Influence of Mengkuang Fiber Orientation on the Strength of Its Composite

by

Noor Fadhilah Binti Elias

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Dissertation submitted in partial fulfillment of
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Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved by,

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(AP Dr Puteri Sri Melor Megat Yusoff)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
May 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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NOOR FADHILAH ELIAS

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ABSTRACT

Natural composites have been used in various types of applications in industries. It contains of resin, which is reinforced by natural fiber. For this final year project, natural composite is produced from mengkuang fiber and epoxy resins. This paper will discuss about the progress of producing the mengkuang filled composite. Extraction of continuous cellulose fiber from mengkuang leaves needs to be done first. Alkaline treatment with different concentrations of NaOH is used in order to extract the continuous cellulose fiber from the leaves. The texture of the chemically purified continuous cellulose fiber was observed by visual inspection. FESEM is used in order to visualize the small topographic surface of the treated mengkuang leaves. After that, the composite with different orientations are produced by using vacuum infusion method. Tensile test concluded the process of this project.

CHAPTER 1: INTRODUCTION

1.1 Background

Currently, natural composites have been used widely for various types of applications in the industries. Natural composites contain of resins and are reinforced by natural fiber, which are usually obtained from different types of plants such as kenaf, rice husk, rice straw, banana leaves and pineapples leaves [1].

Previously, natural fibers were only used for hard board and particle board. However, the use of natural fibers has been widened and matrices have been added to the fibers in order to create limitless application of the composites [2]. Due to the cost and property differences, synthetic fiber has been chosen as a replacement to natural fiber for various applications. However, the energy consumption in order to change the raw material and the production process of synthetic fiber based composite is huge. Thus, natural fiber is once again the preference for the industries.

Compared to synthetic fiber, natural fiber is renewable and biodegradable because it is made from natural ingredients [3]. The renewed ways of natural fiber production can produce high quality fiber and it is equivalent to synthetic fiber. Hence, natural fiber has come out as one of the beneficial industries in the country as the reinforcement to produce strong composites when combined with matrices.

1.2 Problem Statement

Uniform strength in natural composite is difficult to obtain. There are several factors that affect the strength of the composite, including the size of the fiber used, the type of fiber and the amount of fiber used. However, random orientation of the fiber filled in the composite played as a big factor as well. Hence, composites with different orientations of fiber need to be produced and tested with mechanical testing in order to determine the strongest fiber with the correct orientation of the fibers.

1.3 Objectives

- To investigate the influence of mengkuang fiber orientation on mechanical properties of its composite.

1.4 Scope of Project

The focus of this project is to produce mengkuang filled composite with different orientation of the fiber. Different orientation of the fiber inside the composite will provide different levels of strength to the composite produced. In order to obtain the fiber, extraction of the cellulose from mengkuang leaves will be done using the alkaline treatment process with different parameters. After the fiber is obtained, it will be arranged with different orientations and the matrix will be added by using vacuum infusion method. The produced composite with different fiber orientations will be tested using mechanical testing, which is the tensile test. Hence, the strongest composite produced with the suitable fiber orientation can be determined.

CHAPTER 2: LITERATURE REVIEW

2.1 Natural fiber

Nowadays, natural fiber has been used widely within the industries both locally and internationally in many fields [3]. Due to its various advantages, demand for natural fiber is expected to be higher as time goes by, especially in the automotive and construction industries. Usually, the material is used for the interior of passenger cars, furniture and truck cabins. Currently, the effect of global warming can be seen obviously, hence increasing the awareness towards the usage of green products and inspiring the use of natural fiber in the industries.

Many studies had been done on natural fibers, such as kenaf, banana leaves and rice husk. Regardless of the length of the natural fibers obtained, they showed remarkable results in producing good quality fibers and prove to be valuable in composite production. The use of natural fibers in a polymeric matrix enables the production of lightweight, biodegradable, sustainable, and cheaper composite compared to synthetic fibers [1].

Studies showed that the tensile and flexural strengths of natural fiber reinforced epoxy composites can increase about 40% to 60% compared to the composite without any reinforcement [3]. Since natural fibers show potential in developing new materials with good mechanical properties, studies have been conducted to get new sources for producing new fiber materials.

2.2 Pandanus tectorius

In Malaysia, pandanus tectorius or mostly known as Mengkuang leaves have shown their potential to be widely used in the industry as one of the strongest natural fibers. Mengkuang leaves are often used as mats, rope and hats due to its strength and long lasting effect [4]. Thus, numerous studies have been conducted in order to explore its potential as a new source of natural fiber for the local industry. From the studies conducted, the cellulose content of the mengkuang leaves is identified to be high. This high cellulose content gives strength to the leaves and causes them to be long lasting. Before the leaves can be fused with another matrix in order to form natural composite materials, they need to be extracted in the long fiber form. Since the fiber extracted from mengkuang leaf is in the form of long fiber, its mechanical properties will be higher compared to short fiber like rice husk, which only increases slightly, about 15 % from its original percentage [5].

