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doi:10.4028/www.scientific.net/AMR.264-265.743

Compatibilized PP/EPDM-Kenaf Fibre Composite using Melt Blending Method

[1]H. Anuar, N.A.Hassan, F. Mohd Fauzey

Department of Manufacturing and Matreials Engineering, Kulliyah of Engineering, International Islamic University Malaysia, P.O. Box 10, 50728 Kuala Lumpur, Malaysia.
[1]Corresponding email: hazleen@iiu.edu.my

Key words: Thermoplastic elastomer, kenaf fiber, maleic anhydride polypropylene, ethylene-propylene-diene-monomer.

Abstract

Thermoplastic Elastomer (TPE) composite reinforced with Hibiscus cannabinus, L fiber (kenaf fiber, KF) was prepared via melt blending method using internal mixer at temperature 180°C, screw rotational speed at 40rpm for 10 min. TPE matrix is a blend of polypropylene (PP) and ethylene-propylene-diene monomer (EPDM) at a ratio of 70:30. The optimum fiber loading were investigated from 0% to 20% by volume. The effect of coupling agent maleic anhydride polypropylene (MAPP) on the TPE composite has been investigated. The result shown that, with increasing the kenaf fiber content gradually increased the tensile strength and flexural strength for both treated and untreated PP/EPDM-KF composite. However, at 20% of kenaf fiber loading, it showed decreasing in impact strength due to brittleness of the samples. From the scanning electron micrograph (SEM) it has shown that the composite, with compatibilizer promotes better interaction between TPE and kenaf fiber.

Introduction

Natural fiber composites have attracted the attention of scientists and engineers, and many attempts have been made to prepare and evaluate natural fiber composites for various applications [1]. Natural fibers have the advantages of low density, low cost, recyclability and biodegradability. However, the main disadvantages of natural fibers in composites are the poor compatibility between natural fibers and matrix [2]. In order to develop composites with better mechanical properties, it is necessary to impart hydrophobicity to natural fibers by suitable chemical treatments [3]. The selection of proper coupling agents is also important to improve fiber-matrix adhesion so as to produce composite materials with superior strength.

On the other hand, there are few studies which have focused on fabricating of lighter and tougher composites, despite these biocomposites for automotive parts having potential to improve fuel consumption [4]. As industry attempts to lessen the dependence on petroleum based fuels and products there is an increasing need to investigate more environmentally friendly, sustainable materials to replace the existing glass fiber and carbon fiber reinforced materials. Therefore, attention has recently shifted to the fabrication and properties of natural fiber reinforced materials. The automotive and aerospace industries have both demonstrated an interest in using more natural fiber reinforced composites, for example, in order to reduce vehicle weight, automotive companies have already shifted from steel to aluminum and now are shifting from aluminum to fiber reinforced composites for some applications [5].

This article discussed on the mechanical properties of PP/EPDM-KF composite with the present of coupling agent, maleic anhydride polypropylene (MAPP). The effect of fiber loading (0, 5, 10, 15, and 20 vol. %) on mechanical properties of PP/EPDM-KF composite is also investigated and finally this article also reported on morphological fracture surface under SEM observation.

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Experimental

Materials. Kenaf (Hibiscus cannabinus, L) bast fiber (KF) was obtained from (Lembaga Tembakau Negara, Kelantan). Polypropylene (PP) was supplied by Propylene (M) Sdn. Bhd. with density of 0.9 g/cm^3. Ethylene-propylene-diene monomer (EPDM) was obtained from Centre West Industrial Supplies Sdn. Bhd. with density of 1 g/cm^3 and maleic anhydride grafted polypropylene (MAPP) was obtained from Aldrich Chemical Co., USA with density of 0.95 g/cm^3.

Preparation of PP/EPDM-KF Composite. Kenaf was ground by using the Roll Mill, Fritsch Pulverisette 14. The speed of the Rotor Mill used was 80rpm x 1000 and the length of obtained kenaf was in the range of 0.05mm. Kenaf fibre was then sieved by Fritsch Sieve Shaker to ensure the fiber size within 300-500 µm. In order to remove any excess moisture, the kenaf fibers were dried in Contherm Thermotec 2000 oven for 24 hours at 110˚C.

Polymer blends based on PP and EPDM were prepared by melt blending method at ratio of 70:30 using HAAKE Rheomix 600p internal mixer. Blending was carried out at 180 ºC, at 40 rpm of rotor speed for 10 min processing time.

PP/EPDM-KF composite was compounded using the same internal mixer. PP/EPDM matrix will be added with bast kenaf fiber varies from 0-to-20 vol.%. The composite was prepared using the same processing parameters as in the preparation of the matrix. The compound was then transferred into a dumbbell shape mold for an injection moulding at various processing parameters such as pressure (800 bars), metering speed (170 mm/s) and cooling time (10 s).

