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Impact of alkali treatment conditions on kenaf fiber polyester composite tensile strength

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Abstract. The increase of environmental issues awareness has accelerated the utilization of renewable resources like plant fiber to be used as reinforced material in polymer composite. However, there are significant problems of compatibility between the fiber and the matrix due to weakness in the interfacial adhesion of the natural fiber with the synthetic matrices. One of the solutions to overcome this problem is using chemical modification like alkali treatment. In this study, the impact of alkali treatment conditions on short randomly oriented kenaf fiber reinforced polyester matrix composite tensile strength was investigated. The experimental design setting was based on 2 level factorial experiments. Two parameters were selected during alkali treatment process which are kenaf fiber immersion duration (at 30 minute and 480 minute) and alkali solution temperature (at 40^{o}C and 80^{o}C). Alkali concentration was fixed at 2% (w/v) and the kenaf polyester volume fraction ratio was 10:90. The composite specimens were tested to determine the tensile properties according to ASTM D638-10 Type I. JOEL scanning electron microscopy (SEM) was used to study the microstructure of the material. The result showed that alkali treatment conditions setting do have the impact on tensile strength of short randomly oriented kenaf polyester composite. The interaction factors between immersion time and temperature was found to have prominent factors to the tensile strength of composite followed by the immersion time factor.

Introduction

Utilizing of renewable resources like natural fibers as reinforced materials in polymer matrix composite had became aggressive trends since last two decades. This was triggered by the increasing 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 [1]. Furthermore, natural fiber composite also have an advantages like low cost, low density, less damage to processing equipment, reasonable specific strength, absence of associated health hazards and biodegradability [2]. On the other hand, a large inconsistency in characteristic properties due to variability in the natural fiber origin has restricted the extensive application of natural fiber reinforced composites. Generally, the shape, size and strength properties of natural fiber depend on their region of origin, cultivation environment, maturity, retting process, etc. [3]. Natural fibers are hydrophilic in nature as they are derived from lignocellulose, which contain strongly polarized hydroxyl groups. These fibers, therefore, are inherently incompatible with hydrophobic polymer matrix. The major limitations of using these fibers as reinforcements in such matrices include poor interfacial adhesion between polar-hydrophilic fiber and non polar hydrophobic matrix, and difficulties in mixing due to poor wetting of the fiber with the matrix. This in turn would lead to composites with weak interface [4].

Chemical treatment on natural fiber is an alternative solution that often applied to overcome these fiber-matrix interfacial problems. 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 [5]. Recent work conducted by Reza et al. [6] used various alkali solution 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. This finding was good agreement with previously conducted studied by Hashim [7]. He used different alkali treatment conditions setting and found that alkali concentration had a higher impact on diameter changes compared to alkali treatment immersion temperature. Gu [8] investigated the brown coir polypropylene polymer composite tensile behavior after the coir was treated by alkali solution at different concentration from 2% to 10%. The investigation results showed that higher alkali concentration would deteriorate the fiber which lead to the decrease of it composite tensile strength. The effects of alkali treatment and fiber length on mechanical properties of short Agave fiber reinforced epoxy composite the have been examined by Mylsamy et al.[9]. The results indicated 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 [10], 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.

From previous studies results, it was clearly mention the significance of alkali treatment to enhance fiber matrix interfacial bonding. However, there are still less works have been reported focused on alkali treatment conditions factors analysis. Several authors mention different alkali treatment conditions setting which contribute to variability in composite characteristic evaluations [11-13]. Therefore, this study aim to determine the impact of alkali treatment conditions on short randomly oriented kenaf fiber reinforced polyester matrix composite tensile strength.

Material and Methods

Material. Bast type kenaf fiber was supplied by Kenaf Natural Fiber Industries (Malaysia) Sdn. Bhd. This kenaf fiber was subjected to about two weak water retting process before supplied to the laboratory. Sodium hydroxide (NaOH) in pallet form was supplied by BDH Prolabo (UK). Alkali solution concentration was prepared using weight volume percentage (w/v %).

Alkali Treatment Preparation. 2 (w/v%) alkali solution at two different temperature (40^{o}C and 80^{o}C) was set using dyeing machine model Rapid H-12C. The fiber immersion time was at 30 and 480 minute. After immersion, kenaf fiber was washed in running tab water and rinse by distilled water. Acetic acid was used to remove any excessive sodium hydroxide until the nominal pH value 7 was recorded. Next, kenaf fiber were dried in the oven at 100^{o}C~105^{o}C for 24 hour. Finally, alkali treated kenaf fiber were cut into short fiber (about 3 mm) using crushing machine for composite fabrication preparation. Table 1 shows 2 level factorial experiments used in this work.

