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Effect of Filler Loading and NaOH Addition on Mechanical Properties of Moulded Kenaf/Polypropylene Composite

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ABSTRACT

Natural fibre composites can have varying combinations of physical and mechanical properties, such as low density, low cost, high stiffness and strength. Kenaf *(Hibiscus cannabinus)* was used in this study as a natural fibre to reinforce polypropylene (PP) in the fabrication of polymer composite materials. The injection moulding method, with an injection temperature of 170°C, was used in this study. This study aimed to investigate the effect of sodium hydroxide (NaOH) on the mechanical properties of kenaf/PP using the injection moulding method. PP was mixed with different compositions (5, 10, and 15 wt%) of kenaf particles with increasing concentrations of NaOH as a treatment agent to enhance the adhesion between kenaf and PP. Morphological and structural changes of the sample fracture were observed under a scanning electron microscope (SEM). The results showed that the mechanical properties of the composite were increased when the percentage of kenaf composition was increased, and decreased when NaOH concentration was increased. The highest tensile value of the sample was 21.93 MPa at 15 wt% composition of kenaf particles, while the lowest value of 16.42 MPa was observed when NaOH was present. The improvement of flexural strength was highlighted, in 5 wt% composition of kenaf-reinforced PP with NaOH that was 32.07 MPa, but when the NaOH concentration was increased to over 10%, the flexural value decreased to 26.97 Mpa. Based on the results, the researchers concluded that NaOH treatment may increase the bond strength of kenaf composite; however, increasing the NaOH concentration can lead to a decrease in mechanical properties.

Keywords: Injection molding, natural fibre polymer composite, kenaf, mechanical properties, physical properties

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INTRODUCTION

The demand for the development of high-performance engineering products from sustainable materials made from natural resources has recently increased worldwide. The merging of reinforcements, such as fibres and matrix, in composites can provide a way to expand and improve composite properties that can fulfill the requirements of most engineering applications (Akil *et al.*, 2011). The research and development of natural fibres used as filler or reinforcement has gained momentum in the last decade. Natural fibre polymer composites offer a sustainable and renewable alternative to commercial composite materials (Pothan *et al.*, 2003).

Kenaf plant is one of the many types of natural resources that have been extensively investigated over the past few years. *H. cannabinus* L. is a biodegradable and environment-friendly plant. The use of kenaf, a natural fibre-based composite, has increased because the material is readily available, lightweight, biodegradable, non-abrasive, non-toxic, low cost and has low density with high specific strength (Nishino *et al.*, 2003)

Poor merging is the major problem encountered when the natural fibres in polymer composite are not compatible with the matrix (El-Shekeil *et al.*, 2011). The inherent high moisture absorption of the product generated by the dimensional changes of the fibres can lead to microcracking of the composites and degradation of the mechanical properties (Edeerozey *et al.*, 2007). Kenaf fibres are hydrophilic in nature, whereas the polymer matrix is hydrophobic. Polar hydroxyl groups on the surface of kenaf fibre make it difficult to form an interphase surface with the non-polar polymer matrix relative. The hydrogen bonds in kenaf fibres prevent the surface from getting wet, resulting in lack of interfacial adhesion between both fibres and polymer matrix. The lack of adhesion between them results in weak of mechanical and physical properties in the final product (Tserki 2006; Vilay *et al.*, 2008). Various chemical treatments have been used by researchers to enhance the mechanical performance of natural fibres. In this study, the researchers used one of the most common and effective modifications applied to kenaf fibres, which is the alkaline treatment with various concentrations of NaOH (Aziz *et al.*, 2004). The treatment results were assessed by tensile and flexural testing, which showed the mechanical properties of the kenaf composites with different compositions.

Our study aimed to fabricate kenaf reinforced polypropylene (PP) composites using the injection moulding method and determine the effect of NaOH on the strength bonding of fibre-matrix composites. In addition, the suitable composition of kenaf exhibiting better mechanical properties was determined by examining the composition of the mechanical properties of each kenaf particle.

MATERIALS AND METHODS

Kenaf particles in size 40 mesh were used in this study. Kenaf particles were supplied by the National Kenaf and Tobacco Board (Lembaga Kenaf dan Tembakau Negara) (Fig.1). PP and NaOH pellets were supplied by Sigma-Aldrich. The prepared feedstock was composed of PP, kenaf particles and different NaOH percentages (Table 1). The materials were mixed using the Brabender® internal mixer at optimum processing conditions. Reaction temperature, time and rotating speed were 180°C, 30 min and 30 rpm, respectively. Mixing temperature was based on the melting temperature of polypropylene, which is 171°C. The mixing temperature should be higher than the melting point of the polymer matrix to ensure that the polymer is homogenously mixed with the fibre particles. PP was initially placed in the mixer, and the fibre particles were then added when torque stabilised.

