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Determination of Alkali Treatment Conditions Effects Which Influence the Variability of Kenaf Fiber Mean Cross Sectional Area

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***Abstract*—**Fiber cross sectional area value is a crucial factor in determining the strength properties of natural fiber. Furthermore, unlike synthetic fiber, a diameter and cross sectional area of natural fiber has a large variation along and between the fibers. This study aims to determine the main and interaction effects of alkali treatment conditions which influence kenaf bast fiber mean cross sectional area. Three alkali treatment conditions at two different levels were selected. The conditions setting were alkali concentrations at 2 and 10 w/v %; fiber immersed temperature at room temperature and 100^0C; and fiber immersed duration for 30 and 480 minutes. Untreated kenaf fiber was used as a control unit. Kenaf bast fiber bundle mounting tab was prepared according to ASTM C1557-03. Cross sectional area was measured using a Leica video analyzer. The study result showed that kenaf fiber bundle mean cross sectional area was reduced 6.77% to 29.88% after alkali treatment. From analysis of variance, it shows that interaction of alkali concentration and immersed time has a higher magnitude at 0.1619 compared to alkali concentration and immersed temperature interaction which was 0.0896. For the main effect, alkali concentration factor contributes to the higher magnitude at 0.1372 which indicated are decrease pattern of variability when the level was change from lower to higher level. Then, it was followed by immersed temperature at 0.1261 and immersed time at 0.0696 magnitudes.

***Keywords*—**Natural fiber, kenaf bast fiber bundles, alkali treatment, cross sectional area.

I. Introduction

THE trends of utilizing natural fibers as reinforced materials in polymer matrix composite were growth aggressively since last two decades. This was motivated by the increasing awareness of environmental issues, finite petroleum resources, utilization of abundantly available natural fiber and the availability of improved data on the properties and morphologies of natural fibers materials [1], [2]. However, large variability in characteristic properties values is among the big challenges that restrict the extensive application of natural fiber reinforced composites in global market [3]. Generally, the shape, size and strength properties of natural fiber depend on their region of origin, cultivation environment, maturity, retting process, etc. [4]. Another major drawback when dealing with natural fiber is their hydrophilic characteristic. It exhibits poor resistant to moisture, which lead to high water absorption. Finally, it contributes to the inferior interfacial performance and dimensional stability of the natural fiber reinforced composites. Therefore, chemical treatment on natural fiber is an alternative solution that often applied to overcome these problem [5]. One of the common and widely used techniques to clean and modify a natural fiber surface is an alkali treatment process [5-6].

Study conducted by Hashim et al. [7] had found that kenaf fiber mean diameter was reduced by 30.12% to 42.92% after alkali treatment. They mentions that alkali concentration had a higher impact on diameter changes compared to alkali treatment immerse temperature. Gu [8] analyzed tensile behavior of the coir fiber and related composite after alkali treatment. It was found that a decreased trend in coir fiber tensile strength with increased of alkali concentration. The influence of alkali treatment at ambient, elevated temperatures and alkali-steam treatment on tensile strength of jute fibers have been examined by Saha et al. [9]. The results indicated that the uniaxial tensile strength increased by up to 65% for alkali-steam treatment. Boophati et al. [10] explored the Borassus fruit fibers properties effect with 5%, 10% and 15% alkali treatments and found that 5% alkali concentration yield significant improvement in tensile properties of the fiber. Recently, Nitta et al. [11] clarified that cross section of kenaf fiber was drastically changed by the alkali treatment compared to the untreated kenaf fiber. Data based approximation (DBA) method for evaluating cross-sectional area was proposed on the assumption that the shape of each cell in the alkali treated fiber was an ellipse. Natural fiber is known to vary in their diameter and cross sectional area along the fiber length. Any uncertain evaluation of the cross sectional area brings a variation into the determined mechanical properties of the fiber [12]. Furthermore, the alkali treatment for optimal setting conditions is still not clearly specified and it is vary depending on the type of natural fiber. Several authors mention different treatment conditions setting which contribute to variability in fiber properties and its final composite characteristic evaluations [13]-[15]. Therefore, this study was aim to determine the main and/or interaction effects of alkali treatment conditions which influence the variability of kenaf bast fiber mean cross sectional area.

