fiber content possess low impact strength and notched impact strength decreases with the increasing of wood flour content. The positive effect of the coupling agent reduces this phenomenon. The main factors influencing impact strength is the size of the disperse phase. Impact strength of WPC blends decreases as a function of dispersed phase (Albano et al., 2002). SEM micrographs (Figures 1b, 1c and 2) show some fracture surfaces of WPC where the fibers are still covered by the polymer matrix; this result indicates that matrix cohesive failure was the dominant failure mode. Wood flour is kind of stiff organic filler, comparing to PP, so adding wood flour could decrease the impact strength of composite. The scanning electron microscope illustrated that the polymer intimately associated in the wood structure altered the mode of fracture. Composite treated with MAPP like interface modifier exhibited better impact strength than the untreated ones

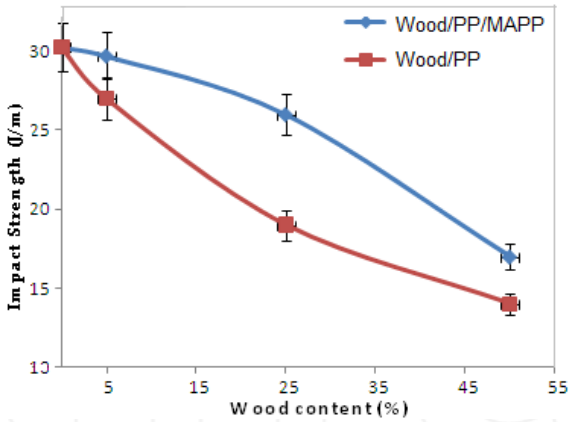


Fig. 7. Izod impact strength of WPC as function of wood content

since the debonding behavior between the interface of wood flour and PP matrix absorb larger impact energy in modified composites than the unmodified ones. Decreased impact strength of wood/ PP/MAPP composites was explained with the stronger interfacial adhesion and rigidity created by the larger functionality of MAPP used (Hristov et al., 2004). It was clear that the addition of wood particles impaired the impact strength of the wood polymer composites. The wood's particles were rigid with high strength and high modulus, which cannot generate deformation when impact is exerted on them. So, they cannot absorb impact energy by terminating the cracks or producing craze. Therefore, the brittleness of the composites increased and the impact strength decreased. A larger number of bonds may form on a unit surface of the wood in the case of larger functionality and this could lead to better stress transfer, but this was contradicted by our results. However, the filler/coupling agent interaction is only one side of the interphase forming in these composites and we must consider also the coupling agent/polymer interface. Large functionality leads to more reactions with the wood and shorter free chains, which cannot entangle with the polymer as efficiently as longer molecules. This leads to smaller deformability of the interphase, and of the entire composite.

4. Conclusion

The effects of the incorporation of wood particles both with and without a compatibilizing agent on the processing and properties of WPC composites were investigated. The morphology (SEM) indicates that the composites treated with MAPP modifiers exhibit much better bonding between flour and matrix. Heat deflection temperature increases with the increasing of wood flour content. When exposed to a source of chemical degradation, the morphology of WPC may be change, and in some cases disruption of the crystalline order occurs as detected by reduction in the fractional crystallinity of PP. Tensile strength, tensile modulus and flexural strength are significantly increased with increasing wood flour content. Mechanical properties, measured in tensile and flexural tests, demonstrated that the wood flour used in this work act as effective reinforcing agents for PP. Addition of wood flour, at all levels, resulted in more rigid and tenacious composite, but had lower impact energy and lower percentage of elongation as compared to the polymer matrix. The increase in mechanical properties demonstrated that MAPP is an effective compatibilizer for wood polypropylene composites. The presence of wood in the composite generated imperfect adhesion between the

components of the composite; this increased the concentration of stress and decreased the impact strength. Increasing the wood content in the composites led to an increased stress concentration because of the poor bonding between the wood flour and the polymer. Although crack propagation became difficult in the polymeric matrix reinforced with filler. The results show that the presence of wood flour in the composite was accompanied by an evolution of the crystallization. This study demonstrated that wood flour could be successfully used as a reinforcing material in a polypropylene matrix. MAPP coupling agent improves the compatibility between wood flour and PP resin. Taking these advantages into account, wood flour reinforced composites can be manufactured successfully using injection moulding. They represent a suitable material which is an alternative to glass fibers reinforcements for lots of applications in the range of lower mechanical loads. The manufacture of wood polymer composites allows not only to recover the waste wood from the forest industry, but also to reduce the use of fossil resources.

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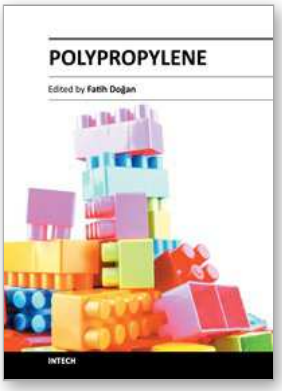

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This book aims to bring together researchers and their papers on polypropylene, and to describe and illustrate the developmental stages polypropylene has gone through over the last 70 years. Besides, one can find papers not only on every application and practice of polypropylene but also on the latest polypropylene technologies. It is also intended in this compilation to present information on polypropylene in a medium readily accessible for any reader.

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