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Effect of Maleated Polypropylene (MAPP) on the Tensile, Impact and Thickness Swelling Properties of Kenaf Core – Polypropylene Composites

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Abstract

The study on the kenaf core fiber – polypropylene (PP) composites with treated and non-treated maleated polypropylene (MAPP) was done. Epolene-43 which is commercially MAPP was used to determine MAPP's effectiveness as a coupling agent for kenaf fiber-composites. The hot pressing system for producing kenaf core-PP composite has been used. The tensile, impact and thickness swelling results of the epolene 43 treated composite samples were better than those of the untreated composites. Scanning electron microscopy micrograph proved that the interfacial region of treated composite board shows good interaction among kenaf's wood fiber and PP components.

Keywords: Kenaf Core; Polypropylene; Epolene 43; Tensile; Thickness Swelling

1   INTRODUCTION

Cellulose fiber is little used as filler in thermoplastics compared to the inorganic fillers, such as talc, mica and glass fiber, despite its offers many advantages such as lower density, higher specific strength and modulus, renewable nature, lower fiber breakage during mixing and lower cost [4, 8]. When cellulosic fiber is compounded with thermoplastic polymers, the main problem encountered is the poor interfacial adhesion between the hydrophobic polymer and hydrophilic filler. Coupling agents have been added to improve the dispersion, adhesion and compatibility between the hydrophilic cellulose and hydrophobic matrix. These agents improved the interface by interacting with both the fiber and its matrix, to form a stronger link between them [3]. Maleated polypropylene has received considerable attention as a coupling agent because of its effectiveness in improving the mechanical properties of wood fiber-polypropylene composites [10]. In this study, we aim to investigate the effects of the presence of epolene 43 that able to change the kenaf filler and PP composites in terms of mechanical and dimensional stability performances.

2   MATERIALS AND METHODS

2.1   Materials

Kenaf varieties of V-36 at the age of four months was harvested from MARDI Serdang, Selangor. The polypropylene used was Propelinas 600G (homopolymer), purchased from Polypropylene (M) Sdn. Bhd. with a density and melt index specified as 0.9 g/cm3 and 12 g/10 min , respectively. Epolene-43 was purchased from Suka Chemicals (M) Sdn. Bhd. It had a low molecular weight (Mn=3900 g/mol, Mw=9100 g/mol), density of 0.93 g/cm3 and acid number 47.

2.2   Preparation of Kenaf Filler

The kenaf core filler is disintegrated using knife ring flaker after passing the process of outer layer debarking. The filler was sieved using a vibrator sieving machine to get the filler size of mesh 60-80 (0.25-0.18 mm).

2.3   Compounding and Processing

Compounding of the materials was carried out using a Haake Rheocord 5000 internal mixer. The propeller speed was set at 35 rpm with temperature of 1800 C. The epolene 43 was loaded while compounding process. The concentrations of epolene 43 used are 1%, 3% and 5% (w/w). The compounds were unloaded after 20 min of compounding process and cut into pellets using a crusher machine. The pellets were transferred to a mould with dimensions of 17 cm x

17 cm x 0.3 cm. The pellets were preheated for 12 min at 1800 C and under pressure, followed by heating at the same temperature for 10 min with 8 tons pressure and then cooled to 300 C for 12 min with the same pressure. Three ratios of the kenaf core-PP mixtures used were: 10%: 90%, 30%: 70% and 50%: 50% (w/w). The kenaf and PP compositions used in this study were listed in Table 1.

Table 1 : Sample formulations of kenaf and PP compositions

Compositions (%)			
Sample code	PP	Kenaf	Epolene 43[a]
K10	90	10	-
K10/1	90	10	1
K10/3	90	10	3
K10/5	90	10	5
K30	70	30	-
K30/1	70	30	1
K30/3	70	30	3
K30/5	70	30	5
K50	50	50	-
K50/1	50	50	1
K50/3	50	50	3
K50/5	50	50	5

[a]Based on dry weight of kenaf fiber

2.4   Testing
2.4.1   Tensile Testing
The tensile tests were conducted on samples with the dimensions of 15 cm x 1.9 cm x 0.3 cm using a Testometric machine model M500-25KN at a cross head speed of 5 mm/min according ASTM D638[1] . The calculations of tensile strength and tensile modulus could be calculated by using the equation given below.