TABLE 1
Composition of Materials Used in the Experiment

Kenaf particles (wt%)	Polypropylene (wt%)	Existence of NaOH (%)
0	100	No / 0
5	95	No / 0
10	90	No / 0
15	85	No / 0
5	90	Yes / 5
10	80	Yes / 10
15	70	Yes / 15

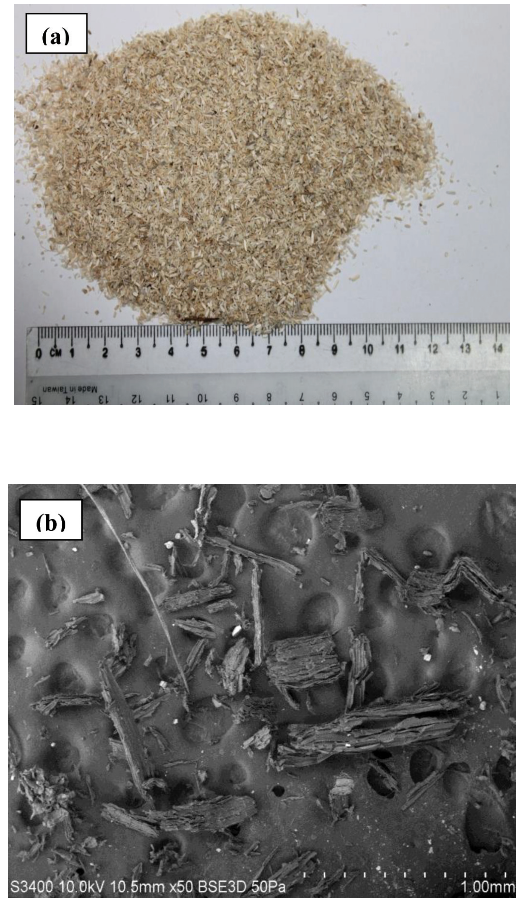

Fig.1: 40 mesh kenaf particles: (a) Digital image; (b) SEM image.

Two types of dumbbell-shaped samples were prepared by injecting kenaf/PP composites and kenaf/PP composites treated with NaOH from different weight compositions into the mould.

All samples were tested by the universal tensile strength and three-point bending flexural strength test according to ASTM D 638 (ASTM, 2000a) and ASTM D 790 (ASTM, 2000b), respectively.

The surface morphology of the fracture specimens were then investigated under a scanning electron microscope to visualise the effect of NaOH on kenaf/PP composites through interfacial adhesion of the samples.

RESULTS AND DISCUSSION

Mechanical Properties of Composites

The universal tensile strength test determines the in-plane tensile properties of the polymer matrix composite materials that are reinforced by high-modulus fibres. The samples were fractured and failed through three possible ways, which may break off at the top, middle or bottom of the beam. Fig.2 shows the middle of the break off of the samples.

Fig.3 shows the effect of the kenaf particle content on the tensile strength of the kenaf/PP composite with NaOH. The mechanical property results were compared with the PP strength properties. Comparison of the histogram patterns showed that the tensile value increased from 5 wt% to 15 wt% composition of kenaf. The highest tensile value of kenaf/PP composite was 21.92 MPa. Loh *et al*. (2001) reported that the addition of micro-powder can increase the hardness and density of the composite. However, the tensile value began to decrease and reached the lowest value of 16.42 MPa at 15 wt% composition of kenaf when 15% NaOH was added. In summary, the tensile strength test results showed that the strength of composite was increased by higher percentage of kenaf composition, but decreased by higher NaOH concentration.