2.3 Extraction of continuous cellulose fiber

Several extraction methods have been identified for the extraction of the fiber from the mengkuang leaves. Some of the identified treatment involves chemical treatment, which can be split into alkaline treatment and bleaching, grinding, enzyme-assisted hydrolysis from biological treatment, or a combination of the methods mentioned. Continuous form of the fiber needs to be obtained in order to use the natural fiber in its optimum potential. The continuous fiber provides a higher reinforcement effect and higher tensile strength as compared to the shorter and discontinuous fiber [6].

2.4 Orientation of fiber

Some studies have been conducted on the strength of composites with a variety of fiber orientations. Orientaton of fiber inside the composite plays a big role in determining the strength of its composite. For their research, pineapple leaves had been used as the fiber. The fiber is in continuous form. The results showed that a larger degree of fiber orientation causes poorer mechanical properties [7]. This is due to the fact that the specimens sustain greater load in 90-degree orientation than in other orientations, whereas extension is maximum in 30-degree orientation.

On the other hand, the tensile strength of the composites decreased when the fiber loading increased. Rice husks had been used as the fiber in their research and the ratio between the fiber and the matrix was 75:25. Risk husk produced short and random orientation fiber inside the composite [8]. It was found that the interfacial adhesion between the filler and matrix is weak due to the porosity and micro cracking. Young modulus also decreased when the filler loading increased.

On top of that, the addition of natural fiber component to the polyethylene resulted in an increase of stiffness in the composite. For this research, banana leaves had been used as the fiber inside the composite. The fiber used was in long and continuous form. Compared to the pineapple leaves and rice husks, the size of fiber produced from banana leaf is bigger and stiffer. It produced natural composites of low density and high strength [9].

2.5 Fabrication of composite

In order to produce the natural composite material, addition of matrix need to be done to the fiber. The fabrication of the composite can be made using vacuum infusion method. By using this method, resin will be driven into a laminate of fiber inside the vacuum bag through vacuum pressure, which is channeled by a tube. Fibers are laid dry inside a mold before the resin is introduced. The mold is sealed inside a vacuum bag by using a tacky tape and connected to a vacuum pump. Once all the air has been removed and complete vacuum is achieved, the vacuum pump will literally suck the epoxy resin into the laminate through the tubes [10].

2.6 Tensile Test

The tensile test is used to characterize the properties related to mechanical behavior of materials. During the test, the sample is subjected to a controlled tension until fails. From the results obtained, the material properties under different conditions of load can be acquired. Properties that are directly measured using the tensile test are ultimate tensile strength, maximum elongation, and reduction in area of the sample. Apart from that, Young's modulus, Poisson's ratio, yield strength, and strain-hardening characteristics can be found [11].

2.7 Field Emission Scanning Electron Microscopy (FESEM)

Field Emission Scanning Electron Microscopy (FESEM) is used to visualize the very small topographic details on the surface or the entire object. Electrons are discharged from a field emission source and accelerated in a high electrical field gradient within the high vacuum column. The electrons are focused and deflected by electronic lenses to produce a narrow scan beam on the object. A detector catches the electrons and produces an electronic signal. This signal is amplified and transformed to a video scan-image that can be seen on a monitor or to a digital image that can be saved and processed further [12].

CHAPTER 3: METHODOLOGY

3.1 Material

The material used for this experiment is the mengkuang leaves in the shape of a mengkuang mat. Chemical reagents needed are sodium hydroxide, sodium chloride and sulphuric acid.

3.2 Extraction of the cellulose

Firstly, the mengkuang leaves are cleaned using distilled water. Next, the leaves are dried under the sun after it is chopped approximately 15 cm x 1 cm in dimension. The leaves are then treated with 2% up to 10% of NaOH at 170^{o}C for 60 minutes. The ratio of the leaves to liquor was 5:300 (g/ml). For each treatment, the leaves are washed with distilled water and dried under the sun for a month.

3.3 Field Emission Scanning Electron Microscopy (FESEM)

After each alkaline treatment, visual inspection is carried out in order to observe the structure and the texture of the mengkuang leaves. The inspection is conducted after the leaves are dried under the sun and washed with distilled water. FESEM is used in order to observe the microstructure of the mengkuang leaves and the images are recorded digitally.

