MECHANICAL PROPERTIES OF PALAS FIBER REINFORCED COMPOSITE

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CERTIFICATION OF APPROVAL

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Approved by,

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UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

January 2016

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.

AHMAD AIMAN AFIF BIN MOHD ZAMRI

ABSTRACT

Recently there is a rapid growth in research and innovation in the natural fiber composites area. This is because natural fiber gives some advantages compared to other synthetic fibers such as low density, environmental friendly, low cost and good mechanical properties. The purpose of this project is to study the mechanical behaviour of palas leaf reinforced composite. The experiments of tensile, impact and flexural tests were carried out on composites made by reinforced palas leaf or licuala grandis as its scientific name as a new natural fiber into polypropylene homopolymer resin matrix. All of the tests were carried out according to the American Society for Testing and Materials (ASTM) standard. This project will focus on the matrix-fiber compositions which are, 80/20, 70/30 and 60/40. These three composition will also be compared with a neat polypropylene. There are two processes involved to produce this composite which are compounding process and injection moulding process. The palas leaf and polypropylene will be mixed together by using the compounding process and will produce a pellet size composite. This pellet will then put into the injection moulding process to produce a desired shape of composite such as dog-bone shape. The tensile, impact and flexural test will be carried out once the injection moulding process is done.

ACKNOWLEDGEMENT

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Not to forget, I offer my highest appreciation to my beloved family for their ever loving support since inception of this project. Thank you also to all my fellow friends that help me a lot in completing this project. They always give advices and guidance to make sure that I will do the excellent work.

Besides that, I also would like to express deep and sincere gratitute to the ADTECH staff who provide me with various kind of machine for fabrication and testing process. Lastly, I would like to thank all of the people who have contributed directly or indirectly towards the success of this project.

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ABBREVIATIONS AND NOMENCLATURES

PP	Polypropylene
ASTM	American Society for Testing and Materials
SEM	Scanning Electron Microscopy

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Composite materials are generally defined as a combination of two or more constituent materials which have different properties. By doing so, a new material is fabricated with new and additional mechanical properties. Usually, the aims for producing composites are to obtain a strong, stiff and lightweight material [1]. Two main components of a composite material are matrix and reinforcement. When the composite is subjected to forces, the matrix would transfer the stresses to disperse phase, and also protect the reinforcement. On the other hand, the primary role of reinforcement in composite material is to enhance the mechanical properties of the material.

Many types of reinforcement are being used in producing a composite, and the most famously used reinforcements are carbon and glass. In composite manufacturing process, these reinforcements are in fiber form. Carbon fibers and glass fibers are widely adopted in the composite industry due to their superior properties such as good strength-to-weight ratio, high modulus of elasticity and density [2]. Because of these reasons, composite is enchanting for various application such as automotive industry, civil structures, aircraft, marine and public work industries.

There are many factors that could affect the properties of a composite such as fiber matrix bond, the type and volume of fiber, the distribution and orientation of fiber within the matrix, the ability to obtain isotropic and orthotropic behavior if required, ease of handling of the reinforcement and a suitable method for manufacture. Because of these factors, the mechanical properties of a composite might be different from each other. [3]

1.2 Problem Statement

Natural fiber reinforced composites found to be an alternative solution to the ever depleting petroleum sources thus they receive greater attention, attraction from research scientist and community. Manufacturer and scientists attracted towards natural fiber based composites due to its biodegradibility, light in weight, non-toxic and relatively stronger and consider being virtuous products which can be use in construction, industry, automotive industry and for furniture production. [4] However, many of this composite were imported from other country and high cost is required to produce it. Furthermore, there were very limited studies that have been done on this palas leaf reinforced composite. Therefore, this project was proposed.

1.3 Objective

The objective of this study are:

- To evaluate the mechanical properties of palas leaf reinforced composite.
- To investigate the suitability of palas leaf as a reinforcement material in polymer composite to replace conventional materials or synthetic fibers as reinforcement in composites based on tensile, flexural and impact properties.

1.4 Scope Of Study

In this study, polypropylene was used as the matrix and palas was employed as the reinforcement. The knowledge of polypropylene will be given attention under this project as it will be used as the matrix. The knowledge on compounding, extruding and injection molding process will also be given attention under this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Composite Materials

These days, composite material was utilized broadly in industries. It is another disclosure. A composite is an auxiliary material which comprises of blend of two or more constituents. The constituents are consolidated at a naturally visible level and are not soluble in one another. One constituent is known as the strengthening stage and the one in which it is inserted is known as the matrix. Composites have additionally been utilized to enhance the execution of some conventional weapons. Composite materials that acquired these days are extremely heterogeneous and exceptionally anistropic which implies the mechanical property of the material relies on the directions [5]. Composites are comprised of individual materials referred to as constituent materials. There are two primary categories of constituent materials : matrix and reinforcement. No less than one part of every sort is required. The matrix material encompasses and backings the reinforcement materials by keeping up their relative positions. The reinforcement grant their extraordinary mechanical and physical properties to improve the matrix properties. A synergism produces material properties unavailable from the individual constituent materials, while the wide assortment of matrix and reinforcing materials permits the designer of the item or structure to pick and ideal mix. [5]