Fig.2: Specimen after tensile test

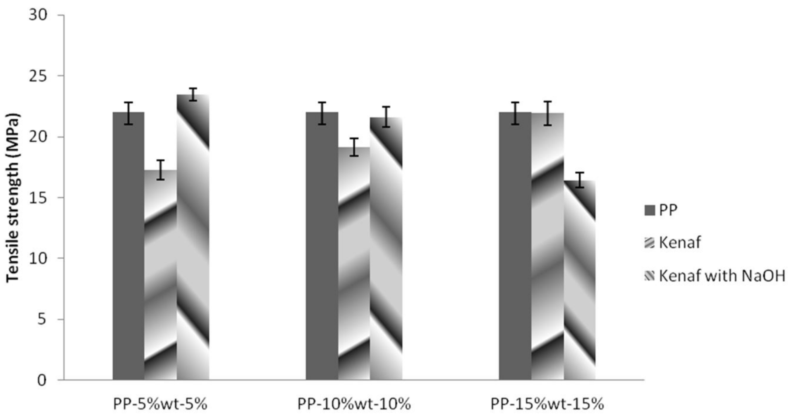

Fig.3: The variation of tensile strength against kenaf particles content with concentration of NaOH.

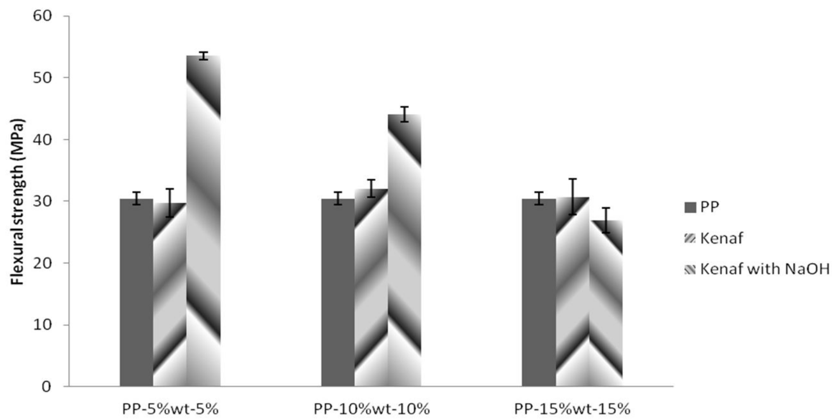

Fig.4: The variation of flexural strength against kenaf particles content with concentration of NaOH.

The flexural strength results shown in Fig.4 indicate that the strength of the composites slightly improved (32.07 MPa) with the addition of 10 wt% kenaf particles. The 15 wt% kenaf sample exhibited slightly decreased flexural strength because of insufficient PP content. The lack of PP in the matrix leads to poor adhesion between the fibres and the matrix. Furthermore, the matrix was not able to hold the fibres during loading, which in turn decreased the utility of the fibres in the load transfer process (Ibraheem *et al*., 2011). The improvement of flexural strength was highlighted in 5 wt% composition of kenaf-reinforced PP with NaOH, because of the removal of impurities in the treated particles of kenaf. However, when the NaOH concentration was increased to over 10%, the value of the flexural strength decreased to 26.97 MPa because 15% NaOH concentration may have been too strong and could have damaged the particles, thereby resulting in decreased mechanical properties and damaged fibres (Mwaikambo & Ansell, 2002).

Fig.5 shows the tensile modulus results reflecting the effect of changes in the content percentage of the treated and untreated kenaf particles. The Young's modulus value of the kenaf/PP composite increased from 5 wt% to 15 wt% composition of kenaf, where the highest value was 1079.61 MPa at 5 wt% of composition. The treated kenaf particles showed stronger strength in the Young's modulus at 5% concentration of NaOH (1079.68 MPa), but the value decreased when the concentration of NaOH was increased (807.12 MPa). According to Nishino *et al*. (2003), the increase in percentage of natural fibres enhanced the properties of the Young's modulus. The increasing concentration of NaOH led to decreased tensile modulus.

Morphological of Fracture Surface of Flexural Specimens

Morphological and structural changes of the fracture surface were observed under SEM. The fracture surface of 5 wt% kenaf/PP composite is illustrated in Fig.6(a). The

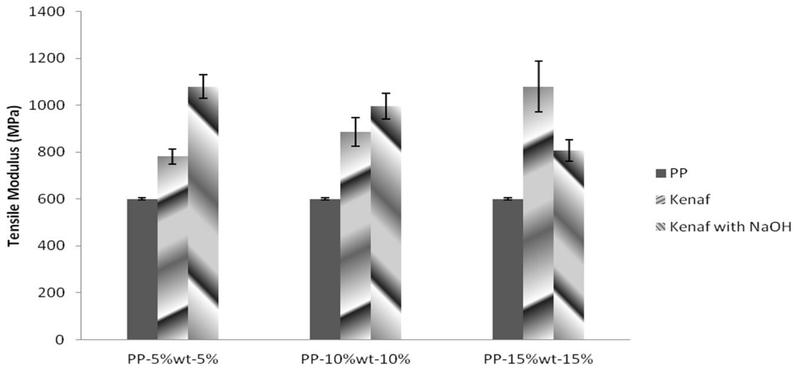

Fig.5: The variation of tensile modulus against kenaf particles content with concentration of NaOH.

