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THE EFFECT OF ALKALI TREATMENT CONDITIONS ON TENSILE STRENGTH OF KENAF FIBER

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ABSTRACT

Alkali treatment is one of the treatments that widely used in natural fiber surface treatment process. However, the different in treatment condition setting produce variability in fiber properties characteristic. This study aims to determine the effect of alkali treatment conditions on kenaf bast fiber tensile strength. Three conditions at two different levels were selected during alkali treatment process. They are kenaf fiber immersion duration (at 30 minute and 480 minute); alkali solution temperature at room temperature (26 ± 1 ºC) and 100 ºC; and alkali concentration (at 2% w/v and 10% w/v). Untreated kenaf fiber was used as control sample and the tensile test was conducted according to ASTM C1557-03. Cross sectional area was measured using Leica video analyzer. The results showed that alkali treatment conditions have a significant effect on kenaf bast fiber tensile strength. The immersion time appears to be most dominant factor that influences the kenaf fiber tensile strength mean value during alkali treatment process with -108.82 magnitudes and followed by alkali solution concentration with - 30.99 magnitudes. On the other hand, temperature factor showed a small effect on fiber tensile strength mean value changes. Finally, from this study analysis of variance results, it indicated that the interaction effect between factors during alkali treatment process was not statistically significant to kenaf fiber tensile strength changes.

Keywords: factorial analysis, alkali treatment conditions, kenaf fiber, tensile strength.

INTRODUCTION

Recently, the demands on renewable resources like natural fibers as alternative reinforced materials in polymer matrix composite have increased extensively. This was attributable to the awareness of environmental issues, depleting petroleum sources, utilization of abundantly available natural fiber and the availability of improved data on the properties and morphologies of natural fibers materials (Satyanarayana, Arizaga *et al.* 2009). However, a large inconsistency in characteristic properties due to variability in the natural fiber origin has restricted the extensive application of natural fiber reinforced composites (Ochi 2010). Furthermore, the major limitations of using natural fiber as reinforcements in polymer matrix composite was it poor interfacial adhesion between polar-hydrophilic fiber and non polar hydrophobic matrix. This in turn would lead to composites with weak interface (John and Anandjiwala 2008).

Alkali treatment was one of the widely used techniques to clean and modify natural fiber surface which will enhance the interface bonding between fiber and polymer matrix (Kabir, Wang *et al.* 2012). The effects of alkali treatment and fiber length on mechanical properties of short Agave fiber reinforced epoxy composite the have been studied by Mylsamy *et al.*(Mylsamy and Rajendran 2011). They found that the composite with alkali treated fiber exhibited a higher tensile, compression, flexural and impact strength than the one with untreated fibers. Another similar study but focused on flexural properties of alkali treated and untreated kenaf epoxy composite was conducted by Yousif (Yousif, Shalwan *et al.* 2012), where the alkali concentration was at 6% and fiber immersed time was 24 hour. As a result, he found that 36% increment in kenaf epoxy composite flexural strength achieved when treated kenaf fiber were used as reinforcement. Edeerozey *et.al* (Edeerozey, Akil *et al.* 2007) reported that kenaf fiber treated with 6% alkali at 95 ºC shows a higher value of unit break compared to alkali treated kenaf fiber at same concentration but at room temperature. They also found that the alkali treated kenaf fiber shows a higher average unit break then untreated kenaf fiber accept for the kenaf fiber that treated at 9% alkali concentration.

Conversely, recent work conducted by Mahjoub *et al.* (Mahjoub, Yatim *et al.* 2014) used various alkali solution concentration and fiber immersion time to evaluate the tensile properties of kenaf fiber. They concluded that the tensile strength of kenaf fiber decreased by increasing the alkali solution concentration and immersion time. They also found that the untreated kenaf fiber shows higher tensile properties as compared to alkali treated kenaf fiber. Higher alkali concentration would deteriorate the fiber strength which lead to the decrease of it composite tensile strength (Gu 2009). From previous studies results, it was clearly mention the significance of alkali treatment to enhance fiber matrix interfacial bonding. Several authors mention different alkali treatment conditions setting which contribute to variability in composite characteristic evaluations (Boopathi, Sampath *et al.* 2012; Roy, Chakraborty *et al.* 2012; Obi Reddy, Uma Maheswari *et al.* 2013). However, there are still few works focused on alkali treatment conditions impact on fiber properties have been reported (Hashim, Roslan *et al.* 2012; Hashim, Ahmad *et al.* 2013). Therefore, this study aim to determine the impact of alkali treatment conditions on kenaf fiber bundle tensile strength.

