Effect of Different Filler Loading on Flexural Properties and Water Absorption Behavior of Kenaf Core Fiber Reinforced Polypropylene Composite

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Abstract. In this investigation, kenaf core fiber (KCF) reinforced polypropylene (PP) composite was prepared via extrusion and compression moulding. The effect of different ratio of KCF filler with PP on flexural properties of composite had been investigated. PP and KCF filler were prepared with different filler loading of 5, 10, 15, 20 and 25 wt% using twin-screw extruder at temperature 180 °C and rotor speed of 70 rpm, followed by compression moulding at the same temperature. The flexural tests were conducted to evaluate the flexural properties of the composite. The results obtained showed that the incorporation of KCF in PP increased the flexural strength and flexural modulus of the composite. The water absorption behaviour of the composite was also investigated. It was found that water absorption of composites increased with increasing of fiber content.

1.0 Introduction

The utilization of polymer composites over the past few years have shown a remarkable increase in demands due to their advantages such as recyclability, easy fabrication, lightweight, low cost, and their flexibility to be molded into the desired shape and design [1]. Generally, polypropylene (PP), which is known as high volume commodity plastic, has contributed significantly to the development of the plastics industry. Various researches have been conducted to explore and commercialize the incorporation of fillers into a PP matrix to fulfill various requirements in engineering applications.

The interest in natural fiber reinforced polymer composite is rapidly growing both in terms of their industrial applications and fundamental research. Natural fiber, which is derived from natural resources, is often applied as reinforcement of composite. Their availability, biodegradability, and low-cost production are the leading causes that attract the interests of researchers toward natural fiber composites. Besides, they are renewable, vast availability, low density and have high specific strength which makes them an attractive alternative to replace the glass and carbon fiber in various applications such as transportation,
It is crucial to study and discuss the use of natural fiber-reinforced composite and their effects on materials’ performances, and either they can be considered as favorable reinforcement in a composite system. Presently, one of the most commonly used natural fibers in reinforced plastic composite in Malaysia is kenaf fiber. Kenaf fiber (*Hibiscus cannabinus* L.), have a low density (1.2 – 1.6 g/cm³) and offer non-abrasive and high stiffness properties that affect both physical and mechanical properties [5]. Kenaf fiber-reinforced plastic composite, which is used for a wide range of applications, were found comparable to existing synthesis composites. The materials’ performances are always presented in terms of their mechanical properties such as flexural properties, tensile properties and impact properties. Their features are connected to engineering performances of materials under critical conditions [6]. For the last decades, numerous studies have been conducted to study the mechanical and water behavior of kenaf fiber-reinforced composite.

Mohammed et al. [7], in his study, stated that the mechanical properties of natural fiber-reinforced composites depend on the type of fiber, its orientation (random or unidirectional), the strength of fiber, physical properties of fiber, and the type of plasticizer used. For example, Subramonian [8] reported in his study of PP-bagasse fiber composite that flexural strength and modulus increased as increasing fiber content. Similar trends, as reported by Fairuz et al. [9] in their study of the effect of fiber loading on mechanical properties of pultruded kenaf fiber reinforced vinyl ester composite. The authors reported that fiber content is having a significant impact on the mechanical properties of composites, as the results obtained from the study showed that the mechanical properties improved by the addition of kenaf fiber to polymer composite.

Besides mechanical properties, water absorption behavior of composite is also considered as one of the essential features in composite studies, to investigate their suitability in outdoor applications. Amoke et al. [10], in their previous studies, reported the relationship between water absorption and fiber loading. They concluded that water absorption increases almost linearly with fiber loading. Besides that, Ismail and Ishak, [11] also reported a similar trend in their studies that the increase in fiber fraction resulted in an overall increase in total water uptake.

Therefore, this study will be focused on the reinforcement of the polypropylene matrix and kenaf core fiber various filler loading. The mechanical properties and water absorption of the composite were investigated.