Tensile strength = W / bd
Tensile modulus = m / bd

where,
W = the ultimate failure load (N),
b = mean width of sample (mm),
d = mean thickness of sample (mm),
m = the slope of stress-strain curve.

2.4.2   Impact Testing

Impact tests were conducted according to ASTM D256 [1]. The Izod method was applied on unnotched samples of 6.0 cm x 1.5 cm x 0.3 cm using the Zwick Impact Pendulum Tester model 5101.

2.4.3   Thickness Swelling Testing

Thickness swelling test was done referred to ASTM D570 [1]. Samples with approximate dimensions 3 cm x 1.5 cm x 0.3 cm were used for thickness swelling. The specimens were immersed in deionized water at 250 C for 24 hours. The specimens were taken out of the water, and then were dried using an absorbent paper and the thickness of the dried samples was immediately measured. Percentages of thickness swelling of the samples were calculated using equation:

$$\text{Thickness swelling (\%)} = \left(\frac{t_2 - t_1}{t_1} \right) \times 100\%$$

where,
t_2 = thickness of the sample after immersion (mm)
t_1 = thickness of the sample before immersion (mm)

2.4.4   Scanning Electron Microscopy (SEM)

The fracture surfaces of the composites from the tensile tests were investigated using a Leica Cambridge S-360 Scanning Electron Microscope. The fracture ends of the specimens were mounted on an aluminum stub and sputter coated with a thin layer of gold to avoid electrostatic charging during examination.

3   RESULTS AND DISCUSSION

The results of the effect of variable of epolene 43 percentages and kenaf loading on the tensile strength of composites are shown in Figure 1.
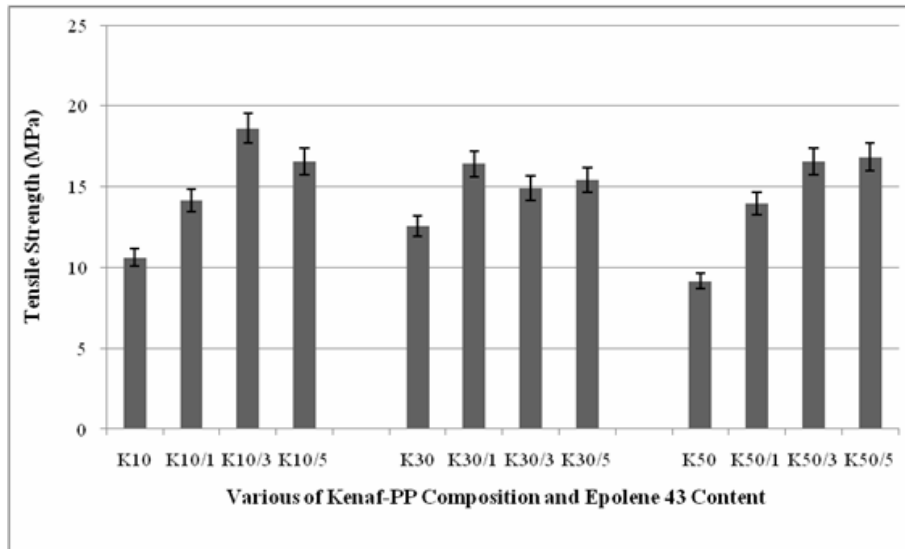
Figure 1 : Effect of Kenaf-PP Composition on Tensile Strength