Numerous commercially produced composites utilize a polymer matrix material usually called a resin solution. There are a wide range of polymers available relying on the starting raw ingredients. There are a few general classes, each with various variation. The most widely recognized are known as polyester, vinyl ester, epoxy, phenolic, polyimide, polyamide, polypropylene, PEEK and others. The reinforcement materials are frequently fiber but also commonly ground minerals. The various methods described below have been created to lessen the resin substance of the final product, or the fiber substance is increased. As a general guideline, lay up results in an item containing 60% resin and 40% fiber, though vacuum implantation gives a final product with 40% resin and 60% fiber content. The quality of the item is incredibly subject to this proportion. Figure 1 shows a combination of materials to produce a composite.

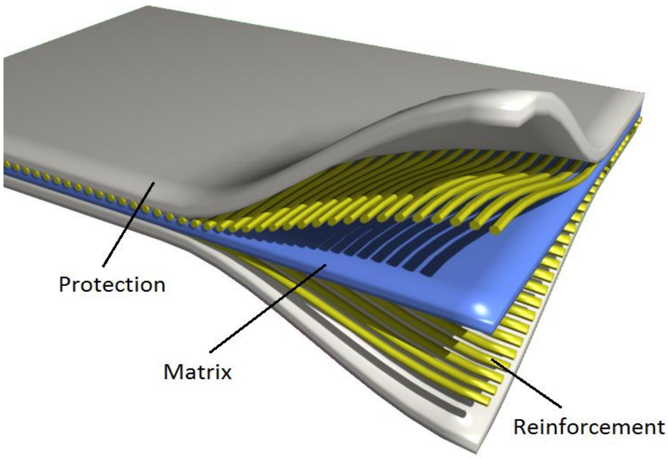


Figure 2 - 1 : Composite Material

2.1.1 Classification of Composites

2.1.1.1 Metal Matrix Composites (MMCs)

The MMCs are materials consisting of metal alloys reinforced with continuos fibers, particulates or whiskers. The addition of these reinforcements gives MMCs superior mechanical properties and unique physical characteristics. The two most commonly used metal matrices are based on Aluminium and Titanium which both have comparitively low specific gravities. Also, Beryllium, Magnesium, Nickel and Cobalt based super alloys can be used as matrix materials regarding the needs and service conditions of the application. As reinforcement, generally SiC particles, Boron and Al_2O_3 fibers, and Borsic (Boron fibers coated with SiC) and TiB_2 coated carbon fibers are employed. Because of their ability to provide the needed strength at the lowest weight and least volume, MMCs are attractive for many structural and non-structural applications.

2.1.1.2 Ceramic Matrix Composites (CMCs)

CMCs in which ceramic or glass matrices are reinforced with continuous fibers, whiskers, or particulates, mainly SiC and Si_3N_4, are rising as a type of advanced engineering structural materials. Ceramics have very attractive properties for many applications; high strength and stiffness at high temperature, low density and chemical inertness. But the one serious disadvantage of this class of material is that their susceptibility to impact damage and catastrophic failure in presence of flaws. CMCs has been toughen the ceramic matrices by incorporating reinfrocements in them thus obtain the attractive high temperature properties with drastically decreasing the risk of sudden catastrophic failures. [6]

2.1.1.3 Polymer Matrix Composites (PMCs)

PMCs consist of a polymer matrix, either thermoset or thermoplastic, and fibers or other materials with sufficient aspect ratio as the reinforcing medium, which, in general, is glass, Carbon, Boron and Kevlar. The low weight of the matrix material is accompanied by the attractive mechanical properties of the reinforcement. As a result, a composite material with quite high specific mechanical properties is obtained, accompanied with low cost and ease of fabrication, which is widely employed in several application areas.

2.2 Natural Fiber

In recent years, huge scholarly and modern innovative work has investigated novel routines for making green and naturally well disposed materials for business applications. Natural fiber offer the possibility to create lower expense items with better execution, supportability, and renewability attributes than conventional materials, especially in the car business. In this respect, natural fiber reinforced polymer composites have developed as an environmentally friendly and costeffective option to synthetic fiber reinforced composites. [2] Natural fibers are low cost, recyclable, low density and eco-friendly material.

The utilization of natural fibers as reinforcement in polymer composites has pulled in significant consideration amidst the most recent couple of decades. Also, natural fibers have appications in fields, for example, the material, paper fabricating, and bioenergy industries owing to their expansive availability and properties. Natural fibers can generally be classified in view of their origin (e.g., plant, creature, or mineral). Plant or vegetable fibers can be further classified into subgroups according to their source (e.g., stem fibers, leaf fibers, seed fibers, or organic product fibers). The chemical composition of plant fibers relies on upon the sort, age, and origin of the fiber, and the extraction process [7]. Figure 2-2 shows the palas leaf or so called as Licuala Grandis scientifically.

