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Evaluation of Mechanical and Morphological Behavior of Polypropylene/Wood Fiber Nanocomposite Prepared by Melts Compounding

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***Abstract*—Weak flexural properties of wood plastic composites (WPCs) limit their structural application. Recently investigation of nano particles looks promising to enhance bending properties of WPCs. In this study, the authors have investigated the effect of different concentrations of nanoclay (modified montmorillonite) and coupling agent on the mechanical and micro-structural properties of polypropylene/ wood-fiber composites. We Bath internal mixer in certain processing conditions used for making the samples and then all samples molded using injection molding for making samples for performing mechanical measurements. Samples prepared in four different concentration of nanoclay 0, 1, 3 and 5 wt% (total weight) and two different concentrations of maleic anhydride grafting (MAPP) 5 and 10 wt%. Mechanical results indicate that both flexural and impact strength of the composites increasing in sample containing 3% nano clay. In other trend, Scanning Electron Microscope (SEM) images show better interaction of wood fibers and polymer matrix when the authors added 5 wt% MAPP as coupling agent.**

Keywords-composite, nanoclay, modified montmorillonite, mechanical properties, SEM.

I. INTRODUCTION

In recent years, thermoplastic composites that fortified by Lignocellulosic fillers are favored as new generation of reinforcing materials. These commodities became popular because of their low cost, biodegradability, easiness of processing and the absence of toxic byproducts [5]. Compare to the advantages of bio-thermoplastic composites they have some drawbacks such as low thermal stability and low compatibility that greatly reduce the overall performance of WPCs. They are mainly used in semi structural applications because they do not possess the bending strength and modulus required for long spans and load-bearing structural applications. Enhancing the bending properties of WPCs could expand their acceptance in load bearing structural applications [3]. Improvement of the interface and inter-phase interactions between the components could enhance the mechanical properties of the composites.

One way for improving the properties of composites is treating with coupling agents. Chemical coupling agents are used to treat a surface and provide compatibility between immiscible polymers, especially thermoplastics, which are non-polar (hydrophobic) substances and polar (hydrophilic) Lignocellulosic fillers, so that bonding occurs between it and other surfaces [6].

Another way for improving the overall properties of composites is the incorporation of nanoclay as reinforcing filler. Montmorillonite based clays (MMT) offer high interest from an industrial point of view since the use of small amounts of them is enough to improve the overall properties of a polymer matrix at a relatively low cost [7–9]. They belong to the aluminosilicate group with 2:1 type layers in which exchangeable cations like Na^{+} and Ca^{2+} can fill spaces between the layers. The exchangeable cations can be replaced by organic cations like quaternary ammonium salts by chemical treatments, producing an organophilic clay (generally called organoclay) with much higher compatibility with the polymer [8].

The main purpose of this work was to evaluate the effect of nanoclay and coupling agent on the mechanical and micro-structural properties of polypropylene/wood fiber nanocomposite. The samples were prepared with various contents of nanoclay and coupling agent. Fracture surfaces were evaluated by SEM.

II. EXPERIMENTAL

A. Materials

The composite materials studied were commercially available polypropylene (PP V30S) with 18 g/10 min melt flow index and 0.92 g/cm3 density. As a compatibilizer agent, it was used a propylene-maleic anhydride graft copolymer (PP-g-MA) supplied with the trade name of Priex 20070. The maleic anhydride grafting level of MAPP was 0.1 wt%. The nanoclay (montmorillonite type) with trade name of Cloisite 10A which has been chemically-modified with a quaternary ammonium salt. Wood fibers were manually screened on a sieve and 40 mesh fibers were used to manufacture experimental samples.

B. Sample preparing

Wood flour was dried at 80 °C for 24 h in an oven to remove moisture. The materials were then blended together in a HAAKE internal mixer for 10 minutes to make samples. The temperature of chamber was 175 °C and the rotational speed was 60 rpm. The compounded materials was removed from mixing chamber, cooled, and then milled to produce granules by pilot scale grinder. The resulting granules were subsequently injection molded at 180 °C to produce standard specimens.

C. Method

The flexural properties and notched Izod impact strength of the composites were measured according ASTM standard D 790 and D 256.

