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Effect of Woven and Alkalization Treatment on Mechanical Properties of Kenaf Fibre Reinforced Polymer Composites

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Abstract: This paper report the effect of weave pattern and alkalization treatment on fabric kenaf fiber reinforced polymer matrix composite. Two types of yarn kenaf namely, non-treated and treated, were prepared for the reinforcement. The yarns kenaf undergo alkalization treatment before the yarn weave into the fabric that based on plain and twill weave design. A vacuum bag resin transfer molding (VBRTM) infused the mixed liquid resin with hardener into the singe ply fabric until complete impregnation. Tensile test performed on the composite found that the weave design and the treatment give a significant impact on the tensile. Composite made from kenaf fabric which has low crimp percentage resulted in high tensile strength. Meanwhile, treatment performed on the yarn also improve the tensile strength of the composite.

Keywords: Kenaf Reinforced Composite, Plain, Twill, Vacuum Infusion

1. Introduction

Kenaf or its scientific name Hibiscus cannabinus L is a warm-season annual fiber. The government of Malaysia identified the kenaf is one of the viable material which has economic potential and manages to develop the industry as the national agenda. The government call to diversified the use of kenaf in various application included the automotive components, food packaging, furniture as well as sports and leisure. Identifying new uses for kenaf has become an important task. The potential of kenaf fiber

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as a composite reinforcement has created significant interest and expectations among material scientists and engineers. The kenaf fiber composites can replace synthetic composites due to the cost-effective content and better properties (listed in Table 1). This advantage makes kenaf fiber composite material is an attractive alternative to synthetic composites for industrial applications.

Table 1: Comparison of natural and synthetic fiber properties [1]

Fibre	Density (g/cm^3)	Tensile Strength (Mpa)	Specific Tensile Strength (Mpa)	Elastic Modulus (GPA)	Specific Elastic Modulus (GPA)
Cotton	1.5-1.6	400	250-267	5.5-12.6	3.5-8.1
Kenaf	1.45	930	641	53	36.5
Sisal	1.5	511-635	341-423	9.4-22	6.3-14.7
E-glass	2.5	2,000-3500	800-1,400	70	28
Carbon	1.4	4,000	2,857	230-240	164-171

Various techniques introduced in previous research work attempt to improve the mechanical properties of the kenaf fiber composite. Meon et al. used alkalization treatment by soaking the fiber in sodium hydroxide [2]. The treatment decreases the fiber diameter, improves the aspect ratio, contributing to the creation of rugged surface topography, improved adhesion to the fiber matrix interface, thus increasing mechanical characteristics. The strength of alkalized fiber showed improvement when subjected to a tensile force. Increasing the fiber content in the composite also would affect the strength of the composite. El- Sheikel et al. [3] found that the composite exhibit the best tensile strength when the fiber content is 30% in weight percentage of the composite.

Meanwhile, Rassmann et al. [4] proved that the strength of the kenaf fiber composite also determines by the type of resin system. The epoxy resin provides good strength than the polyester and vinyl ester. However, Rassmann et al. [4] claim that polyester has good elastic modulus compared to the other resin.

The woven and non-woven kenaf fabric is expected play an important role in the mechanical properties of the composite. As reported by Abu Bakar et al. [5], different fiber structure resulted in different elasticity and strength. Drapability of twill weave fabric is better than the plain weave, but the tensile strength of plain weave is higher than the twill weave [6]. Meanwhile woven kenaf required more processing time than the non-woven. The users and manufacturers need to understand better the behavior of woven kenaf composites and therefore make informed decisions during the design process. Thus, in this work, the effect of weave pattern, plain and twill, made from treated and untreated yarn kenaf on the tensile of the kenaf fiber reinforced composites were investigated.

2. Materials and Methods

This work used a kenaf yarn with a linear density of 759 tex, which obtained from Juteko Bangladesh Pvt Ltd. The process started with alkalinization treatment. The treatment changed the chemical constituent behavior in natural fiber. The yarn kenaf soaked in solution of 6% sodium hydroxide (NaOH) that mixed with 2500 ml distilled water. The treated kenaf than dried in the oven at 40 ^oC for 3 hours. After the yarn kenaf completely dried, a manual loom machine weave the yarn into two types of fabric pattern, namely as plain and twill. The plain and twill weave pattern of the fabric has two sets of yarn called as warp and weft, which both interlace in ninety degrees. The interlace between the warp and weft, creating waviness on the fabric. A crimp percentage were used to determine the waviness of the warn and weft. Table 2 lists the properties of the fabric. Figure 1 illustrates the difference between both weave pattern.