Figure 2 - 2 : Palas leaf (Licuala Grandis)

2.3 Thermoplastic

Thermoplastic polymers have good properties, which make them exceptionally suitable for the grid material in fiber-strengthened composites. The benefits of thermoplastic polymers include their high natural resistance, high effect quality and high recyclability [8]. However, thermoplastic composite material has extensive issue in manufacturing the basic parts.

2.4 Rule of mixture

Fiber-reinforced composites are commonly used because of their potential for weight reduction, enhance strength and stiffness, and improved reliability. In order to know the mechanical behaviour of the composite, the properties of two constituents in the composite material which are the matrix and the reinforcement fiber should be studied. The most widely used models for predicting the ultimate strength of the composite has been the simple rule-of-mixtures which given the equation below:

$$\sigma_c = \sigma_m V_m + \sigma_f V_f \text{ - - - - - - - Eq. 1 [9]}$$

where V_m and V_f represent the volume fractions of the matrix and the fibers (reinforcement), respectively. σ_m and σ_f are their respective strengths, with σ_c being the strength of the composite material [11].

$$\sigma *_{cl} = \sigma'_m V_m + \sigma_f * V_f \text{ - - - - - - - Eq. 2 [9]}$$

Where $\sigma *_{cl}$ represent longitudinal tensile strength for continuous and aligned fibrous composite, σ'_m represent stress in matrix at composite failure and $\sigma_f *$ represent fiber tensile strength.

2.5 Tensile Test

The tensile test is used to depict the properties related to mechanical behavior of materials. In the midst of the test, the specimen is subjected to a controlled weight until fails. From the results produced, the material properties under assorted conditions of load can be obtained. Properties that are particularly measured using the tensile test are ultimate tensile strength, maximum elongation, and reduction in area of the specimen. On top of that, Young's modulus, Poisson's ratio, yield strength, and strain-hardening attributes can likewise be discovered [10]. The main outcome of a tensile test is a load versus elongation curve which is then converted into a stress versus strain curve. The Figure 2-3 below shows the stress-strain curve that we will get from tensile test.

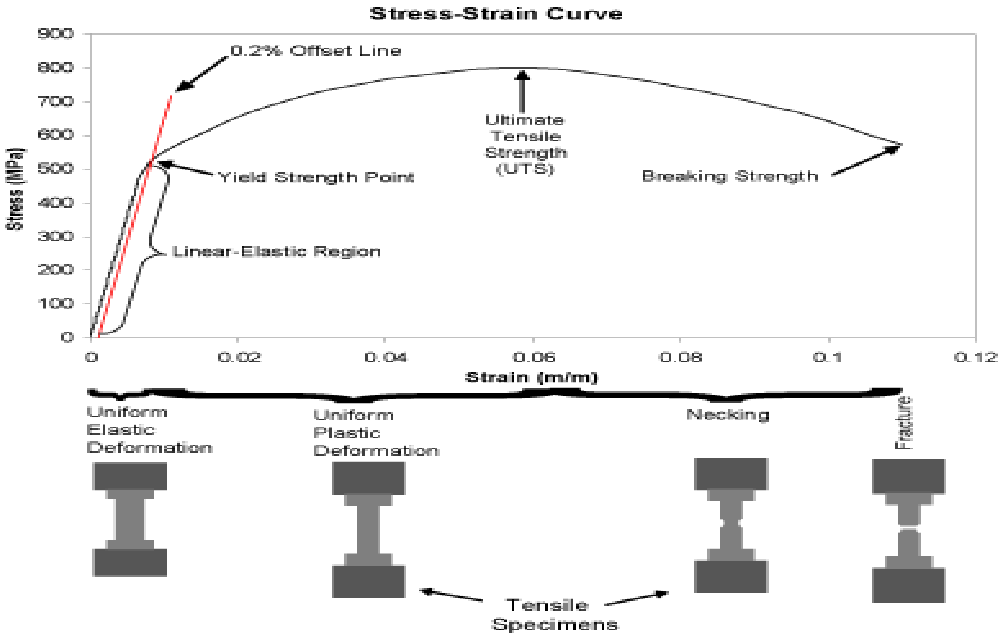


Figure 2 - 3 : Stress-Strain Curve [10]

The Equation 3 below shows the formula for engineering strain by using the elongation value that we get from the tensile test. This engineering strain will then be used to calculate the Poisson's ratio as shown in Equation 4. The calculated Poisson's ratio will then used to calculate the Modulus of Elasticity of the material as shown in Equation 5.

$$\mathcal{E} = \frac{\Delta L}{L_0} = \frac{L - L_0}{L_0}$$ ------- Eq. 3 [10]

$$\nu = -\frac{\varepsilon_{lateral}}{\varepsilon_{axial}}$$ ------- Eq. 4 [10]

$$E = 2\,(\,1 + n\,)\,G$$ ------- Eq. 5 [10]

Where :

E = Modulus of Elasticity (Young's Modulus)

n = Poisson's ration

G = Modulus of Rigidity (Shear Modulus)

1.2.1 Tensile testing of the composite

The preparation of the test specimens starts with the mold fabrication. Dog bone shape specimen is produced by using the ASTM D638 Type I standard.