Overall, the tensile strength of the composites treated with epolene 43 increased as epolene 43 loading increased compared to untreated composites at three kenaf and PP compositions. The incorporations of epolene 43 had enhanced the tensile strength of composites, which may be due to a good compatibility at interfacial regions between filler and matrix which clearly shown in Figure 8. It is believed that a good filler-matrix interaction could be derived from the formation of an ester bond between the anhydride groups of epolene 43 and the hydroxyl groups at the surfaces of the kenaf filler (Figure 2).
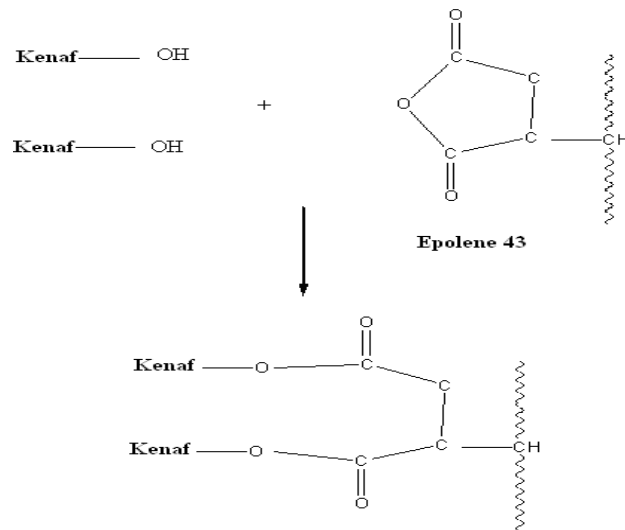
Kenaf——— OH

+

Epolene 43

Kenaf——— OH

Kenaf ——O

Kenaf ——O

Figure 2 : Possible Schematic of Epolene 43 Treated Kenaf-PP Composites

Furthermore, as epolene 43 is a derivative of PP, it should be compatible with PP matrix. Other researchers have reported a similar result in case of EFB-PP composites [5]. Generally, composites treated with epolene 43 at 3 and 5% loading display better tensile strength than those at 1%. A higher content of anhydride groups of epolene 43 could be the main reason. Thus, the higher anhydride groups will form more ester bond between epolene 43 and hydroxyl groups of kenaf surfaces. From the Figure 2, the strength of the composite decreases as the percentages of filler increased, the situation is clearly observed from the samples without treated. This is in agreement with the trends observed in other lignocellulosic filled composites [5, 6]. Unlike fibers, which have a uniform cross-section and a relatively high aspect ratio, the ability of irregularly shaped fillers such as kenaf to support stress transmitted from the matrix is rather poor. The decreasing of tensile strength will be amplified if the contents of filler are increased. With more filler, more filler bundles are formed from the hydrogen bonding and the composite becomes less able to bear the stress transmitted from the matrix as clearly shown in the SEM micrograph in Figure 7.

The tensile modulus of composites increases as the epolene 43 loading increased (Figure 3). The results indicate that the epolene 43 is able to enhance the stiffness of the composites. Similar results also reported by other researchers [5]. Epolene 43 at 5% displays a higher modulus than at 1 and 3% especially at kenaf and PP 10/90% and 50/50% compositions. It may be due to the more

anhydride group from epolene 43 that connected with hydroxyl groups from kenaf fiber as explained before. From the Figure 3, the modulus had increased as the filler loading increased. This is a common phenomenon, which has been reported by other researchers in the case of lignocellulosic filled composites [5, 6 and 14]. Since the kenaf filler has a more inherent stiffness than the matrix, the increase in filler loading had increased the stiffness of the composites.
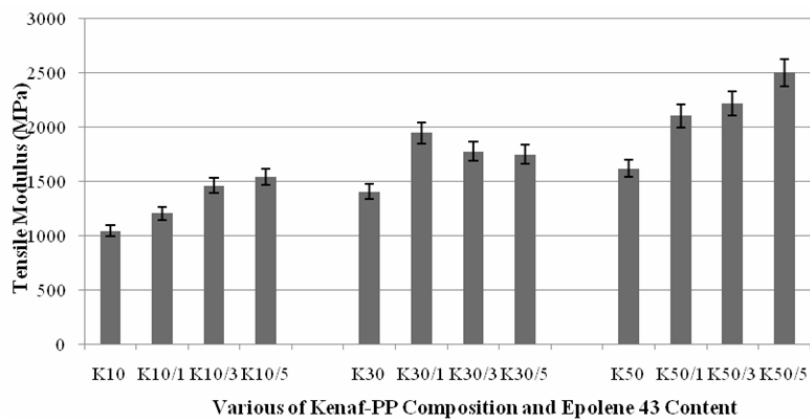