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II. Material and Methods

A. Material

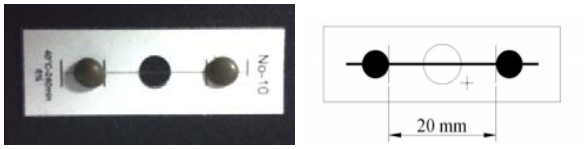
Kenaf bast fiber (KBF) was supplied by Kenaf Natural Fiber Industries (Malaysia) Sdn. Bhd. This KBF was subjected to about two weak water retting process before supplied to the laboratory. KBF was randomly selected and uniformly cut into a length of 10 cm.

B. Alkali Treatment

Sodium hydroxide (NaOH) solution concentration was prepared using weight volume percentage (w/v %). Kenaf fiber was immersed into 2 and 10 w/v % NaOH concentration. The immerse time were set at 30 and 480 minute; at room temperature (approximately 27^0C) and 100^0C solution temperature. Treated fibers were washed in running tab water and rinse by distilled water. Acetic acid was added into a beaker to remove any excessive NaOH until the nominal pH value 7 was recorded. The alkali treated KBF were dried in oven at 100^oC~105^oC for one hour.

C. Cross Sectional Area Measurement

Leica Micro video analyzer equipped with Mesdan image analysis software which directly measure the captured fiber width image was used to evaluate the KBF cross sectional area. A test specimen mounting tab according to ASTM C1557-03 was prepared for a KBF cross section area measurement as shown in Fig. 1. A kenaf fiber was assumed to have an elliptical shape with a major and a minor diameter. A KBF cross sectional area were measured at five locations in 20mm gauge lengths along two orthogonal directions using Leica Micro system video analyzer. The first diameter was measured and followed by next diameter measure at about 90^0 from the earlier measurement, which is the major and minor axis if assuming the cross section is in an elliptical shape [16]. The cross sectional area, A is then calculated using, $A = \pi ab/4$, where a and b are the diameters along the major and minor axes of the ellipse, respectively. The measurement was repeated fifteen times for each set of alkali treatment conditions. Finally, five extreme values in each group are removed and the remained ten data are used in calculation. A KBF with no obvious defects are selected as test samples under the video analyzer observation. 3 levels full factorial experiment designs was used and the data analysis was conducted using Minitab software. Standard deviation value was used as a response of interest to identify the significant alkali treatment conditions effect which affect KBF mean cross sectional area.



(a) Kenaf bast fiber test frame (b) Specimen dimension schematic diagram

Fig. 1 Kenaf bast fiber mounting tab according to ASTM C1557-03

III. Results and Discussions

A. Cross Sectional Area

Table I presents results of kenaf bast fiber mean cross sectional area (CSA) for untreated and alkali treated under various conditions setting. From the results, it show that untreated KBF mean cross sectional area value is higher compared to alkali treated KBF at any conditions setting. The mean cross sectional area value decrease about 6.77% to 29.88% after alkali treatment. Both alkali concentration and fiber immersed duration show a decrease pattern in mean cross sectional area value when the immersed temperature was changed from room temperature to 100^oC. The increase of alkali concentration and immersed duration level demonstrated the decrease pattern in the KBF mean cross sectional area value about 6.77% to 10.77% at room temperature and 13.29% to 29.88% at 100^oC. Standard deviation value shows a high variability exist in fiber cross sectional area measurement even though precaution action was taken during selecting the fiber and removing data outlier. The measured standard deviation range was 110.9 ~ 170.2.

B. Main Effect and Interaction Plot

Fig. 2 illustrates the Pareto chart of alkali condition treatment effects to compare the relative magnitude and statistical significance of both main and interaction effects. The graph shows that interaction of alkali concentration and immersed time has a higher magnitude (0.1619) compared to alkali concentration and immersed temperature interaction (0.0896). The magnitude value was calculated using analysis of variability in Minitab.