Generally, the tensile properties of composites are markedly improved by adding fibers to a polymer matrix since fibers have much higher strength and stiffness value compared to the matrix [12]. Tensile tests were conducted for the composite specimen using the electronic tensometer setup to obtain the tensile properties. The dog-bone specimens of the composites were prepared according to the ASTM D 638 standards. The specimens were machined to a standard size of 165 mm 13 mm 4 mm for a gauge length of 50 mm. For this testing, the load cell of 5 kN was utilized in the tensometer with the same cross head speed of 1 mm/min. Five identical test specimens were used for each testing and numbered in series as T1, T2, T3, T4 and T5. Properties such as tensile strength, tensile (elastic) modulus, tensile load and elongation at break of the composites were measured from the experimentation. During tensile testing, the specimens were broken in between the gauge length of the specimen and the corresponding image was shown in Figure 2-4. [13]

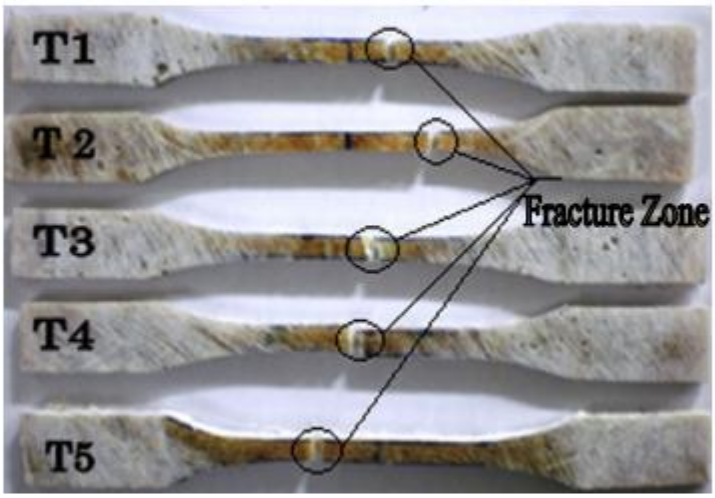


Figure 2 - 4 : Tensile tested specimen

2.6 Impact Test

The fracture of material can be either bendable or fragile. More vitality retained with a flexible crack than with a fragile break. The capacity of a material to withstand shock loads is regularly used to portray the sturdiness of a material. The impact test is additionally used to figure out if heat treatment of metal has been effectively carried out or not. A nearly little change in heat treatment can likewise lead to a very recognizable changes in impact test outcomes .

The impact strength of the composite increased as the volume fraction of fiber increased, reaching a maximum value at 30%. Beyond 30%, the impact strength shows a decreasing trend.

2.7 Flexural Test

The three point bending flexural test gives out values for the modulus of elasticity in bending E_f, flexural stress σ_f, flexural strain ε_f and the flexural stress-strain response of the material.

Calculation of the flexural stress σ_f :

$$\sigma_f = \frac{3FL}{2bd^2}$$ for a rectangular cross section - - - - - - - Eq. 6 [16]

Calculation of the flexural strain ϵ_f:

$$\epsilon_f = \frac{6Dd}{L^2}$$ - - - - - - - Eq. 7 [16]

Calculation of flexural modulus E_f

$$E_f = \frac{L^3 m}{4bd^3}$$ - - - - - - - Eq. 8 [16]

In these formulas the following parameters are used:

σ_f = Stress in outer fibers at midpoint, (MPa)

ϵ_f = Strain in the outer surface, (mm/mm)

E_f = flexural Modulus of elasticity,(MPa)

F = load at a given point on the load deflection curve, (N)

L = Support span, (mm)

b = Width of test beam, (mm)

d = Depth of tested beam, (mm)

D = maximum deflection of the center of the beam, (mm)
m = The gradient (i.e., slope) of the initial straight-line portion of the load deflection curve, (P/D), (N/mm)
R = the radius of the beam, (mm)

By doing this three point bending flexural test, we also can get the fracture toughness of the specimen. The stress intensity factor at the crack tip of a single edge notch bending specimen is :

$$K_1 = \frac{4P}{B}\sqrt{\frac{\pi}{W}}\left[1.6\ \left(\frac{\alpha}{W}\right)^{1/2} - 2.6\left(\frac{\alpha}{W}\right)^{\frac{3}{2}} + 12.3\ \left(\frac{\alpha}{W}\right)^{\frac{5}{2}} - 21.2\left(\frac{\alpha}{W}\right)^{\frac{7}{2}} + 21.8\left(\frac{\alpha}{W}\right)^{\frac{9}{2}}\right]$$ - - - - - - - - - - - - - Eq. 9 [16]

Where : P = applied load

B = thickness of specimen

α = crack length

W = width of specimen

According to ASTM standard,

$$K_1 = \frac{6P}{BW}\alpha^{1/2}Y$$ - - - - - -Eq. 10 [16]

Where ;

$$Y = \frac{1.99 - a/W(1-\frac{a}{W})(2.15-\frac{3.93a}{w}+2.7\left(\frac{a}{w}\right)^2)}{\left(1+\frac{2a}{w}\right)\left(1-\frac{a}{W}\right)^{\frac{3}{2}}} \quad \text{----- Eq. 11 [16]}$$

The predicted values of K_1 are nearly identical for the ASTM and Bower equations for crack lengths less than 0.6W.