Figure 3 : Effect of Kenaf-PP Composition on Tensile Modulus

The elongation at break results from Figure 4 demonstrated a high percentage of elongation of sample that treated with epolene 43 compared to untreated. The covalent bonds created among hydroxyl groups on the kenaf surfaces with anhydride groups of epolene 43 were resulted of better stress received from matrix to the filler, thus increased the elongation at break values. A percentage of elongation at break of sample contains of more filler decreased. It may due to the hydrogen bonding has made the filler bundled thus weakening the sample. The elongations at break values for treated samples were observed slightly the same at 1-5% of epolene 43 loading. Kenaf and polypropylene compositions of 10:90% show the higher elongation at break rather than other formulations of kenaf and polypropylene.
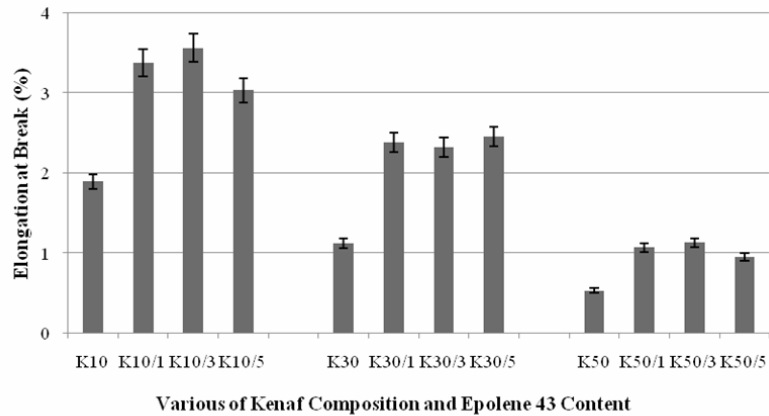
Figure 4 : Effect of Kenaf-PP Composition on Elongation at Break

Figure 5 shows the impact strength of the epolene 43-treated and untreated composite. Adding epolene 43 to the composites improved the wetting of the EFB filler in the matrix resin. In the impact test, cracks proliferate through the polymer as well as the interfacial region, so a good interfacial region would improve the crack resistance and, consequently the impact strength. Basically, the impact strength increased with the epolene 43 loading from 1% to 5% probably due to the interfacial region becoming better in resisting cracking. This finding is in line with those by other researchers on lignocellulose-filled composites [5, 13]. One finding from other researcher which is using conifer fiber treated with epolene 43 had better impact strength than an untreated sample due to esterification of the fiber hydroxyl groups and anhydride in MAPP, chemically bridging the fiber and matrix and improving the transfer of stress from the matrix to the filler [2]. The impact strength decreased with increasing filler content in both the treated and untreated composites. This observation was not unexpected for a filled plastic and has been made before by some other researchers [9, 12]. The probable reason is the agglomeration of fillers, weakening the interfacial regions and making composites less resistant to crack propagation.
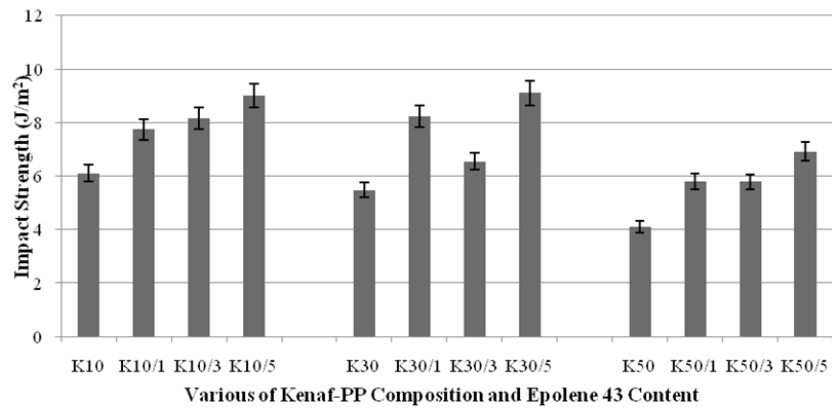
Figure 5 : Effect of Kenaf-PP Composition on Impact Strength