3.4 Chemical Composition Determination

The percentage of cellulose fiber were determined by using TAPPI standard; T203. 25mL treated mengkuang solutions were added to 10.0 mL of 0.5N potassium dichromate solution. 50mL of concentrated H_2SO_4 was added carefully, followed by 50mL of water after 15 minutes. 2 to 4 drops of Ferroin indicator was then added and titrated with 0.1N ferrous ammonium sulfate solution until it turned purple in color.

3.5 Vacuum Infusion Molding Method

Firstly, the laminate set up needs to be done for the fiber inside the vacuum bag with different orientations. After that, the fiber laminate setup is connected to the vacuum chamber using the resin outlet tube.

After the preparation for the laminate setup is done, the vacuum pump is connected to the power supply. The vacuum chamber needs to be connected to the vacuum pump prior to that. Vacuum chamber is needed in order to collect the excess resin during the process.

After that, the fiber laminate setup is connected to the vacuum chamber using the resin outlet tubing. Clamp the resin inlet tube and infuse the laminates setup for 5 minutes to ensure that no leakage occurred at the laminate setup.

If the leakage testing shows the positive results, the resin inlet tubing is immersed inside the resin. The resin will flow through the laminates until all fibers are fully impregnated with the resin once the vice is unclamped. After that, the end of the tube is re-clamped and the composite setup is cured inside the oven for 2 hours with the temperature of 90 °C. Once the composite setup is cured, the vacuum bag, peel-ply and net are peeled off from the composite.

The sequence of the composite will be in this manner:

1) Epoxy
2) Mengkuang fiber
3) Epoxy
4) Mengkuang fiber
5) Epoxy
6) Mengkuang fiber
7) Epoxy

Calculation:

Based on the stacking sequence, the expected volume fraction of the fiber needs to be determined. The equation below will be used to find the density of the composite:

$\rho_c = \rho_f + \rho_m$ ------------ Equation [1]

For the density of the mengkuang fiber, the equation below will be used:

$\rho_{f1} = \frac{m_{f1}}{v_{f1}}$ ------------- Equation [2]

Volume of the mengkuang fiber will be determined using this equation:

$v_{f1} = \frac{m_{f1}}{\rho_{f1}}$ -------------- Equation [3]

Assumption: Fiber is fully impregnated by the epoxy resin during infusion process.

For this project, volume fraction used for the fiber will be 60%. Hence, the volume fraction of the matrix, which is epoxy, will be 40%.

The mass of matrix to be used will be calculated using this equation:

$\rho_m = \frac{m_m}{v_m}$ -------------- Equation [4]

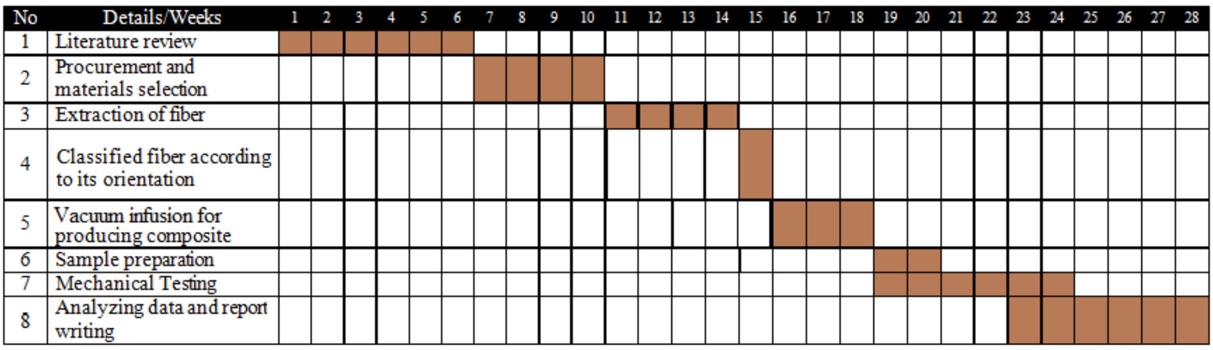
Ratio of resin and hardener = 60: 40

3.6 Tensile test

The composite produced will be taken to the Universal Testing Machine and undergo tensile testing. The sample, which is the natural composite produced shaped into dog bones, will be applied with load. After a certain time, the sample will break, and the data from the testing needs to be recorded. The test will be done according to ASTM standard D3039. The load used is 50kN and test speed is 2 mm/min.

3.7 Gantt Cart

Below is the Gantt chart in order to achieve the objective of the project.