MATERIAL AND METHODS

Material

Kenaf bast fiber (KBF) was supplied by Kenaf Natural Fiber Industries (Malaysia). This kenaf fiber 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. Sodium hydroxide (NaOH) in pallet form was supplied by BDH Prolabo (UK).

Alkali treatment preparation

NaOH solution concentration was prepared using weight volume percentage (w/v %). Kenaf bast fiber was immersed into 2 and 10 (w/v %) NaOH concentration. Fiber immersion time was at 30 and 480 minutes; at room temperature (approximately 27oC) and 100oC 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 100oC~105oC for one hour.

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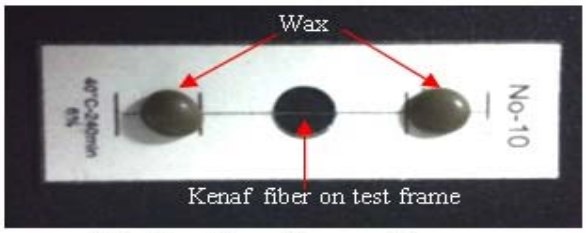
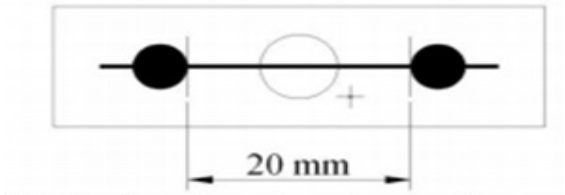
Cross sectional area measurement

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 KBF without obvious defects are selected as test samples under the video analyzer observation. A test specimen mounting tab according to ASTM C1557-03 was prepared as shown in Figure-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 different locations at center area of gauge lengths along two orthogonal directions. The first diameter was measured and followed by next diameter measure at about 900 from the earlier measurement, which is the major and minor axis if assuming the cross section is in an elliptical shape (Xue, Du *et al.* 2009). $A = \pi ab/4$, 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. The mean cross sectional area was used as a kenaf fiber area to determine the fiber tensile strength. The results of cross sectional area measurement was published previously (Hashim, Roslan *et al.* 2013). 2 levels full factorial experiment designs was used and the data analysis was conducted using Minitab software.



(a) Kenaf bast fiber test frame

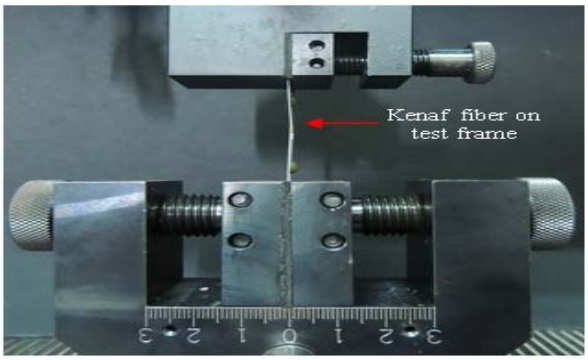


(b) Specimen dimension schematic diagram

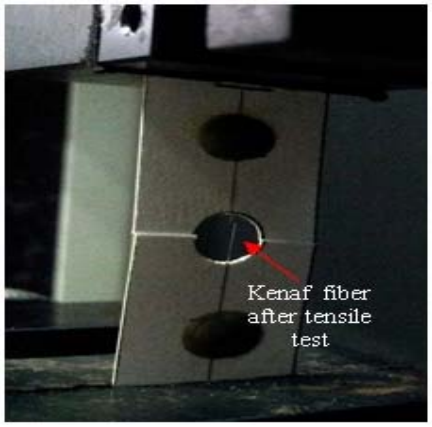
Figure-1. Kenaf bast fiber mounting tab according to ASTM C1557-03.

