Properties of Kenaf Fibers/Epoxy Biocomposites: Flexural Strength and Impact Strength

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Abstract. Kenaf is a non-woody plant, which has high potential fiber to be used as polymer matrix reinforcement. Different compositions of kenaf fiber as bio reinforcing material at different fabrication process parameters will produce different biocomposite properties. This study uses kenaf fibers in the composition of 10, 20, and 30 wt.% as reinforcing material. Kenaf fiber and epoxy resin were mixed based on predetermined compositions, stirred using a mechanical stirrer at 200 rpm for 10 minutes. Then the mixture is poured into a mold and placed on a hot press machine. Pressure of 50 kg/mm² for 30 minutes at 150°C is used to produce kenaf fiber/epoxy biocomposite. The result showed that the increasing of kenaf fiber content in the matrix is succeeded to increase the flexural and impact strength of the biocomposite kenaf fiber/epoxy produced. The highest flexural strength (136 MPa) and highest impact strength (180 KJ/m²) were obtained at a composition of 30 wt.% Kenaf fiber.

1. Introduction

Kenaf (Hibiscuss cannabinus L.) from the Malvaceae family, is a non-wood plant whose fiber has good potential to be used as a reinforcing or filler material in the polymer matrix. Kenaf grow fast about four to five months after sowing the seeds, and are able to reach height of more than 3 m with a base diameter of 3 to 5 cm [1]. Kenaf can grow well under various weather conditions. Different polymer composite manufacturing techniques can be applied based on the type of matrix used. The appropriate formation process can turn the material into a new material with the desired properties. The injection, extrusion, or compression molding, and hot pressing were still the main manufacturing processes until now [2]. In general, the processing method for biodegradable polymer materials such as polylactide (PLA), is similar to that developed for conventional composite materials. According to Barkoula et al. [3], composites produced through injection molding show a lower impact strength compare to composite produce by compression molding.

Fabrication of natural fibers with PP is one of the most suitable routes for developing natural-synthetic polymer composites [4]. Several techniques are carried out to ensure proper matrix fusion and good fiber impregnation. Zampaloni et al. [5] in his research, focused on the use of kenaf fibers as reinforcing materials with polypropylene (PP) as a matrix to obtain biocomposite with a good fiber distribution. The first experiment used a 130 mm kenaf sandwich between two layers of PP sheets,
indicating poor distribution of kenaf fiber. To improve the uneven kenaf distribution, 20 mm long chopped kenaf were mixed with PP matrix using a mechanical stirrer. This method produces a circular pattern, causes clamping and voids, making it more difficult to achieve even distribution of fibers. Finally, the sieving method of powdered polypropylene microfin (to be the layered shifting of a powder) is used (20μm compared to the original PP size of 400μm) using cut-off kenaf fibers. This method has been proven to be able to produce better fiber distribution. Meanwhile, Lee et al. [6] used a hot-pressing technique to evaluate the effect of kenaf fiber length orientation and laminate properties. The study results indicate that mechanical properties increase with the increasing of fiber content at parallel orientation to the direction of load. The study reported that the highest tensile strength was obtained at 50% kenaf content using horizontal fiber orientation. Long and continuous fibers are easy to orient and process compared to short fibers. This is because short fibers are more difficult to control and to determine the right process orientation [7]. Hao et al. [8] produced PP kenaf material with a ratio of 50/50 using carding and the needle-punching technique. The results showed that the mobility of liquid polypropylene will increase at high temperatures. This greatly determines the fiber bonds formed in the matrix. The results also show that 6 mm is too thick for a sample, because 1 minute duration of processing time is not enough for heat transfer from surface to inside of the sample.

This study were carried out to find out the effect of length variations (1 cm and 3 cm) and composition based on weight percent (wt.%) of kenaf fiber to the flexural strength and impact strength of the biocomposites produced.

2. Materials and method

2.1 Materials

The reinforcing fiber used is kenaf fiber at average fiber diameter of 30 µm, obtained from The National Kenaf and Tobacco Board, Malaysia. The binder (matrix) used is epoxy resin type 635 thin. The ratio of epoxy resin and hardener is 4:1, according to the manufacturer. While the viscosity of the epoxy resin used is 6 Poise.