CHAPTER 4: RESULT AND DISCUSSION

1. Visual observation

Visual observation was done after the fiber was obtained and underwent alkaline treatment. The results of the observation can be seen in Table 1:

Table 1 – Visual inspection of mengkuang leaf according to NaOH concentration

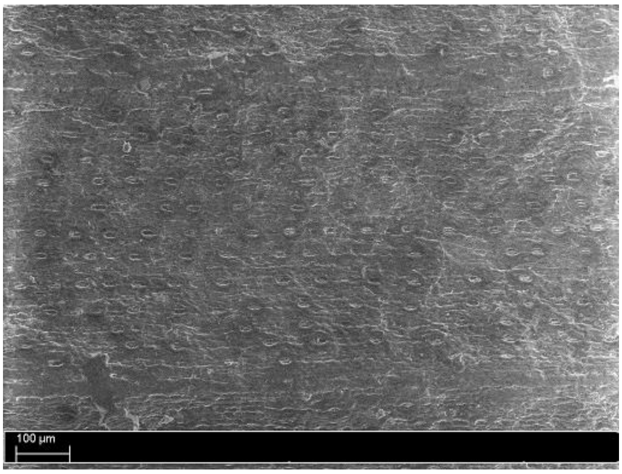
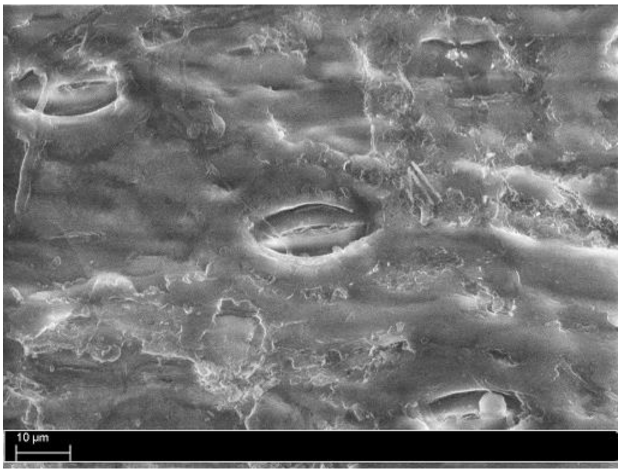
Concentration of NaOH	Description
Original mengkuang leaf without alkaline treatment  Figure 1	The fiber cannot be seen at all due to the hemicellulose layer of the leaf and the colour was light brown.
2% concentration of NaOH  Figure 2	The hemicellulose was pull off from the leaf and the fiber can be seen but surrounded by impurities and lignin of hemicellulose. The leaf is slightly stiff compared to the leaf without treatment.
4% concentration of NaOH  Figure 3	The fiber can be seen clearer with lower amount of hemicellulose. The leaf started to become soft.

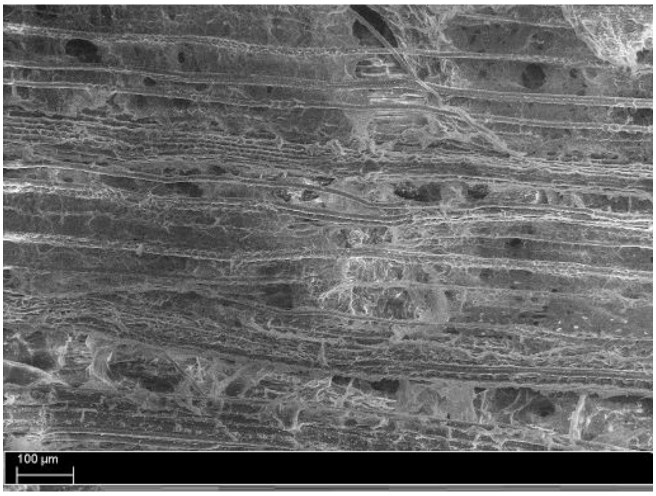
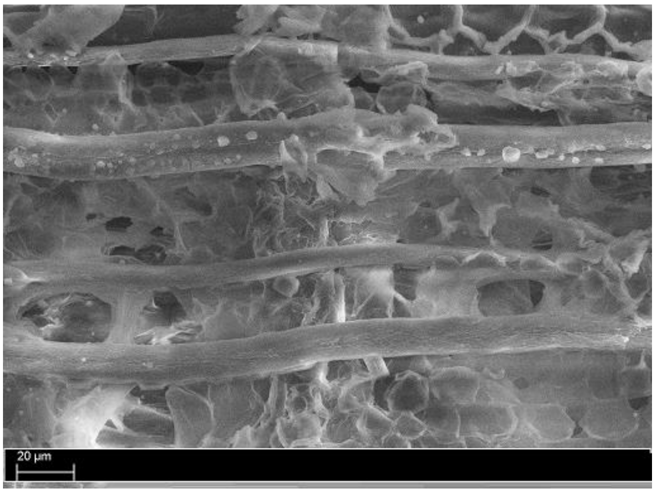
6% concentration of NaOH  Figure 4	The fiber can be seen clearly with no lignin of hemicellulose. The colour of leaf became faded and the leaf became softer.
8% concentration of NaOH  Figure 5	The fiber started to be in twisted form. Some part of the fiber became too soft and started to dissociate. The colour became fader and whiter.
10% concentration of NaOH  Figure 6	Fiber became twisted and the texture was damaged.