2.8 List of research on fiber reinforced composite with different type of fiber

Researchers	Composites	Weight Compositions	Remarks
Subasinghe et al. (2015) [17]	• Kenaf fiber reinforced PP.	70/30	• Improvements of 43% and 35% were obtained in tensile and flexural strengths, respectively, compared to neat PP. • Reduction of 21% in impact strength was observed. • 7.5mm were better length to produce higher properties.
Bledzki et al. (2007) [18]	• Abaca fiber reinforced PP.	• 80/20 • 70/30 • 60/40 • 50/50	• Tensile, flexural and impact showed an improvement of the strength up to 40 wt.% fiber loading and then both strength decreased with increasing fiber load.
Sakthivel et al. (2014) [19]	• Coir fiber reinforced PP. • Luffa fiber reinforced PP.	80/20	• Improvements of 43%, 32% and 35% were obtained in tensile, flexural and impact strengths, respectively, compared to neat PP. • Highest tensile strength obtained by coir reinforced polypropylene. • Highest flexural and impact strength obtained by luffa reinforced polypropylene.

Bledzki et al. (2015) [20]	• Abaca fiber reinforced PP. • Jute fiber reinforced PP. • Kenaf fiber reinforced PP.	80/20	• Improvements of 43%, 32% and 35% were obtained in tensile, flexural and impact strengths, respectively, compared to neat PP. • Highest tensile strength obtained by coir reinforced polypropylene. • Highest flexural and impact strength obtained by luffa reinforced polypropylene.

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

This study has been conducted according to a set of guidelines. First step, the matrix, polypropylene and reinforcement materials is selected based on research papers, journals and articles. Next, the polypropylene and reinforcement materials are mixed together to produce a composite pellet by using the compounding machine at ADTECH facilities in Taiping. Then, the composite pellet was inserted into the injection moulding machine to produce a desired shape of composite by using the injection moulding machine at ADTECH facilities in Taiping. After that, three test were conducted upon the specimen produced which are tensile test, impact test and flexural test by using the testing machine at ADTECH facilities in Taiping. Data and results of the testing has been recorded and analysed. Last but not least, the specimens underwent SEM process to produce the micrograph of the specimen. The data and result from the SEM process has been recorded and analysed.

3.2 Process Flow Chart

The project was anticipated and further research for its feasibility are referenced based on several theses and books. The provided process flow indicate the steps taken for realization of this project as shown in Figure 3-1.