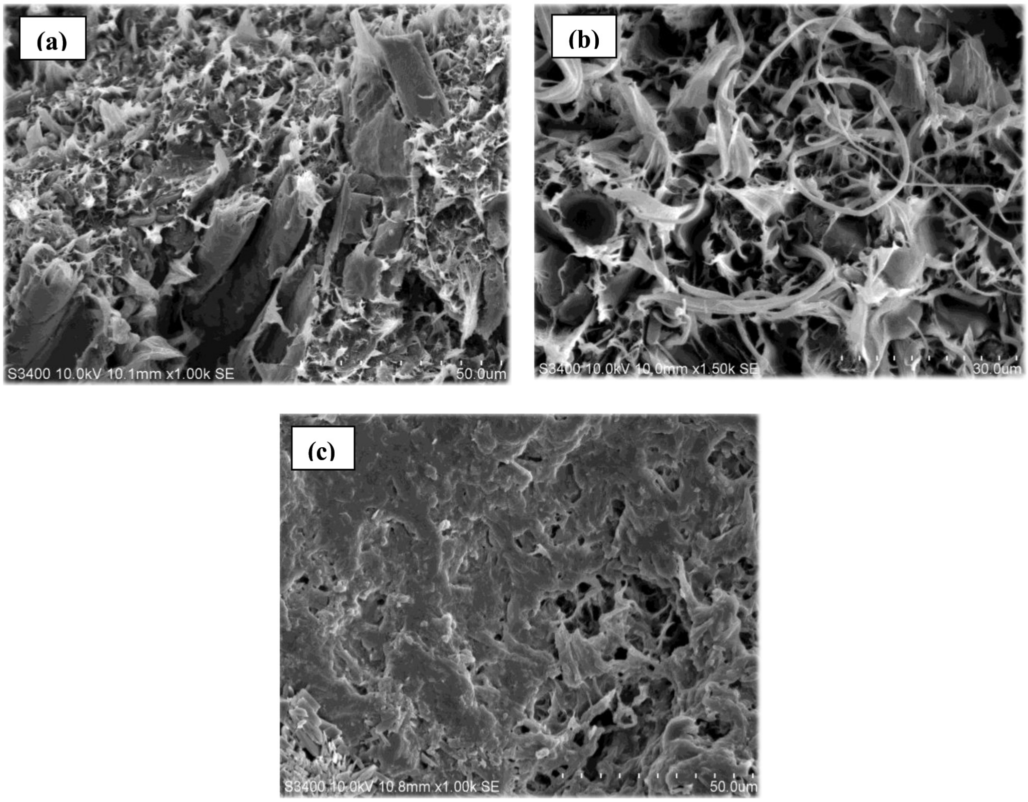

Fig.6: SEM micrograph for flexural fracture structure of kenaf/PP composites: (a) 5%wt kenaf/PP; (b) 10%wt kenaf/PP; (c) 10%wt kenaf/PP with NaOH.

combination of kenaf particle breakage and the particle pull-out indicates that the adhesion of kenaf/PP was adequate. Fig.6(b) shows the fracture surface of 10 wt% kenaf/PP composite and reveals a strong bond between PP and kenaf particles. The content of particle loading is higher and well coated with a polymer. The melted PP was distributed effectively and penetrated the kenaf particles. Treatment on kenaf/PP composites with NaOH showed poor fibre-matrix adhesion, as shown in Fig.6(c). The fracture surface of the specimens was fully covered with the NaOH residues, and the strength continuously decreased with increasing NaOH concentrations.

CONCLUSION

Our study examined the application of Kenaf as a natural fibre reinforced with PP in the fabrication of polymer composite materials. Kenaf/PP was treated with different NaOH concentrations. After treatment, the samples were subjected to mechanical testing and their morphology was examined under SEM. The strength of the kenaf/PP composite decreased with increasing NaOH concentrations. At 15% of NaOH, the concentration proved to be too strong and caused damage to the particles, resulting in decreased mechanical properties of the sample. Nevertheless, the incorporated kenaf particles acted as good reinforcement in the polymer composites and improved the mechanical property strength of the composites with kenaf particle increment loading.

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