Table 2: Fabric pattern properties

Woven	Yarn Diameter (mm)	Warp (count/cm)	Weft (count/cm)	Crimp warp (%)	Crimp weft (%)
Plain	1	5	4	16	8.1
Twill	1	5	5	3	6.2

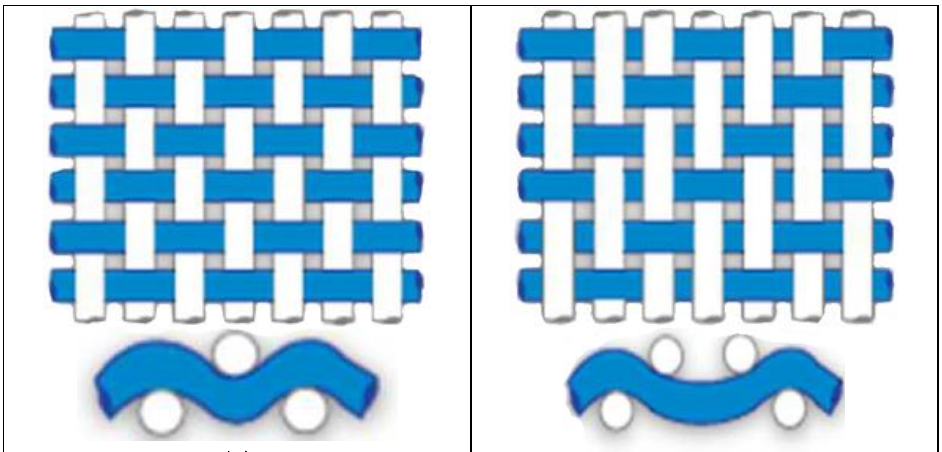

(a) (b)

Figure 1: Weave pattern (a) plain (b) twill

The research work prepared the composite from unsaturated polyester resin that mixed with the catalyst of methyl ethyl ketone peroxide (MEKP). The mixing provided the chemical reaction between the resin and catalyst which generate heat and cures or harden the resin. A mixing ratio of 100:2 in weight percentage was applied. The mixtures were stirred before infused into the kenaf fabric. A vacuum bag resin transfer molding (VBRTM) infused the mixed liquid resin with hardener into the singe ply fabric until complete impregnation. The complete kenaf reinforced polymer composite was than de-moulded and cut into specimen for test. In this work, two parameters and two levels were selected in the experiment. Table 1 lists the investigated parameters and levels. Figure 2 shows the overall kenaf reinforced polymer composite processing.

Table 1: Parameters and levels

Parameters	Levels
Fabric pattern	Non-woven
	Twill weave
	Plain Weave
Type of kenaf yarn	Treated
	Non-treated
Yarn diameter	1 mm

The fiber microstructure examinations were performed on the yarn treated and non-treated yarn kenaf using the SEM. The examination provides the reason and identified the effect of alkalinization treatment in micro-scale. Tensile and three-point bending flexural tests were carried out on the specimen using Instron universal testing machine, according to ASTM D638 and ASTM 790 respectively. The microstructure examination also performed on the crack sample to investigate the crack mechanism.