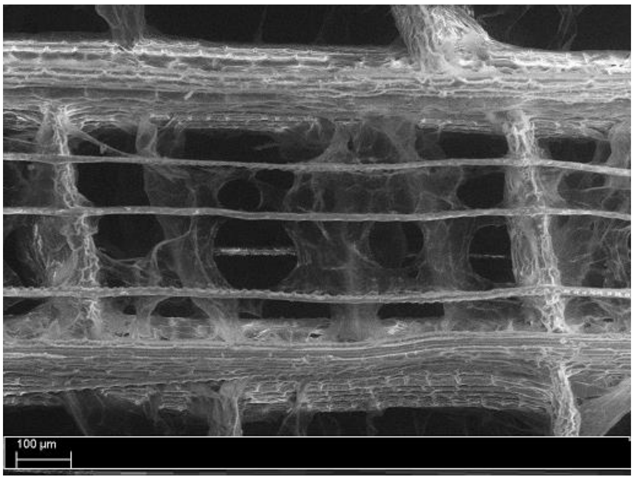
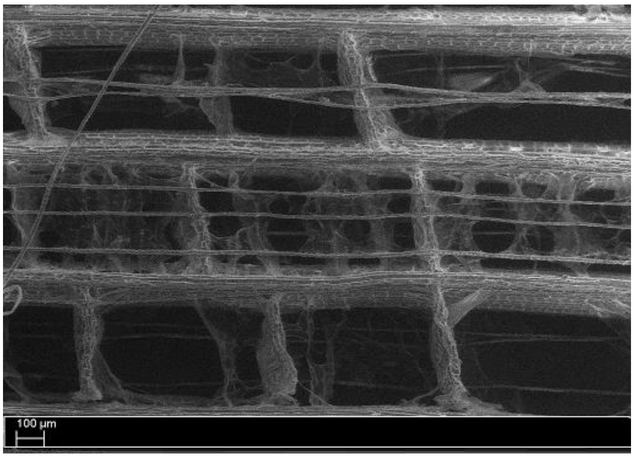
2. FESEM

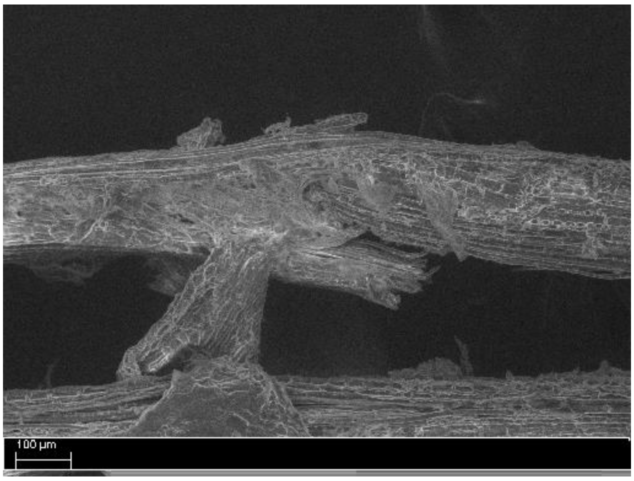
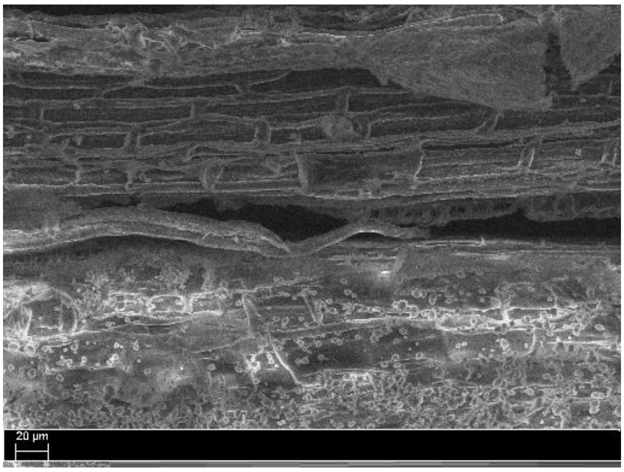
The fiber underwent FESEM scanning to obtain the micrograph of each fiber. The result can be seen in Table 2 below:

Table 2 – FESEM scan of mengkuang leaf according to NaOH concentration

Concentration of NaOH	Description
Original mengkuang leaf without alkaline treatment  Figure 7  Figure 8	Figure 7 and Figure 8 show the Field Emission Scanning Electron Microscopy (FESEM) scan of the original mengkuang leaf without alkaline treatment. In this figures, the mengkuang cellulose fiber cannot be seen clearly because it is surrounded by hemicelluloses and lignin. Thus, alkaline treatment is needed in order to remove the impurities from the leaf. In some area, spots that show the existence of cellulose fiber under the layer of hemicellulose can be seen. However, the number of spots is small.

2% concentration of NaOH  Figure 9  Figure 10	From Figure 9 and Figure 10, the fiber can be seen although it is surrounded by unwanted elements and impurities. A higher concentration of NaOH is needed in order to remove the impurities around the fiber so only the cellulose fiber can be obtained.

4% concentration of NaOH  Figure 11	From Figure 11, it can be seen that the amount of hemicellulose became smaller. Fiber can be seen clearer compared to leaf with 2% concentration of NaOH. Hence, a higher concentration of NaOH is needed to avoid the hemicellulose layer from surrounding the cellulose fiber.
6% concentration of NaOH  Figure 12	From Figure 12, fiber can be seen clearly in rectangular form. The existence of hemicellulose layer is still surrounding the fiber, but the amount is very small.

8% concentration of NaOH  Figure 13	From Figure 13, fiber can be seen clearly without any hemicellulose in the surrounding. However, the fiber started to show failure in some part of it.
10% concentration of NaOH  Figure 14	From Figure 14, it shows that the fiber underwent failure. The fiber started to break although the highest amount of cellulose fiber can be obtained from 10% concentration of NaOH.

3. Tensile test for mengkuang fiber

Mengkuang fiber underwent tensile testing after the FESEM scanning. The tensile testing results obtained are as follows:

Table 3 – Result of tensile testing for mengkuang fiber from 2% to 10% concentration of NaOH

Specimen	**Width (mm)**	**Thickness (mm)**	**Area (mm^2)**	**Elongation Break (%)**	**Tensile Strength (Mpa)**	**Elastic Modulus (GPa)**
2% Alkaline Treatment	7.310	0.430	3.143	1.018	14.179	1.40
4% Alkaline Treatment	7.228	0.428	3.094	0.658	18.071	3.03
6% Alkaline Treatment	7.308	0.354	2.587	3.528	14.956	4.94
8% Alkaline Treatment	7.210	0.480	3.461	1.342	11.141	2.20
10% Alkaline Treatment	7.310	0.430	3.143	1.360	11.052	0.75

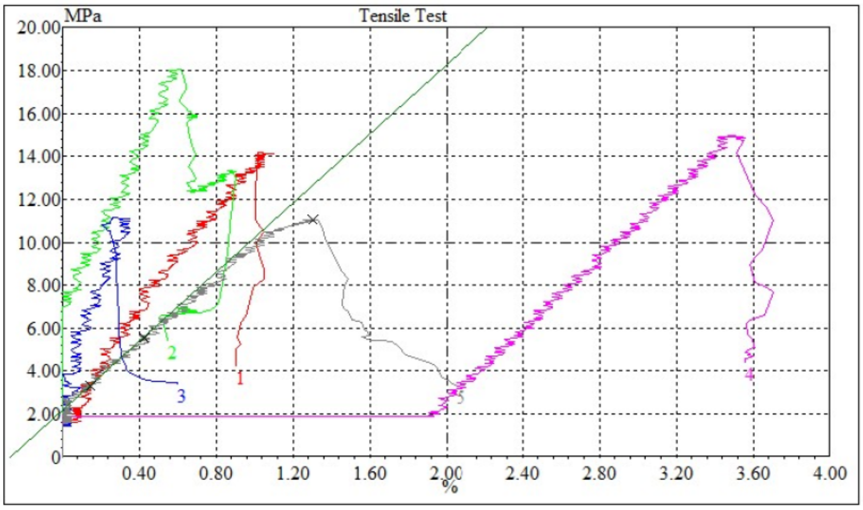


Figure 15 – Graph of tensile test for mengkuang leaves with 2% to 10% NaOH concentration

4. Composites with different orientation

After the leaves underwent tensile testing, composites with different orientation of fibers were produced. The composites can be seen in the figure below:

Figure 16 – Composites for mengkuang fiber of 6% NaOH concentration with different orientations

The composites with different mengkuang fiber orientation underwent tensile testing after been cut with average dimension of 12cm long x 3 cm width. The results for tensile testing can be seen as follow:

Table 4: Result of tensile test for composites with different orientations of mengkuang fiber for 6% alkaline treatment

Orientation (˚)	**Modulus (GPa)**	**Peak Stress (Mpa)**	**Peak Load (kN)**
0	0	8.69	0.895
45	0.099	17.976	2.65
90	2.801	14.248	2.421

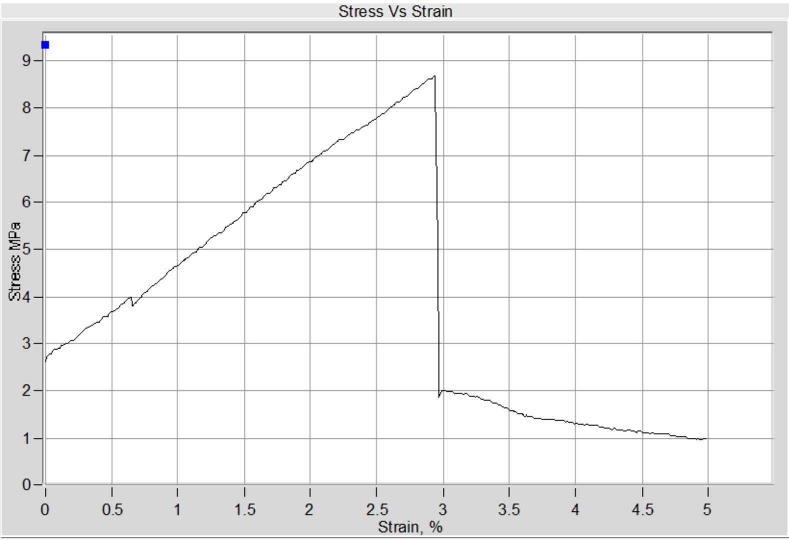


Figure 17 : Stress- strain graph for composite with 0˚ mengkuang fiber orientation

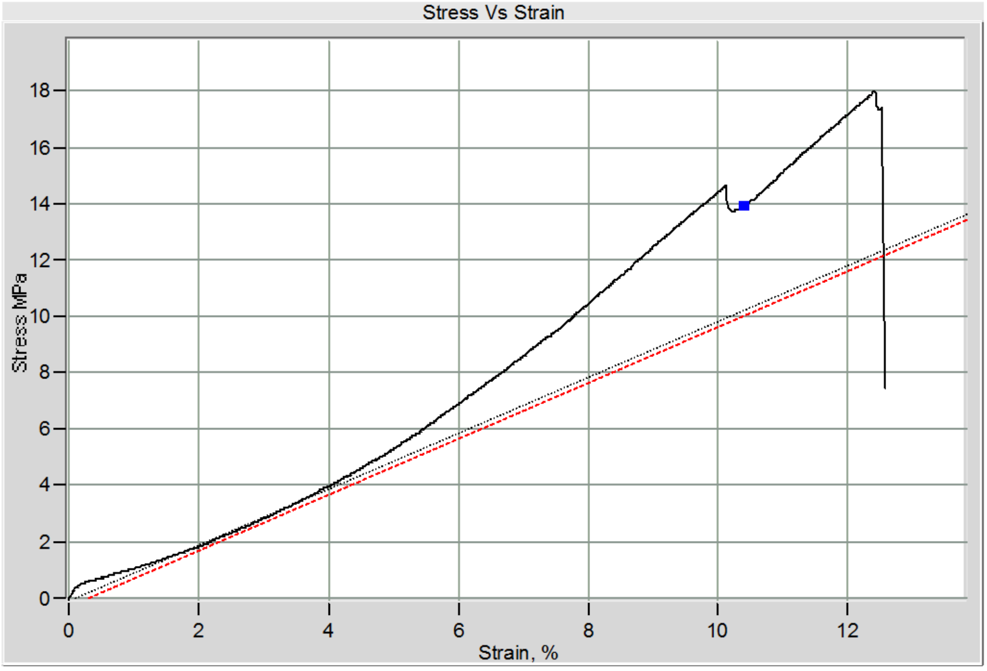


Figure 18 : Stress- strain graph for composite with 45˚ mengkuang fiber orientation