### 2.0 Materials and Methods

#### 2.1 Material Selection

In this study, PP, as shown in Fig. 1(a) is used as matrix material was supplied by Lotte Chemical Titan (M) Sdn. Bhd. in the form of homo-polymer pellets. KCF, as presented in Fig. 1(b) was obtained from Rahmatullah Sdn. Bhd. Malaysia. Once collected, KCF was dried, ground, and sieved into 150 μm mesh size to produce powder KCF.

#### 2.2 Sample Preparation

##### 2.2.1 Preparation of PP/KCF composite

Different ratios of KCF fibers (5, 10, 15, 20, and 25 wt%) were added to the PP matrix using formulation shown in Table 1. The sample that contains a pure PP matrix was used as the references and the control of the experiment. The KCF filler was physically mixed with the
PP matrix before extrusion. The mixture was oven-dried at 60 °C for 24 hours to remove the moisture before processing. The mixture then was melt blended in co-rotating twin-screw extruder. Extrusion will be conducted at a temperature around 180 °C and a rotor speed of 70 rpm. After that, the strands were air-dried and pelletized. Then, the pellets were oven-dried at 60°C for 24 hours before they were processed in the hot press compression moulding machine at 180 °C. Once the flat sheet was obtained, the specimens were cut into the following shape and dimension instructed in standard ASTM for flexural test and water absorption test.

**Table 1.** The formulation of PP/KCF composite.

| Samples     | PP Content (wt%) | KCF Content (wt%) |
|-------------|------------------|-------------------|
| PP Neat     | 100              | 0                 |
| PPKCF5      | 95               | 5                 |
| PPKCF10     | 90               | 10                |
| PPKCF15     | 85               | 15                |
| PPKCF20     | 80               | 20                |
| PPKCF25     | 75               | 25                |

Fig. 1. Raw material before compounding, (a) PP; (b) KCF

Fig. 2. Composite after compression moulding.
2.3 Mechanical Test

The flexural test was carried out by using an Instron Universal Tensile machine in the room atmosphere. The specimens were prepared for the flexural test according to ASTM D-790 with a crosshead speed of 30 mm/min and a support span of 50 mm. The software used in this test calculated the flexural strength and flexural modulus of the specimens.

2.4 Water Absorption Test

The water absorption test was carried out as elucidated in the ASTM D-570 standard. The test specimens were prepared with the dimension of 15.0 mm width x 30.0 mm length x 3.0 mm thickness, with smooth and squarely trimmed edges. The samples were then dried in an oven at 60 °C for 24 hours. After the drying process, all specimens were weighed, and dry weights of specimens were recorded. The samples were horizontally submerged in distilled water at room temperature, and weight change was monitored continuously as a function of time. For each composite, five specimens were tested. Absorption behavior of the composite was studied every 24 hours up to 672 hours (28 days), where the samples were removed from distilled water, wiped dry to remove any surface moisture, and then weighed using a high accuracy analytical balance. The percentage of water absorbency was calculated by using Equation 1.

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\text{Percentage of Water Absorption, } \% = \frac{W_f - W_s}{W_i} \times 100\%
\]

Where \(W_f\) = Initial weight of the sample before immersion inside the water, \(W_s\) = Weight of wet sample

3.0 Result and discussion

3.1 Flexural properties

The most common purpose of the flexure test is to measure flexural strength and flexural modulus. These two values are often used by researchers to measure the material’s ability to resist flexure forces. When flexural forces are applied to the specimens, the upper and lower surface of a sample under a three-point bending load is subjected to tension and compression stresses. In contrast, the axisymmetric plane is subjected to shear stress. Therefore, flexural properties are often considered as the result of combinations of tension and compression. The sample is deemed to fail when the flexural stress reaches a critical point [12, 13].

In this study, the effect of KCF loading on the flexural properties of PP/KCF composite is presented in Table 2. The bar charts for flexural strength and flexural modulus of PP/KCF composite are plotted and presented in Figures 3 and 4, respectively, for better observation. From Fig. 3, the results showed that the flexural strength of composite increases slightly with increasing of KCF filler content. The trend for flexural strength with different filler loading can be shown in Fig. 3. It can be observed that by initial incorporation of 5 wt% of KCF filler, flexural strength showed increment from 44.34 MPa to 46.08 MPa. The flexural
strength continuously increased to 48.37 MPa when KCF reached its maximum filler loading at 20 wt% and decreased as more filler was added into the matrix. A significant drop of flexural strength from 48.37 MPa to 40.65 MPa can be observed at 20 wt% to 25 wt% of filler loading.