Kenaf fiber tensile test

Kenaf fiber was place on mounting tap according to ASTM C1557-03. To fix the fiber as straight as possible between the clamps, they were glued with a wax into a paper frame that was cut just before the tensile test conducted. Tensile test was performed using Lloyd Instrument Universal Testing Machine (model LR30K) with a 10N load cell as shows in Figure-2. A cross head speed setting was 1.0 mm/min and gauge length of 20 mm was chosen. These tests was performed in ambient temperature (23 ± 0.5ºC, 56.5 ~ 60.7 % RH). Six specimens was tested under each conditions and the average value was calculated.



(a) Test specimen front view.



(b) Test specimen side view

Figure-2. Kenaf bast fiber tensile test specimen at (a) front view and (b) side view.

RESULTS AND DISCUSSION

Kenaf fiber tensile properties

The impact of alkali treatment conditions on the tensile strength of kenaf bast fiber was investigated. Table-1 shows the results of tensile test conducted. Untreated kenaf bast fiber shows a higher tensile strength (352.22 MPa) compared to alkali treated kenaf bast fiber at all treatment conditions. However, at lower alkali concentration and lower immersion duration with high temperature setting, kenaf fiber tensile strength average was approximately equivalence to untreated kenaf fiber tensile strength (345.29 MPa) and maximum load to break the fiber (2.08 N). The lowest tensile strength and maximum load to break the fiber is 169.97 MPa and 0.91 N respectively when the alkali treatment conditions was set at higher alkali concentration, immersion duration and immersion temperature. From the result, kenaf fiber tensile strength shows a decrement pattern with the increment of all treatment conditions. The reduction in kenaf fiber tensile strength probably was due to fibrillation phenomenon during alkali treatment. During alkali treatment, cellulose molecular chains in a microfibril and lose their crystalline structure which result to reduction of overall kenaf fiber crystallinity. Additionally, alkali treatment removes impurities, wax, lignin as well as hemicellulose of kenaf fiber (Cao, Sakamoto *et al.* 2007). This result shows good agreement with previous study conducted by Reza et. al and Nitta *et al.* (Nitta, Goda *et al.* 2013; Mahjoub, Yatim *et al.* 2014) which highlight that tensile strength of kenaf fiber reduce after alkali treatment. Conversely, Edeerozey *et al.* stated the tensile strength of alkali treated kenaf fiber increased compared to untreated kenaf fiber (Edeerozey, Akil *et al.* 2007). The variability of tensile strength for all test conditions was found to be quite large with the range from 9.29 to 91.76.

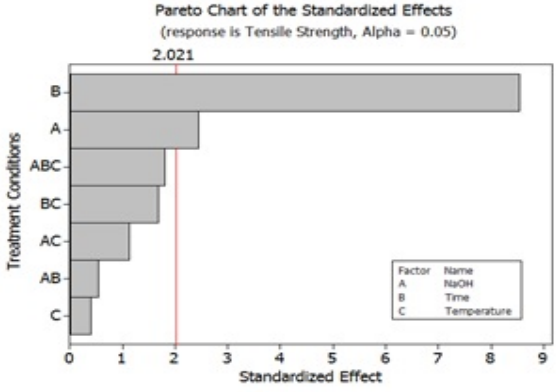
Table-1. Tensile strength of kenaf bast fiber under different alkali treatment condition.

		Maximum load (N)	Tensile strength (MPa)	Maximum load (N)	Tensile strength (MPa)
		Temperature (°C)			
Alkali (w/v %)	Duration (minute)	Room Temperature		100	
0	0	2.0 (0.2)	352.22 (50.87)	-	-
2	30	1.73(0.15)	327.68 (27.99)	2.08 (0.11)	345.29 (44.05)
	480	1.48 (0.1)	223.88 (9.29)	1.10 (0.1)	244.91 (50.56)
10	30	1.81 (0.16)	294.73 (27.36)	1.32 (0.06)	329.72 (91.76)
	480	1.28 (0.1)	223.38 (18.35)	0.91 (0.1)	169.97 (25.85)