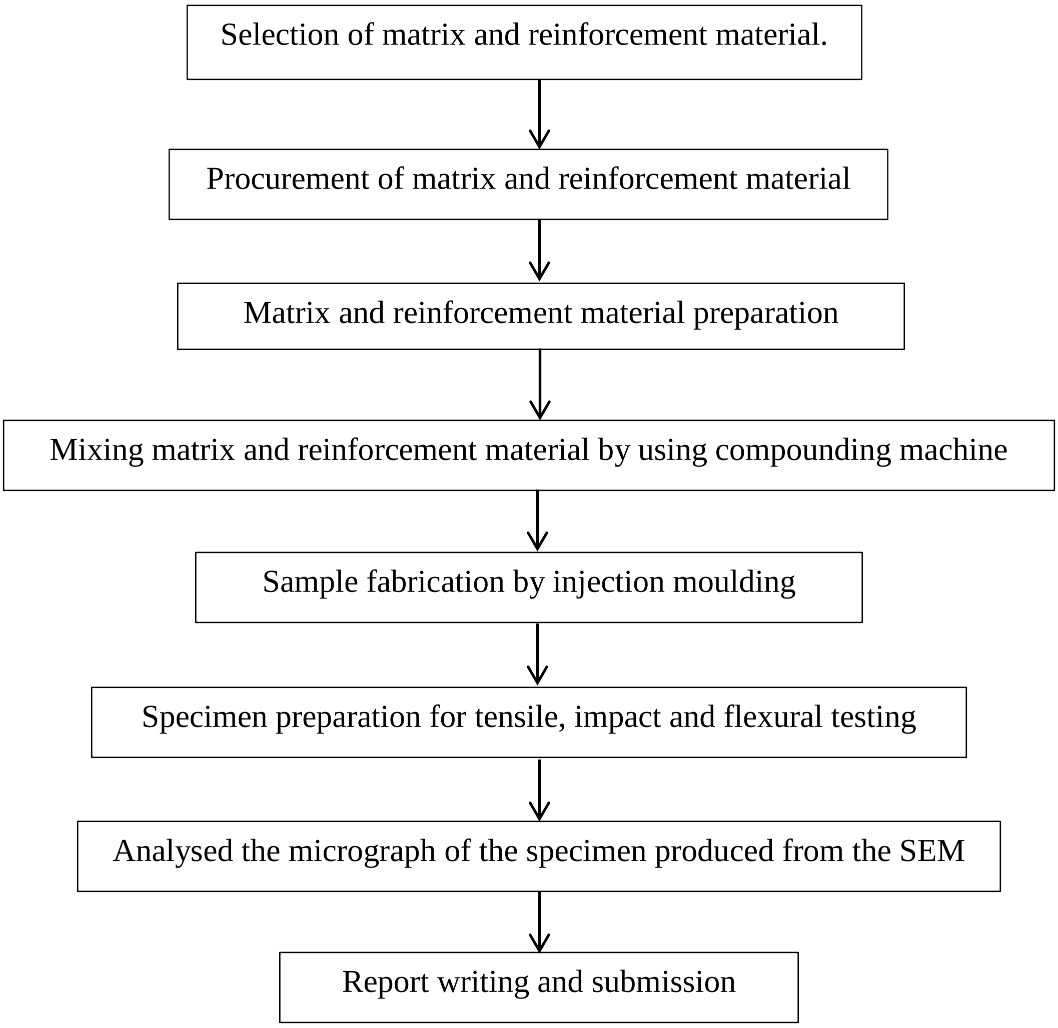


Figure 3 - 1 : Process flow chart of the study.

3.3 Material Details and Dimension

3.3.1 Dimension details

The palas leaf was cut into small pieces as shown in Figure 3-2. The amount or weitght of the palas leaf required is 800g for this project. 600g of palas leaf is enough to make 45 pieces of specimen. Considering safety factor, the author decided to prepare 800g of palas leaf.

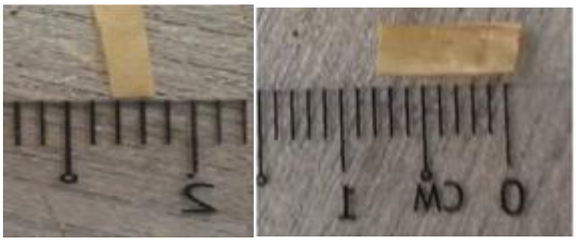


Figure 3 - 2 : Palas leaf dimension

Length : 7.5 mm ± 0.5 mm

Width : 1.0 mm ± 0.5 mm

Thickness : N/A

3.3.2 Fiber and Matrix Preparation

Testing / Composition	**Neat PP (gram)**	**80/20 (gram)**	**70/30 (gram)**	**60/40 (gram)**
Tensile Test	**500**	**550 – 20% fiber**	**550 - 30% fiber**	**550 - 40% fiber**
Flexural & Impact	**500**	**550 – 20% fiber**	**550 - 30% fiber**	**550 - 40% fiber**

3.4 Material Selection

3.4.1 Fiber Selection

The author have decided to choose palas leaf as the reinforcement material since there are very few studies that have been done on this palas leaf. The author also decide to take the palas leaf that were used to make a diamond-shaped dumpling made from rice packed that were wrapped using the palas leaf. This food is commonly known as “ketupat” in bahasa. The palas leaf from the “ketupat” can be recycled and used as the reinfrocement material hence cost of acquiring the reinforcement material can be reduced.

3.4.2 Matrix Selection

The reinforced composite is fabricated through the combination of two elements namely; matrix and reinforcement material. The author selected polypropylene as the matrix since it is a recyclable polymer. Polypropylene is also a chemical and thermal resistance polymer. All the necessary documents regards to the technical specification upon the matrix can be seen in the Technical Datasheet of Polypropylene Homopolymer resin in appendices section. The main properties of the matrix are as shown in Table 3-1:

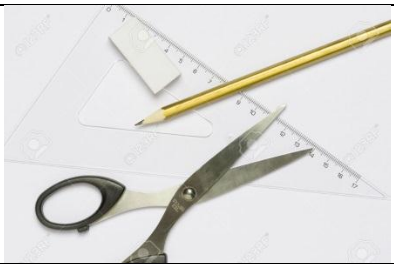
Table 3 - 1 : Main properties for polypropylene homopolymer resin.

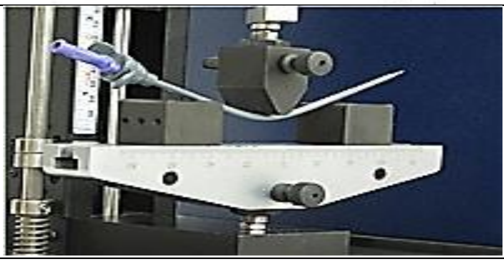
Material	Melting Point (°C)	Tensile Strength (MPa)	Flexural modulus (MPa)	Impact Strength (Joule)
Polypropylene	165.0	40.2	1705.7	2.9

3.5 Materials, Tools and Equipment

A number of tools and equipment needed in order to complete the project are listed in Table 3-2.

Table 3 - 2 : List of equipment and functions.