The morphology of the fractured surfaces of the composites after impact test was investigated using a scanning Electron Microscope (SEM) model Philips XL 30. The fractured surfaces were sputtered with gold on an ion sputter coater at an accelerating voltage of 25 kV.

III. RESULTS AND DISCUSSION

A. Flexural Properties

The flexural strength and modulus of the composites measured using 3-point bending tests are shown in Fig. 1 (a and b). The flexural modulus and strength increases with increase of nanoclay up to 3 wt% at the same concentration of PP-g-MA and then decreases at 5wt% of nanoclay. It is well known that the nano-scale filler with very high aspect ratio can improve the flexural modulus of the polypropylene [4]. The decrement of flexural modulus and strength at 5 wt% of nanoclay could relate to the agglomeration of nanoparticles. Rong et al. [10] reported the modulus of composites at higher organoclay loading might not be increased because of the clay agglomerates inhibiting plastic deformation of matrix by the constraining effect of clay agglomerates. It is also observed that the flexural modulus of the composites with 10 wt% MAPP is higher than those using the 5 wt% MAPP at different levels of nanoclay. The observed increase attributed to the presence of the MAPP that enhances the interface adhesion between wood flour and PP matrix [2]. The flexural strength of the composites with 5 wt% MAPP is higher than those using the 10 wt% MAPP. Generally, mechanical properties increase with increased concentration of a coupling agent up to a certain limit, and then decline at higher concentrations. Lu et al. reported the reason that higher coupling agent concentrations result in lower mechanical properties of the composite possibly lies in 1) the formation of different by-products, 2) increase in concentration of unreacting or ungrafting coupling agents, and 3) interference with coupling reaction. Consequently, an excess of a coupling agent is detrimental to the coupling reaction and may act as an inhibitor rather than a promoter of adhesion [6].

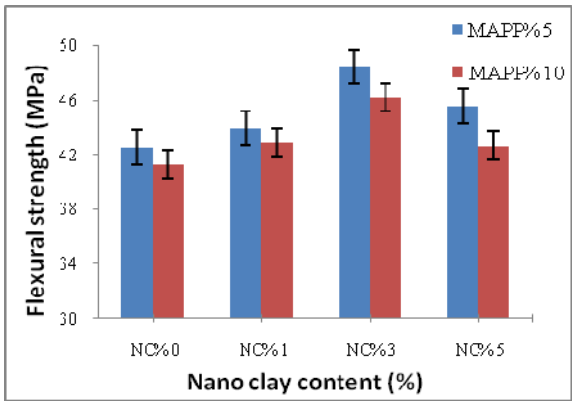


Figure 1. a) Flexural strength of composites with different amount of nanoclay and MAPP

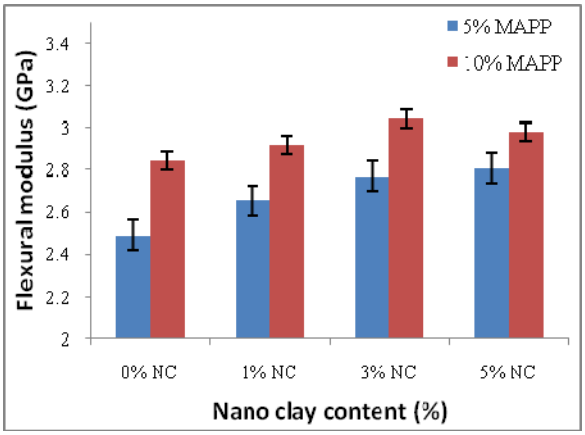


Figure 1. b) Flexural modulus of composites with different amount of nanoclay and MAPP

B. Impact strength

The influence of nanoclay and compatibilizer contents on the Izod impact strengths of the composites are shown in Fig. 2. The Izod impact strength of composites increased with the increase in nanoclay contents at the same concentration of MAPP. The maximum Izod impact strength (27.01 MPa) was obtained at the nanoclay loading of 5 wt%. These results indicate that the enhancement in the impact strength could be attributed to the more homogeneous dispersion of the fiber, which leads to more uniform distribution of the applied stress. Improvements in

impact strength depend on the homogeneity of specimens achieved during processing as well as on interfacial issues relating to the specific filler types and matrices [1].