TABLE I
KBF Cross Sectional Area (CSA) (mm^2) under Various Alkali Treatment Conditions

Alkali treatment condition	Alkali solution temperature	
(w/v % & minute)	Room Temperature (approximately 27^0C)	100^oC
Untreated fiber	6472 (138.00)	-
AT-2%-30min	6034 (130.2)	5612 (133.5)
AT-2%-480min	5932 (162.3)	4841 (170.2)
AT-10%-30min	5882 (121.0)	5318 (151.0)
AT-10%-480min	5775 (110.9)	4538 (136.9)

( ) standard deviation value

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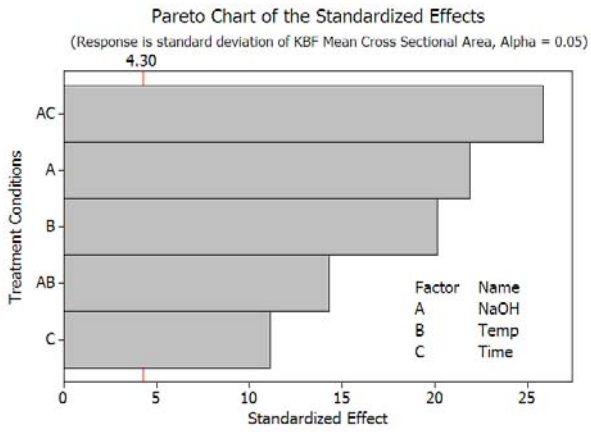
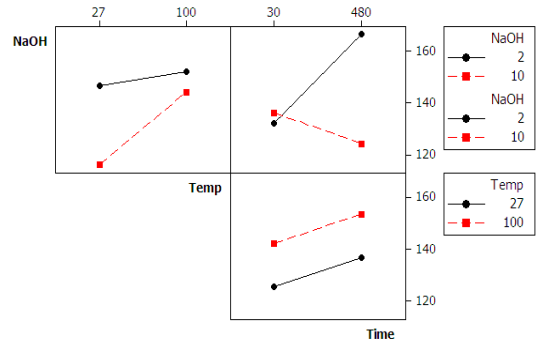
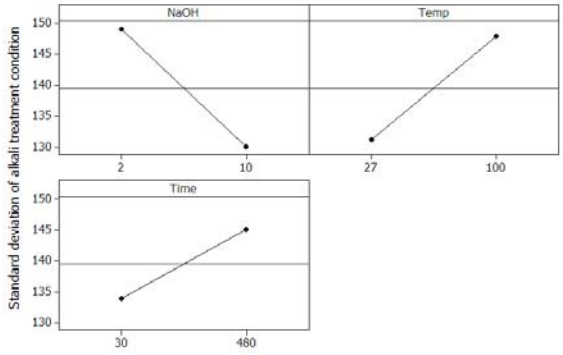


Fig. 2 Pareto chart of alkali treatment condition effect on KBF mean cross sectional area



(a) Interaction plot



(b) Main effect plot

Fig. 3 (a) Interaction plot and (b) Main effect plot of alkali treatment condition effect on KBF mean cross sectional area variability

For the main effect, the alkali concentration contributes to the higher magnitude which is 0.1372 and followed by immersed temperature (0.1261) and immersed time (0.0696). Fig. 3 shows the interaction and main effect plot of alkali treatment condition effect on KBF mean cross sectional area variability. From alkali concentration and immersed time interaction plot, the variability value is small at 30 minute immersed time. However when the immersed time getting longer, it show an increase pattern in variability at low level alkali concentration; where high level alkali concentration setting show a slightly decrease pattern.

For alkali concentration and immersed temperature interaction, similar changing pattern was recorded. Both alkali concentration setting shows an increased pattern in cross section area variability when the immersed temperature was increased from room temperature to 100^0C. However, the magnitude of variability changed for alkali concentration at 10 w/v % is larger than 2 w/v % setting. In main effect plot, alkali concentration shows a decreased pattern in variability when the setting was changed from lower to higher. However, for immersed temperature and time setting, it shows an increase pattern when a treatment conditions was changed from lower to higher setting. These patterns showed that, different levels of the factor affect the response differently. The bigger it slope value show the greater the magnitude of the main effect.

IV. Conclusions

The study result showed that kenaf fiber bundle mean cross sectional area was reduced 6.77% to 29.88% after alkali treatment compared to untreated kenaf mean cross sectional area. The decrease was due to swelling reaction during alkali treatment process at different conditions setting which affect the fiber structure, dimension and morphology. The interaction plots reveal that alkali concentration and immersed time has a higher impact on the variability of the KBF mean cross sectional area. Alkali concentration and immersed temperature also had an interaction affect on mean cross sectional variability but at a lower magnitude. This was followed by the main effects of alkali treatment conditions which are alkali concentration, immersed temperature and immersed time.

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