Figure 6 shows the effects of the epolene 43 treated and untreated composites on thickness swelling. The results obtained show that treated composites display lower thickness swelling than those untreated. It is known that lignocellulose materials absorb water by forming hydrogen bonding between hydroxyl groups of kenaf and water in the cell wall region [14]. Thickness swelling of lignocelluloses materials occurs when the cell wall is bulked by the water at the cell wall regions. For the treated composites, the formations of hydrogen bonding are diminished by formations of chemical layer on the filler surfaces. Thus, it protects the water from making an interaction with OH groups of kenaf. The percentages of thickness swelling of treated composites decreased as epolene 43 increased. Figure 6 also demonstrates the thickness swelling increased with increasing filler content.
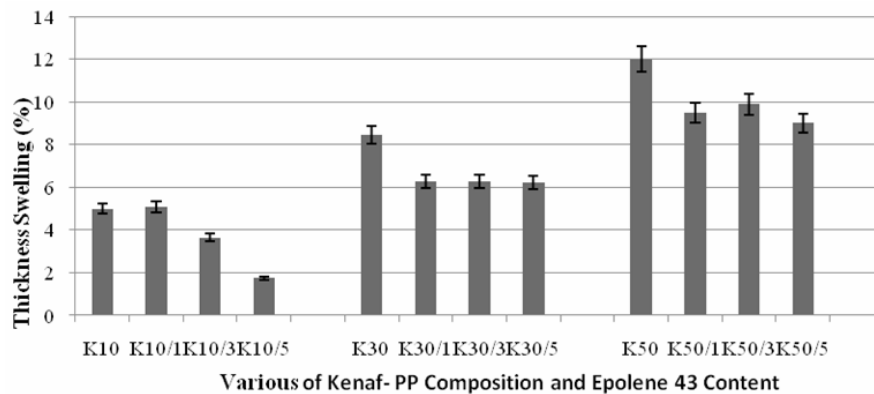
Figure 6 : Effect of Kenaf-PP Composition on Thickness Swelling

Figure 7 shows the SEM micrograph of untreated composites. It shows that the weak interactions between filler and PP matrix through the loose adhesions (holes). Since the interactions between both of them are important in enduring the stress been given while testing, the weak adhesions have resulted in lower strength of tensile properties. In addition, the filler is in a bundled form due to hydrogen bonding created among the filler, thus, it has decreased the strength of the composites. Composites with epolene 43 treated filler showed better adhesion between filler and matrix at the interfacial regions than untreated composites in Figure 8. The good adhesion of treated composites at interfacial region again due to the covalent bonds created between epolene 43 anhydride groups and the filler surfaces. The results of SEM micrograph have proven the outstanding nature of mechanical and physical properties shown by epolene 43 as explained before.
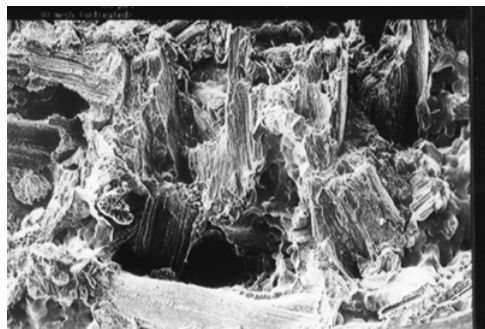

Figure 7 : The SEM Micrograph of Untreated Kenaf-PP Sample

Figure 8 : The SEM Micrograph of Epolene 43 Kenaf Treated Sample

4 CONCLUSIONS

The study showed that the tensile, impact and dimensional stability properties of kenaf-PP composites were enhanced by adding the epolene 43 and the higher the epolene 43 loading the better the properties. The mechanism involved was coupling by the anhydride group bridged to the hydroxyl groups of the filler for better transfer of stress from the matrix to the filler. SEM showed the evidence of good compatibility and adhesions between PP matrix and filler with epolene 43 treated rather than those untreated filler.

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