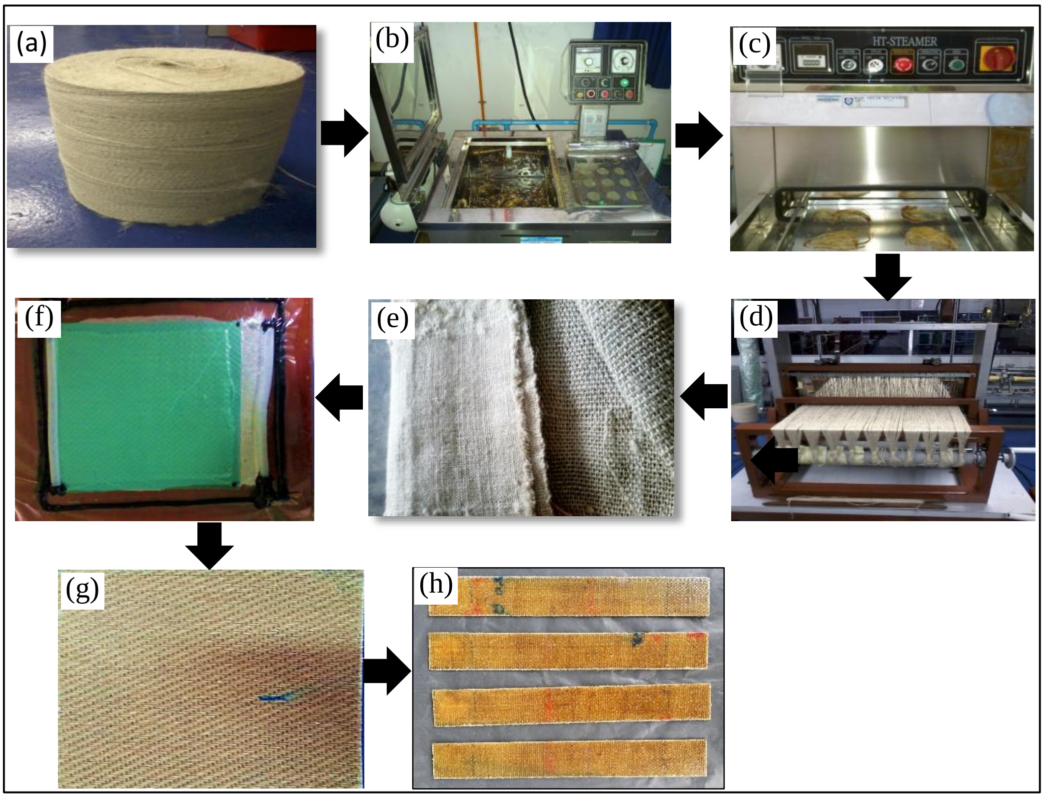


Figure 2: Process flow of the kenaf fiber composite (a) Yarn kenaf (b) alkalinization (c) drying (d) woven yarn kenaf into the fabric (e) kenaf fabric (f) resin infusion into the fabric (g) complete kenaf reinforced polymer composite (h) test specimen

3. Results and Discussion

Figure 3 shows the tensile strengths of kenaf fiber reinforced composite produced from two different fabric pattern and types of yarn kenaf, the treated and non-treated. In this figure and all subsequent figures, the error bars correspond to one standard deviation from the mean. The result indicated that the fabric made from a twill weave pattern, which have low crimp percentage resulted in higher tensile strength than the plain weave pattern for both treated and non-treated. The twill weave pattern has maximum stress of approximately 31 MPa, which is 10% larger than the plain weave. The result is in agreement with the findings of Hübner et al. [5] and Stig [7] for textile fabric. Kenaf fabric with low crimp percentage provide

The result also found that the treatment performed on the yarn kenaf affected the strength of the composite. The composite produced from treated yarn kenaf for both weave pattern, plain and twill, has maximum stress higher than the non-treated. Comparing the untreated and treated plain weave results in a maximum stress difference of approximately 11.2 MPa or an increase of approximately 70% from 16 MPa. This indicated the treatment performed on the yarn kenaf was significantly improving the mechanical properties of the composite. In the case of the twill weave pattern, the treatment performed on the yarn kenaf also enhanced the strength of the composite to 31 MPa from 23 MPa.

Tensile crack examination on the treated and non-treated specimen using the SEM revealed that the failure mainly correlated with the formation and propagation of matrix micro-cracks accompanied by successive fiber failure. As shown in Figure 4 (a) and (b), both type of woven kenaf shows the crack failure mainly consisted of matrix fracture, fiber-matrix debonding, fiber pullout and fiber breakup. The void and fiber pullout in non-treated kenaf found to be more prone than the treated kenaf. The condition indicated that the interface bonding between the kenaf fabric and the matrix composite of the treated kenaf is superior compared to the untreated.

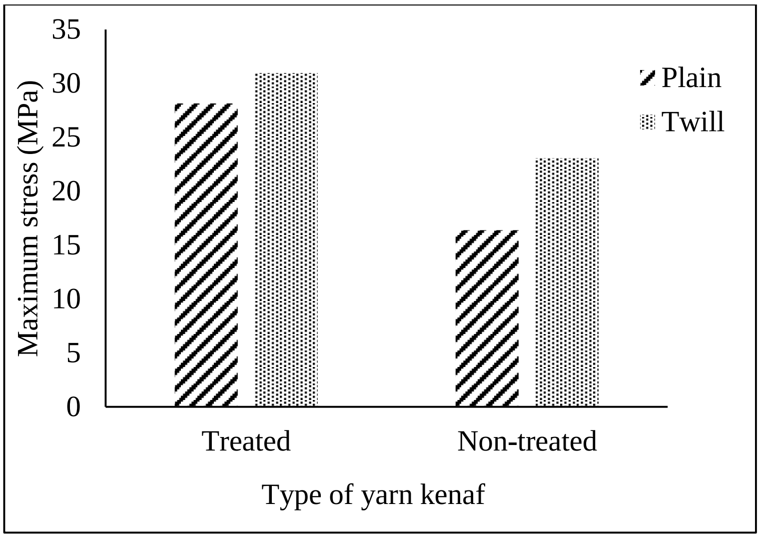
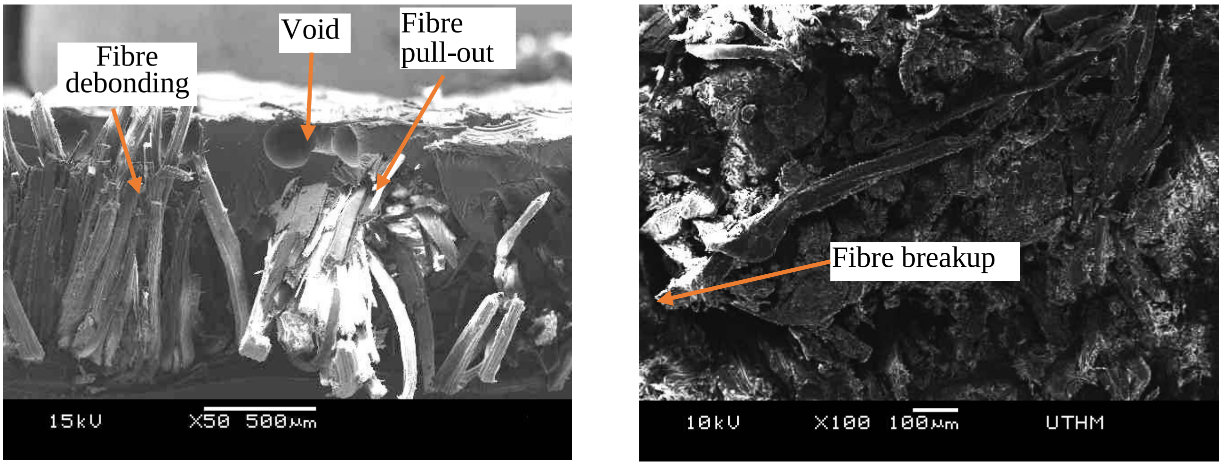