Composite Fabrication. A percentage of short kenaf fiber used in the composite is 10% by weight and calculated using Rule of Mixture. Polyester resin 2597P-I and Methyl ethyl ketone peroxide (MEKP) was used as a matrix with ratio 100:1. Kenaf fiber and polyester was blend together and then simple hand lay-up process was applied for fabricating kenaf polyester composite as shows in Fig. 1. The mild steel plate at 260 mm x 240 mm x 3 mm was used as a mould. The mould was covered with transparent plastic and pressed at 0.5 ton for 2 hour. After 2 hour, the composite were removed from press machine and cured at room temperature for 24 hour.

Specimen Test and Testing Processes. Composite was cut into desire dimension for tensile test specimen according to ASTM D638-10 Type I using CNC machine. The length, width and thickness of each sample were approximately 165, 20 and 3 mm. Five samples from each conditions was tested. Tensile test were performed using Shimadzu Universal Testing Machine (model AG-I, 10kN). A cross head speed setting was 5 mm/min and a gauge length of 50 mm as show in Fig. 2.

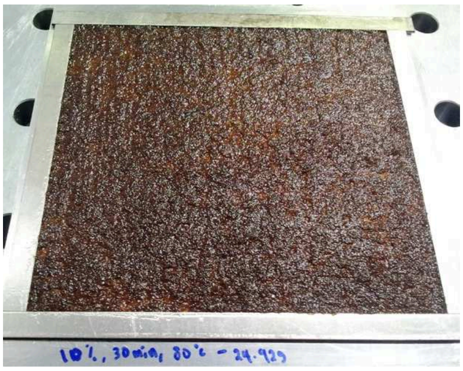


Fig. 1: Kenaf polyester composite fabrication

Fig.2: Tensile test on the specimen

Results and Discussion

Composite Tensile Properties. The impact of alkali treatment conditions on the tensile strength of short kenaf fiber polyester composite was investigated. Table 2 shows the results of tensile test conducted. At 30 minute fiber immersion time, composite tensile strength was increased about 10% with the increment of immersion temperature from 40^{o}C to 80^{o}C. However, at 480 minute fiber immersion time, composite tensile strength at 80^{o}C was lesser compared to the alkali treated kenaf composite at 40^{o}C. The decrement was about 15%. This indicates that the tensile strength of kenaf fiber reduces by increasing the immersion time [6] and temperature[14].

Table 1: Alkali treatment conditions and their levels for experiment

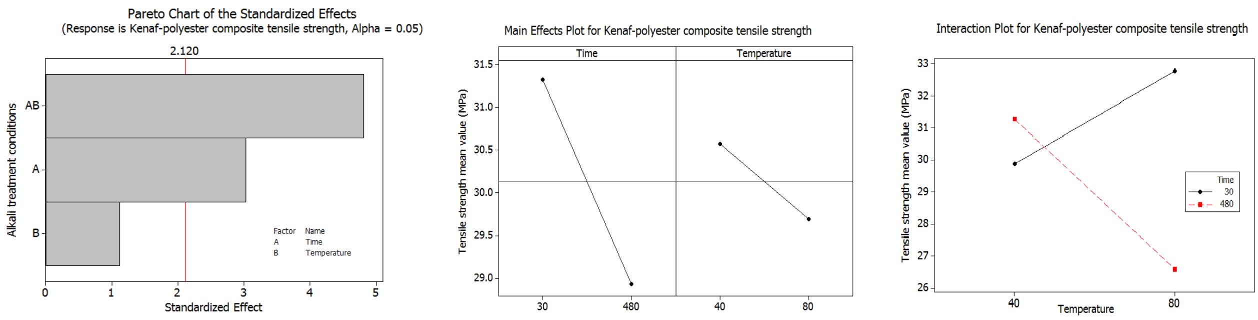
Treatment Conditions	Low Level	High Level	Response
Immersion Duration (minute)	30	480	Short kenaf fiber polyester composite tensile strength
Immersion Temperature (^{o}C)	40	80	

Table 2: Tensile properties of composite under different alkali treatment conditions