Although many researchers reported that the impact strength increases with increase of MAPP (up to 5 wt%), the impact strength of composites in this research decreases with increasing of MAPP content (from 5 wt% to 10 wt%). This decrement could be related to the inhibitor action of coupling agent that mentioned above.

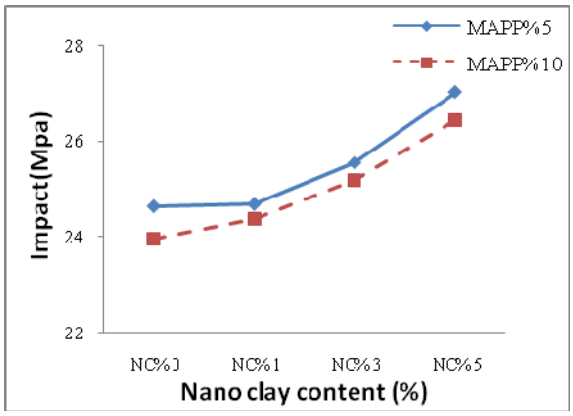
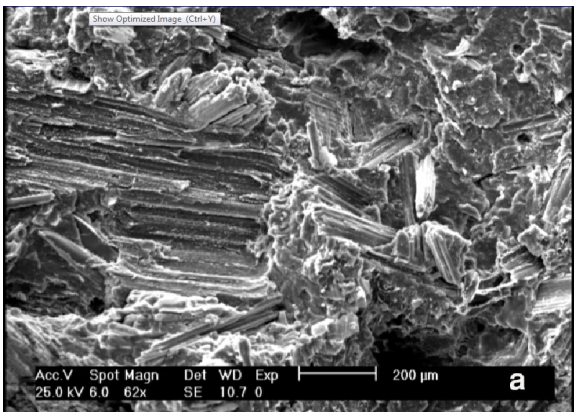


Figure 2. Impact strength of composites with different amount of nanoclay and MAPP

C. *SEM micrographs*

The impa ct fracture surfaces of 5 wt% and 10 wt% MAPP incorporated composites were supported by SEM micrographs in Fig. 3. Wood flour was uniformly dispersed inside the composites and a few deep holes and cavities were observed in the composites. These images demonstrated that good adhesion existed between wood flour and PP matrix in the presence of both 5 wt% and 10 wt% MAPP and the stress is well propagated between the components, resulting in enhanced flexural strength in response to stress. But the higher amount of MAPP does not lead to significant increase in mechanical properties.



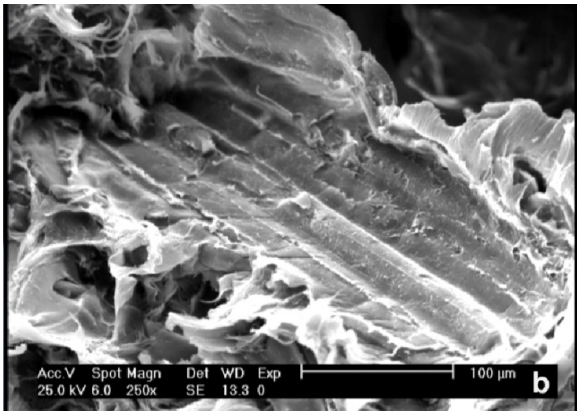


Figure 3. SEM micrograph of the fracture surfaces of composites (a) 5 wt% MAPP (b) 10 wt% MAPP

IV. CONCLUSION

The reinforcement of PP matrix with nanoclay is an efficient way to obtain an overall improvement on mechanical properties of the wood-polymer composites. The flexural modulus, strength and Izod impact strength enhanced with increasing nanoclay content, due to the high aspect ratio of nano-scale filler. Mechanical properties increase with increased concentration of a coupling agent up to a certain limit. However, the higher amount of MAPP does not lead to significant increase in mechanical properties. SEM images showed a few holes and cavities in the composites at the presence of both 5 wt% and 10 wt% MAPP and it indicated good adhesion between wood flour and PP matrix. According to the mechanical results and SEM images, it seems that the optimum results are obtained with 5 wt% MAPP and 3 wt% nanoclay.

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