No	Item	Diagram	Function
1	Scissors and ruler.		To measure the dimension and cut the palas leaf
2	Compounding machine		To mix matrix (PP) and reinforcement material (palas) to produce pelet size of composite.

3	Injection Moulding		To produce dog bone shape of PP and palas leaf composite.
4	Universal testing machine		To carry out tensile test.
5	Impact Test		To carry out charpy impact test.
6	Flexural Test		To carry out 3 point bending flexural test

3.6 Testing

3.6.1 Tensile properties

- The samples for tensile testing are loaded on the universal testing machine and test is conducted as per ASTM D638.

3.6.2 Impact Izod properties

- The samples for impact loading are loaded on the impact testing machine and test is conducted as per ASTM D256.

3.6.3 Flexural properties

- The samples for flexural testing are loaded on the flexural testing machine and test is conducted as per ASTM D790

3.7 Process

3.7.1 Fiber preparation

The palas leaf from “ketupat” was cleaned and let dried as shown in Figure 3-3 below.

Figure 3 - 3 : Drying process of palas leaf.

It is then cut into small pieces (short fiber) by using scissor. The palas leaf was cut according to the dimension that have been fixed by the author. The length is 7.5 mm ± 0.5 mm while the width is 1.0 mm ± 0.5mm as shown in Figure 3-4.

Figure 3 - 4 : Short palas fiber

3.7.2 Mixture Preparation

Polypropylene granules and the palas leaf is weighed by using the weight balance. The polypropylene and palas leaf is then mix together based on the composition of the mixture which are 80/20, 70/30 and 60/40.

3.7.3 Compounding process

The mixture is then put into the compunding machine or also known as extruder. This machine will crush and melt the mixture so that they will mix well together and produce a long tube-shape composite which will then be cut into a pellet size.

Figure 3 - 5 : Compounding or extruder machine

3.7.4 Injection Moulding Process

The mixture is then put into the injection moulding machine for fabrication purpose as shown in Figure 3-6 below.

Figure 3 - 6 : Injection Moulding Machine

The shape desired is produced by using different mould that was inserted in the injection moulding machine. Figure 3-7 shows the shape for impact and flexural specimen while Figure 3-8 shows the shape for tensile specimen.

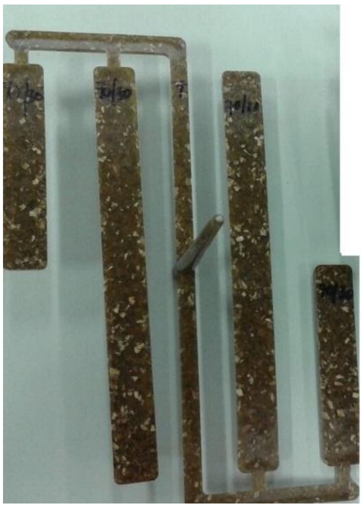


Figure 3 - 7 : Specimen for impact and flexural test

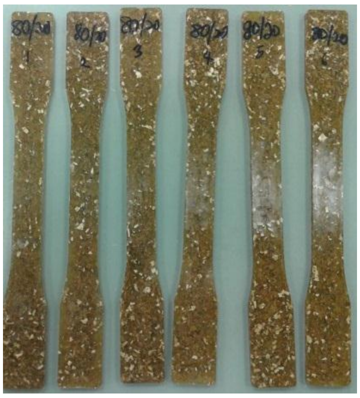


Figure 3 - 8 : Specimen for tensile test

3.7.5 Tensile Testing

For each composition (80/20, 70/30 and 60/40) five best specimens were selected for tensile testing. The test has been conducted according to the ASTM D638 Standard. The speed of the machine was set to 20mm/min. The test was conducted at room temperature, T=25^{o}C. The average length, width and thickness of each specimen were calculated. Figure 3-9 below show the neat Polypropylene undergo tensile testing while Figure 3-10 shows the specimen after the test.

Figure 3 - 9 : Tensile testing for neat Polypropylene.

Figure 3 - 10 : Specimen break after tensile test.

3.7.6 Izod Impact Testing

For each composition (80/20, 70/30 and 60/40) five best specimens were selected for impact testing. The average length, width and thickness of each specimen were calculated. The test has been conducted according to the ASTM D256 Standard. The specimen need to undergo notching process before it can proceed to izod impact test. The place to be notched were marked using a permanent marker. Figure 3-11 below shows the specimen after marking while Figure 3-12 shows the specimen after notching process.

Figure 3 - 11 : Labelling before notching process.

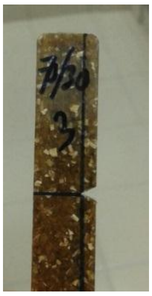


Figure 3-12: Notched specimen

Figure 3-13 shows the machine used for notching process. All of the specimen that will undergo izod impact test will be notch first by using this machine.

Figure 3-13: Notching machine.

After notching process is done, the specimen is then tested using the izod impact testing machine. Figure below shows a specimen is undergone impact izod test.

Figure 3-14: Izod Impact testing machine.