Characterization of Composites

The tensile test of TPE was measured by using the Instron machine according to ASTM D638 with crosshead speed 50mm/min. The gauge length was kept at 35mm. Flexural strength was measured under three-point bending according to ASTM 790. The compression speed was 5 mm/min. Impact test was conducted using Advanced Pendulum Impact (API) charpy testing machine according to ASTM D256. Seven samples were tested for each composition.The Scanning Electron Microscopy (SEM) of tensile fracture surface of the composites has been carried out using JSM 5660 JEOL.

Results and Discussion

Tensile Properties. Tensile properties of PP/EPDM-KF composites are illustrated in Figs. 1-2. Figure 1 demonstrated that the tensile properties of reinforced PP/EPDM with and without MAPP by different volume of kenaf fiber. The results show that the tensile strength of PP/EPDM matrix was higher than PP/EPDM-KF without MAPP which is about 16.7 MPa. However, the tensile strength of the PP/EPDM-KF with MAPP is higher than the PP/EPDM matrix. This results show that the present of coupling agent improved the strength of the composite. It was also observed that as the fiber content increases, the tensile strength of composites with MAPP increased too. This is because the tensile strength doubled with the addition of kenaf fiber as compared to unreinforced PP/EPDM matrix. The low tensile strength of the composite without MAPP indicates lack of adhesion between the components in the composite system. The compatibilizer may improve the tensile strength of the polymer blends because it plays a role as an adhesive between PP/EPDM and kenaf fiber. The application of silane coupling agent has improved tensile strength of the same composition as compared to non-treated glass composites. Silane treated glass fiber will promote fiber-matrix adhesion due to linkages among the functional group. Subsequently, good bonding capably transfers the stress along the fiber-matrix interphase [6].

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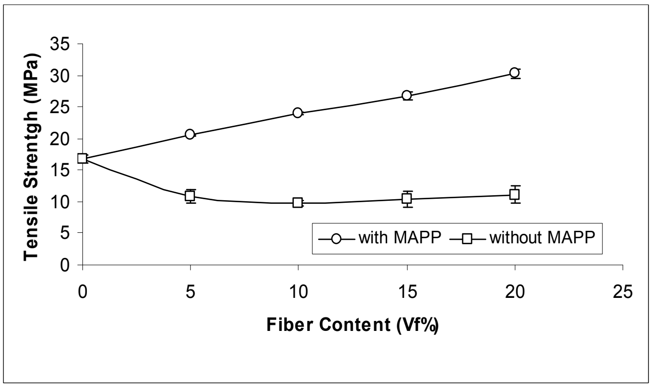

Fig. 1: The tensile strength of untreated and treated PP/EPDM-KF composite

Tensile modulus of PP/EPDM-KF composite is described in Fig. 2. The results illustrate that the tensile modulus of PP/EPDM matrix is lower than the tensile modulus of PP/EPDM-KF composites with and without MAPP. The stiffness of the PP/EPDM-KF composites showed significant improvements with the addition of the fiber as compared to unreinforced PP/EPDM matrix. It is noted also that the modulus of composite with MAPP is higher than the modulus of composite without MAPP. Generally tensile modulus increases with fiber content. This shows that the tensile modulus of PP/EPDM-KF composite is affected by the rigidity of the reinforced fibers [6]. Additionally, the tensile modulus is higher at higher fibre content which could be due to higher tensile modulus of kenaf fiber [7]. This is in agreement with [8] where the treated and untreated flax fiber showed higher tensile moduli than molded 100% polypropylene due to the higher tensile modulus of flax fiber.

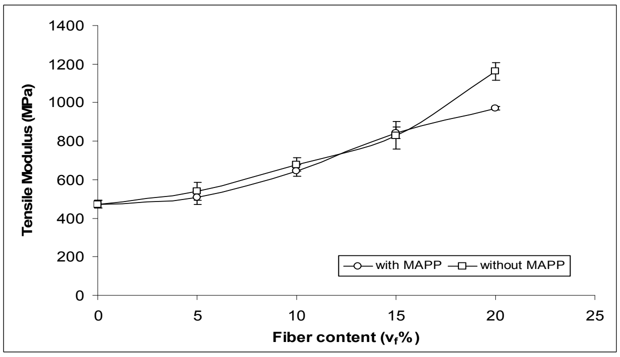

Fig. 2: The tensile modulus of untreated and treated PP/EPDM-KF composite

Impact Strength. The effect of kenaf fibre content and compatibilzer agent, MAPP on PP/EPDM composite are described in Fig. 3. In general, the impact strength increases with increasing fiber content. The optimum value of impact strength can be observed at 15% of kenaf fiber content which is about 13.19 kJ/m^2. The impact strength of the composite depends on the amount of fiber and the kenaf fibre properties and processing.