2.2 Fabrication processes of kenaf fiber/epoxy biocomposites

The fabrication process of kenaf/epoxy biocomposites were consists of two stages. In stage 1, epoxy resin and hardener with a ratio of 4:1 were stirred using a mechanical stirring machine (RW-IKA) with a rotation speed of 200 rpm for 10 minutes. In stage 2, kenaf fibers based on predetermined compositions was also stirred at the same rotation speed and time, which is 200 rpm for 10 minutes. The mixture of epoxy resin and kenaf fiber is then poured into the mold and placed on a hot pressing machine with a pressure of 50 kg/mm², at a temperature of 150 °C, for 30 minutes.

2.3 Characterization

The characterization performed on kenaf fiber/epoxy biocomposite are flexural strength and impact strength tests. The flexural strength testing was carried out using the ASTM D 790 standard while the impact strength uses the ASTM E 23 Standard. Each composition of kenaf fiber/epoxy biocomposites were tested 3 times for each test. Scanning electron microscopic (SEM) Hitachi S-3400 N was used to see the kenaf fiber dispersion in the matrix (epoxy resin) used.

3. Results and discussion

3.1 Variation of kenaf fiber on flexural strength

The variation of kenaf fiber addition to the flexural strength of kenaf fiber/epoxy biocomposites are shown in Figure 1. Kenaf fiber addition as reinforcing material showed an increase in flexural strength for both fiber lengths used (1 cm and 3 cm). The highest flexural strength of kenaf
A fiber/epoxy biocomposite was obtained at 1 cm fiber length at the highest kenaf fiber composition (30 wt.%), i.e., 130 MPa. In the same composition, kenaf fibers which have a length of 3 cm produce the lower flexural strength (125 MPa). This is caused because longer fibers found not to be well dispersed in the epoxy matrix [6-10].

![Figure 1. Variation of kenaf fiber on the flexural strength of kenaf fiber/epoxy biocomposites](image1)

### 3.2 Variation of kenaf fiber on impact strength

The effect of variations of kenaf fiber addition (10 wt.%, 20 wt.% and 30 wt.%) and variations of kenaf fiber length (1 cm and 3 cm) on the impact strength of kenaf fiber/epoxy biocomposites are shown in Fig. 2.

![Figure 2. Variation of kenaf fiber on the impact strength of kenaf fiber/epoxy biocomposites](image2)
Overall, kenaf fiber addition from 10, 20, to 30 wt.% with variation of kenaf fiber length of 1 and 3 cm were successfully increased the impact strength of kenaf fiber/epoxy biocomposite. The highest impact strength were obtained at a composition of 30 wt.% for both fiber lengths (1 cm and 3 cm), namely 180 KJ/m² and 140 KJ/m². Significant differences in the impact strength of biocomposite kenaf fiber/epoxy obtained at the same composition (30 wt.%), caused of 1 cm long kenaf fibers were more evenly dispersed in the matrix (epoxy resin). This condition causes a perfect bond between kenaf fiber as reinforcement and the matrix [8, 9]. Kenaf fiber length of 3 cm look more agglomerate in the matrix, thus reducing the impact strength obtained [11-15].

![Figure 3](image)

Figure 3. Scanning electron microscopic (SEM) images of fracture surface of kenaf fiber/epoxy biocomposite

Figure 3 shows SEM image from the fracture surface of kenaf fiber/epoxy biocomposite produced. Fig. 3a and 3c shows that the fiber length of 1 cm in composition of 10 wt.% and 30 wt.% are well dispersed in the matrix (epoxy resin). This condition produces a good bond between epoxy resin as a binder and kenaf fiber as reinforcement so that increase the flexural and impact strength obtained [9]. In contrary, Fig. 3 (b) and 3 (d) shows that 3 cm long kenaf fiber in composition of 10 wt.% and 30 wt.% tends to be agglomerates and show some voids, resulting in lower flexural strength and impact strength [10].
4. Summary
Research on flexural and impact strength of kenaf fiber/epoxy biocomposite by varying the length and content of kenaf fiber as reinforcing material was completed. The results obtained can be summarized as follows:

1. The addition of kenaf fiber as reinforcement material (10 wt.%, 20 wt.% and 30 wt.%) with a fiber length of 1 cm and 3 cm managed to increase the flexural strength and impact strength of kenaf fiber/epoxy biocomposite.
2. The highest flexural strength and impact strength were obtained at fiber length of 1 cm and highest kenaf fiber content of 30 wt.% that is 130 MPa and 180 KJ/m².
3. Kenaf fiber length of 1 cm is dispersed properly for all compositions compared than 3 cm length.

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