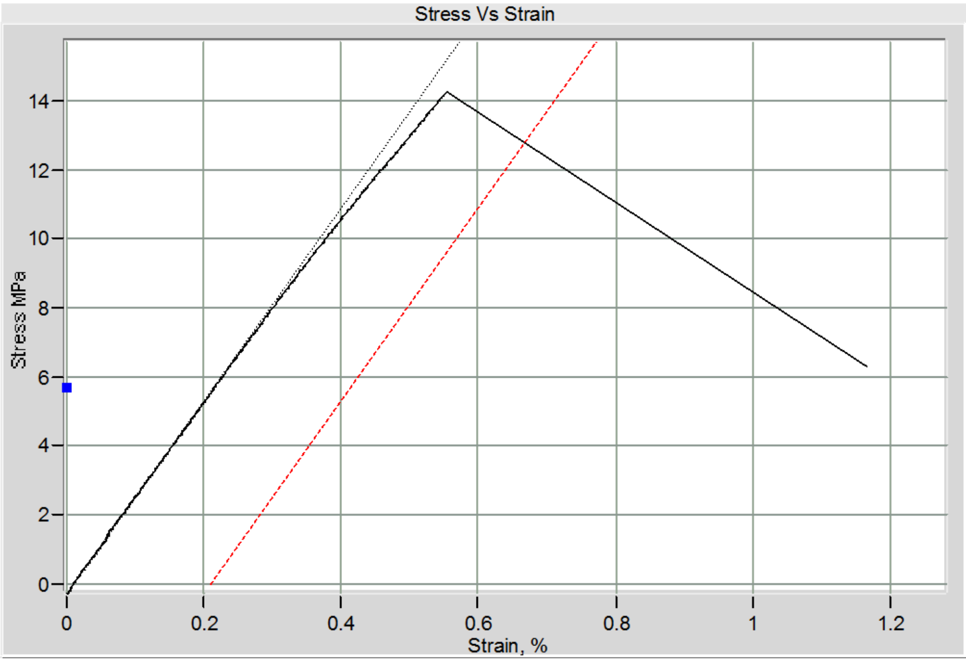


Figure 19 : Stress- strain graph for composite with 90˚ mengkuang fiber orientation

From the results obtained from visual observation, the lignin of the mengkuang leaves can be observed clearer when the concentration of NaOH is higher. However, the solution can cause damage to the leaves when the concentration is high. The damage could be seen starting from when the concentration of NaOH solution reached 8% and higher. It can be referred from Figure 5 and Figure 6. It proves that alkaline treatment can affect the texture and structure of the mengkuang leaves.

Through FESEM, microscopic examination of the mengkuang leaves for both treated and untreated leaves is done in order to obtain the morphology analysis for the leaves. Morphology analysis is used to shows the micrograph inside the mengkuang leaves. From the results for FESEM obtained, the mengkuang cellulose fiber can be seen clearer with higher concentration of NaOH. This can be referred from Figure 7 until Figure 14.

From the tensile testing result for mengkuang fiber in Table 3, it can be seen that the fiber with higher concentration of NaOH have bigger value of Young's Modulus (E). It shows that alkaline treatment can increase the mechanical properties of mengkuang fiber successfully and effectively.

Tensile testing for composites with different orientation shows that when the degree of orientation of fiber higher, the value obtained for modulus is higher. From Figure 16, it can be seen that the composite with 0˚ orientation did not manage to undergo plastic deformation before it was broken. For composite with 45˚ orientation, the composite managed to undergo both elastic and plastic deformation with the modulus of 0.099GPa. Composite with 90˚ orientation obtained the highest value of modulus, which is 2.801Gpa. From the graph in Figure 19, it can be seen that the composite underwent a very small elastic deformation and huge plastic deformation.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

As a conclusion, this paper focuses on extraction of continuous mengkuang fiber and producing its composite with different orientations of fiber. From the results obtained, the cellulose fiber inside the mengkuang leaves became higher due to the alkaline treatment that has been done to the leaves. FESEM scan shows that when the concentration of NaOH higher, the mengkuang cellulose fiber can be seen clearer. However, from the visual inspection, too much concentration of alkaline treatment on the mengkuang leaves can cause damage to the leaves. Hence, the suitable concentration of NaOH needed to be used in order to extract the cellulose fiber without causing any damage to the leaves. From the results obtained, the suitable NaOH concentration is 6%. After the alkaline treatment process is done, composites with different orientations are produced. Tensile test for the composites showed that when the degree of orientation is higher, the modulus of the composite is higher. 90˚ is the best orientation for the composite.

From the results obtained, it is determined that the objective for this final year project is achieved. However, for the better results, it is recommended that the composites with different orientation can be done to fibers with all concentrations and undergo tensile testing. Hence, it is suggested that another final year student can do this project for better results.

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