Treatment Condition		Tensile Strength (MPa)
Time (min)	Temperature (^{o}C)	
30	40	29.87 (2.31)
30	80	32.79 (2.08)
480	40	31.28 (0.92)
480	80	26.60 (1.39)

( ) standard deviation value

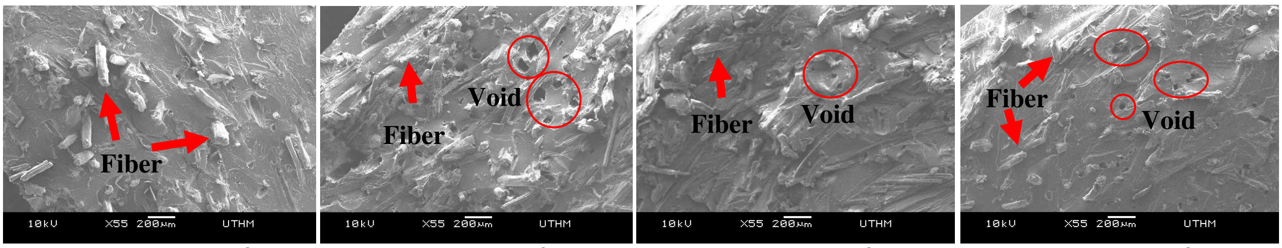
Main Effect and Interaction Plot. Using the tensile test results, a factorial analysis was done to identify the alkali treatment condition significant effect. Fig. 3(a) illustrates the Pareto chat of alkali treatment conditions to compare the relative magnitude and statistical significance of both main and interaction effects. From Pareto chart, it shows statistically that temperature effect its own has no significant effect on composite tensile strength. However the interaction of immersion time and temperature obviously has a significant impact on composite tensile strength. Fig. 3 (b) and (c) illustrates the main effect and interaction plot of immersion time and temperature on kenaf polyester tensile strength. The main effect value of immersion time and temperature was -2.393 and -0.879. Both main effect values indicate the negative sign, which suggest that increasing the both setting value will decrease the kenaf polyester composite tensile strength. Fig. 3(c) indicated that there is strong interaction between temperature and immersion time. Composite tensile strength is higher when immersion temperature is kept at high level (80^{o}C) and immersion time is kept at 30 minute. Similarly, the composite tensile strength is lower when immersion temperature is kept at high level (80^{o}C) and immersion time is kept at 480 minute.



(a) Pareto chart (b) Main effect plot (c) Interaction plot

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

Fiber Surface Microstructure. It is expected that the kenaf fiber surface will be different for all conditions due to the different in level setting. The main different will be in terms of their smoothness and roughness. According to the Bachtiar et al., tensile strength of alkali treated sugar palm epoxy composite decrease when the soaking duration getting longer from 4 hour to 8 hour. This was probably due to the damage of the fiber after alkali treatment [15]. Fig.4 (a)-(d) shows the SEM micrographs obtain from the fractured surface of the composites. In general, it was seen that the interfacial bonding between fiber and matrix shows good performance. The void also was found at certain area of the fractured surface. At higher temperature and immersion time setting, Fig.4 (d) it can be seen that most of the fiber was broken inside the matrix which indicate the better adhesion for the increase of temperature and immersion time. Unfortunately, this phenomenon is not sufficient to enhance the composite tensile strength for the samples at this condition setting due to the fiber damages could lead to the tensile strength reduction.



(a) 30 min 40^{o}C (b) 30 min 80^{o}C (c) 480 min 40^{o}C (d) 480 min 80^{o}C

Fig.4: SEM micrographs of kenaf polyester composite at different alkali treatment conditions after tensile test at fractured surface

Conclusions

The study result showed that alkali treatment conditions do have the impact on tensile strength of short randomly oriented kenaf polyester composite. The interaction factors between immersion time and temperature was found to have significance influence particularly on composite tensile strength followed by the immersion time factor. The hydrophilic character of kenaf fiber has been reduce due to alkali treatment and therefore has increased the interfacial bonding between kenaf fiber and polymer matrix surface. However, at longer immersion time and higher temperature setting during alkali treatment could damage the kenaf fiber. Thus, it could lead to inferiority in composite strength property. From the scope of this study, it could be suggested that to increase composite tensile strength using alkali treatment, the alkali treatment conditions should be set at higher immersion temperature and shorter immersion time.

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