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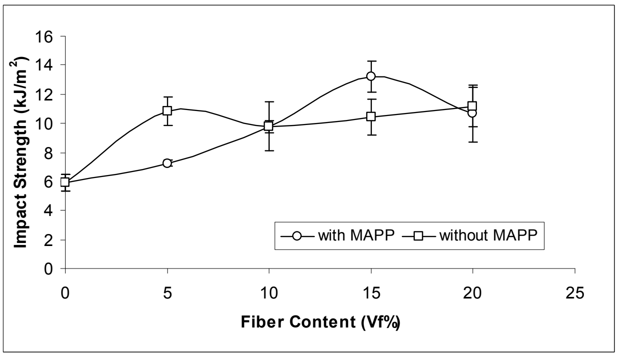

Fig. 3: The impact strength of untreated and treated PP/EPDM-KF composite

Morphological Examination. The improvement in tensile strength for treated and untreated samples was then examined under scanning electron microscope. SEM micrographs in Fig. 4 represented the tensile fracture surfaces of untreated PP/EPDM-KF composite with 20% Kenaf fiber. As shown in Fig. 4 it is clearly seen the formation of void at the end of fiber pull-out due to less adhesion or interaction between kenaf fiber and PP-EPDM matrix. The high level of fiber pull-out, debonding and fibrillation for kenaf fiber PP-EPDM composites without MAPP is due to the poor adhesion between kenaf fiber and polymer matrix [9].
Tensile fracture surface of PP/EPDM-KF composite with MAPP is shown in Fig. 8. The formation of void is less at the end of fiber pull-out during tensile testing for treated sample as compared to untreated sample. This results is due to good interaction between TPE and Kenaf fiber and also proven the increasing in tensile properties. However, from the SEM micrograph as shown in figure 7, kenaf fiber demonstrated irregular size and non-uniform cross section that has contributed to give lower tensile strength.
The addition of the MAPP coupling agent appears to produce a significant improvement of the wettability of kenaf surface by the polymer. The improved bonding is clearly seen in Figure 8 where the fiber has pulled out from the matrix but a fair amount of polymer residue remains on the fiber [12].

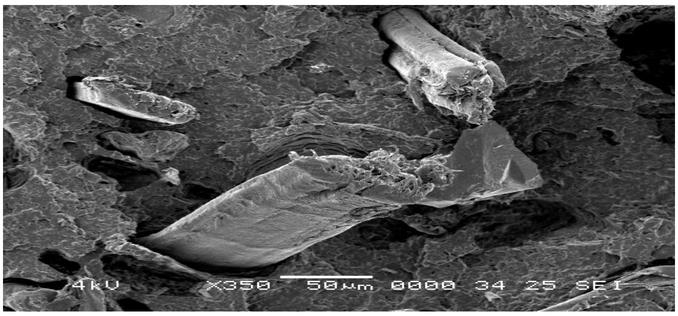

Fig. 4: SEM micrograph of the fracture surface of composite with 20% kenaf fibers without MAPP at 350x magnification.

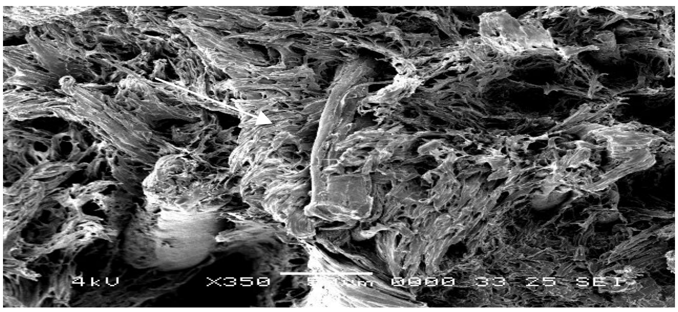

Fig. 5: SEM micrograph of the fracture surface of composite with 20% kenaf fibers with MAPP at 350x magnification.

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Conclusions

It can be concluded that for untreated composites, the tensile strength were 24 MPa and tensile modulus were 1161 MPa. However, in treated composites the tensile strength were 30 MPa and the tensile modulus were 969 MPa. Besides that, the flexural strength for treated composites were 47 MPa compared to untreated composites were 38 MPa. The results obtained in this study indicate that enhancement of the mechanical properties of PP/EPDM-KF composite is possible by addition of coupling agent (MAPP) to improved adhesion between the Kenaf fiber and PP/EPDM matrix.
The effect of fiber loading from 0% to 20% also showed the improvement in mechanical properties about 50% in tensile strength. From the SEM micrograph examination, it is observed there is no fiber-matrix interaction in untreated composite but, matrix was adhered to kenaf fiber in treated composites and formed less void at the end of fiber pull-out due to increase in interfacial adhesion between fiber and matrix.

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Advances in Materials and Processing Technologies II
doi:10.4028/www.scientific.net/AMR.264-265

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