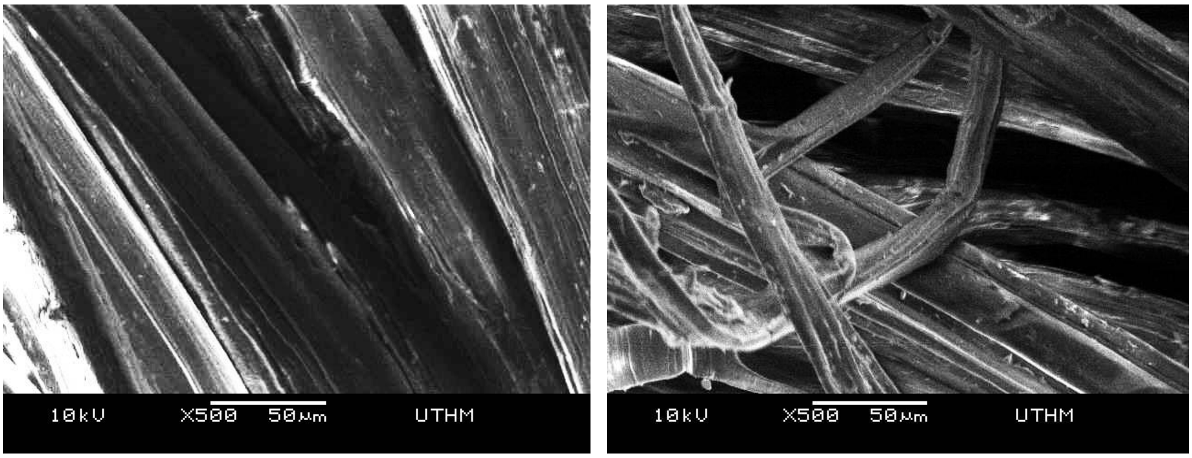
Figure 3: Maximum tensile stress



(a) (b)

Figure 4: Tensile crack examination (a) non-treated (b) treated

Figure 5 shows SEM image on single yarn kenaf before and after treatment. The image shows that alkalinization treatment has changed the physical properties of the yarn kenaf. The treatment has shrunk the size of the fiber and create tangled microfiber. The treatment broke hydroxyl group, a bundle of cellulose molecules that form the cellulose fibers [8]. The shrinkage of the yarn kenaf reduces the density of weave packing which in turn decreasing the void formation in the matrix composite. The shrinkage of the treated yarn kenaf also causes the kenaf polymer composite loaded with more fiber and less matrix polymer. Since the strength of the composite rely on the fiber, increment in the fiber volume fraction would increase the strength of the composite. Beside, the treatment also improved the resin absorption into the fiber. The kenaf fabric with high resin absorption has good fiber-matrix interface bond, thus improving the strength of the composite [3], [9].



(a) (b)

Figure 5: Kenaf thread (a) before treatment (b) after treatment

4. Conclusion

In this work, the selection of the weave design and yarn treatment was found to be the essential factor governed the strength of the polymer composite. The weave design and the alkalinization treatment significantly affected the tensile strength. The weave design of twill, which has low crimp percentage, resulted in higher tensile strength compared to the plain weave design. The strength of the composite also improved by performing kenaf yarn alkalinization treatment which performed prior to weaving the kenaf and polymer infusion. The treatment performed on the kenaf has shrunk of the yarn kenaf, reduce the density of weave packing which in turn decreasing the void formation in the matrix composite and

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