( ) standard deviation value

Main effect and interaction plot

Three factors at two levels experimental design was used to determine the main and interaction effect. Average value was used as response mean value and factorial analysis was done to identify the alkali treatment conditions significant effect. Figure-3(a) illustrates the Pareto chat of alkali treatment conditions to compare the relative magnitude and statistical significance of both main and interaction effects. From Pareto chart, it shows statistically that immersion time and alkali concentration has a significant impact on kenaf fiber bundle tensile strength. Figure-3(b) and (c) illustrates the main effect and interaction plot alkali treatment conditions. The main effect value of immersion time and alkali concentration was -108.82 and -30.99. Both main effect values indicate the negative sign, which suggest that increasing the both setting value from lower level to higher level will decrease the kenaf fiber bundle tensile strength. Figure-3(c) indicated the interaction of treatment conditions found within the scope of this study. There was a small interaction of alkali concentration, immersion time and temperature. Kenaf bast fiber mean tensile strength was higher at low alkali concentration and immersion time when immersion temperature was kept at high level (100 °C). Conversely when alkali concentration and immersion time was set at higher level, kenaf bast fiber mean tensile strength was decreased. However, from analysis of variance result, this small interaction was found to be not significant statistically because all the two and three way interactions *p* value was greater than 0.05.



(a) Pareto Chart

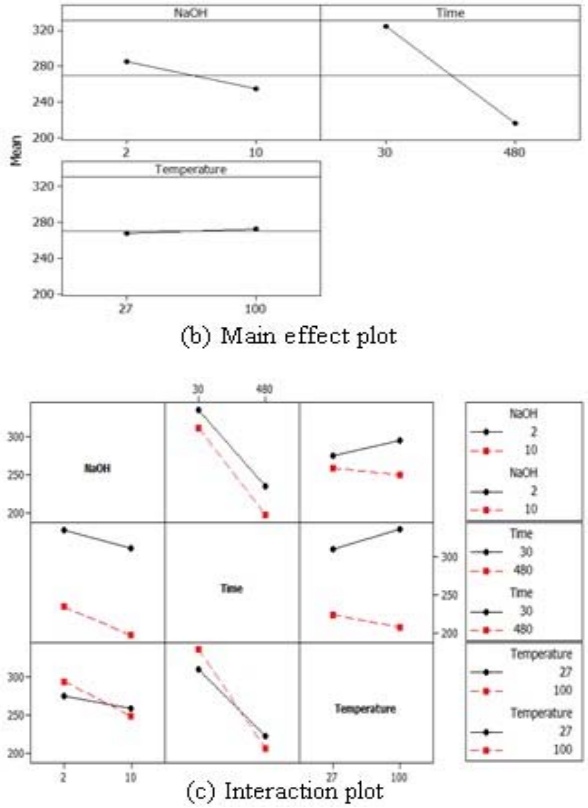


Figure-3. (a) Pareto chart, (b) Main effect plot, (c) Interaction plot for the temperature and immersion time impact on kenaf polyester tensile strength

CONCLUSIONS

This study was conducted to determine the significant level of effect by three considered alkali treatment conditions on dictating the kenaf fiber tensile strength mean values. The results showed that alkali treatment conditions do have the impact on tensile strength of kenaf bast fiber. The immersion time appears to be most dominant factor that influences the kenaf fiber tensile strength mean value during alkali treatment process with -108.82 magnitudes. The negative sign indicated that, kenaf fiber mean tensile strength was decreased when the immersion time increased from 30 minute to 480 minutes. Additionally, the alkali concentration factor is also found to be significant which reduced the fiber tensile strength when higher alkali concentration was used. Furthermore, this work also shown that temperature setting had a small impact on fiber tensile strength mean value changes. Increasing the immersion temperature from room temperature to 100oC will slightly increase the fiber tensile strength mean. From analysis of variance results, the interaction effect between the factors was found to be not statistically significant. Finally, this study also found that the untreated kenaf bast fiber shows a higher tensile strength (352.22 MPa) compared to alkali treated kenaf bast fiber at all treatment conditions. From the scope of this study, it could be suggested that to increase kenaf fiber tensile strength using alkali treatment, the alkali treatment conditions should be set at lower alkali concentration range and shorter fiber immersion time.

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