Based on the results obtained, lower flexural strength recorded at 5 wt% of KCF loading indicates that there were poor dispersion and fiber distribution, thus lead to poor adhesion between fiber and matrix. At the lowest loading of KCF filler, the KCF filler is unable to disperse and distribute well in the polymer matrix, therefore resulting in lower flexural strength. The dispersion and distribution of fiber in the matrix started to improve when more fiber is added to the matrix and give better strength [14]. The flexural strength dropped drastically when the ratio goes beyond 20 wt%. These results suggested that the addition of filler loading up to 20 wt%, the flexural strength decrease due to insufficient filling of the matrix in the composites, which limit the ability to wet and infiltrate the KCF filler. Ilangovan et al. have reported similar trends, in their study of PP composite reinforced raw bagasse. They stated that the flexural and tensile strength of the composite could be improved by adding the number of fibers in composite until it reached its maximum filler loading [15].

The flexural modulus of PP/KCF composite is presented in Fig. 4. The result showed a similar trend with flexural strength, but with significant improvement. It can be observed in Fig. 4 that the flexural modulus of the composites significantly increases from 1.16 GPa to 1.86 GPa with increasing fiber loading. In general, the increment of flexural modulus is heavily influenced by KCF content in composite. Since KCF is made up of lignocellulosic components, it has its stiffness that contributes to overall stiffness of composite [16]. Therefore, the significantly improved flexural modulus of the PP/KCF composite, which can be observed in Fig. 4, is due to high kenaf content combined with the stiffness of the composite. Tarres and the co-workers supported these observations as they stated in their study that good dispersion of reinforcement inside the polymer matrix could be achieved by observing the linear increase in the composite modulus [17].

![Fig. 3. Flexural strength of PP/KCF composite.](image1)

![Fig. 4. Flexural modulus of PP/KCF composite.](image2)
Table 2. Flexural properties of PP/KCF composite

| KCF Loading (wt%) | Flexural Strength (MPa) | Flexural Modulus (GPa) |
|-------------------|------------------------|-----------------------|
| 0                 | 44.34                  | 1.16                  |
| 5                 | 46.08                  | 1.49                  |
| 10                | 46.53                  | 1.63                  |
| 15                | 47.75                  | 1.72                  |
| 20                | 48.37                  | 1.76                  |
| 25                | 40.65                  | 1.86                  |

3.2 Water absorption behaviour

The water absorption rate of PP/KCF composite with various fibers loading was determined and presented in Fig. 5. The moisture uptake of each composite was identified by the percentage of the weight gain relative to the initial dry weight of the samples. From the result obtained, it can be observed that the water absorption amount of composite increased with increasing fiber content. In the first ten days of immersing the specimens in the distilled water, the results showed a rapid increase of the percentage of water absorption, and then only slightly increased until composite finally reached equilibrium point, where no more water uptake into a composite. Das and Biswas [18] have reported similar trends. In their study, they further explained that increasing water absorption of the composite is due to the hydrophilic nature of fiber compared to the PP matrix and greater interfacial area. Other than that, Hosseinihashemi et al. reported that as the fiber loading increased, the cellulose content also increased, thus increasing the number of hydroxyl (OH) groups in composites. Water absorption of the composite increased as these OH groups come in contact with water to form hydrogen bonding and result in weight gain of the composite [19].
4.0 Conclusions

The effect of different filler loading on the mechanical properties of PP/KCF composite has been studied. The results of this study showed that the flexural properties of PP/KCF composite increased with increasing of KCF loading until it reached 20 wt%. Further addition of fiber after that decreased the flexural properties due to insufficient filling of the matrix in the composite. Water absorption also shows significantly increased with increasing fiber content.

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