3.7.7 Flexural Testing

For each composition (80/20, 70/30 and 60/40) five best specimens were selected for flexural testing. The average width and thickness of each specimen were calculated. The test has been conducted according to the ASTM D790 Standard (Procedure A). The speed of the machine were set to 1.28mm/min. Before conducting the test, the author used the formula below to find the support span length for the test.

$$R = \frac{zL^2}{6d}$$

Equation 12 : Speed rate formula

Where R = speed rate,

Z = 0.01 (Procedure A)

= 0.1 (Procedure B),

L = support span length,

d = thickness of specimen

The support span length of the machine were adjusted based on the value L that the author got which is 48mm. Figure 3-15 shows the speciment being tested using the flexural testing machine.

Figure 3-15: Flexural test on neat Polypropylene.

3.8 Project Timeline

Table 3-3 below shows the gantt chart with appointed key milestone set throughout the FYP I period.

Table 3 - 3 : Gantt chart and Key Milestone for FYP I

Key Milestone and Project Activities	**Duration (Week)**													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Research Work				7/11										
• Selection of matrix and reinforcement material														
• Selection of fabrication method														
• Selection of standard test method														
Materials and tool procurement														31/12
• Palas leaf														
• Polypropylene														

Table 3-4 shows the gantt chart with appointed key milestone set throughout the FYP II period.

Table 3-4: Gantt Chart and Key Milestone for FYP II

Key Milestone and Project Activities	**Duration (Week)**													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Reinforcement material preparation														
• Cut palas leaf			■	■	■	■	■							
Fabrication of composite								11/3						
• Compounding process							■	■						
• Injection Moulding							■	■						
Testing									15/3					
• Tensile Testing								■	■					
• Impact (Izod) Testing								■	■					
• Flexural Testing								■	■					
• SEM									■	■				
Data Analysis and Report Writing											■	■	■	■

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Tensile Properties

For the tensile test, the author measured the tensile strength and tensile modulus of the neat polypropylene and also for all of the specimens from different compositions. 5 best specimens were selected to undergo the test and the average value was taken.

4.1.1 Tensile Strength

Figure 4-1 shows the histogram for tensile strength of all the specimen including neat polypropylene.

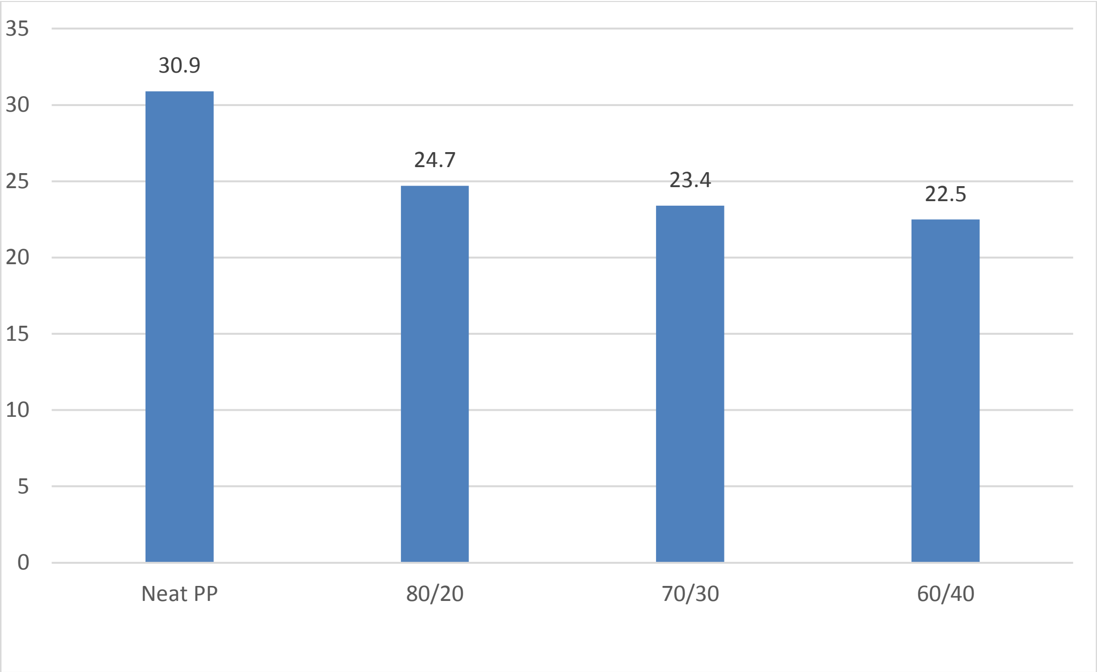


Figure 4 - 1 : Tensile Strength of the specimen in MPa.

From the graph, we can see that there is no improvement on tensile strength of the composite compared to the neat polypropylene. The strength decreased as the fiber content increased. After the specimen is produced by injection molding process, the specimen straightaway underwent tensile testing. After the injection molding process, the specimen should undergo tensile testing 48 hours afterwards. This might be the cause of failure in this testing.

4.1.2 Tensile Modulus

Figure 4-2 shows the bar chart for tensile modulus or Young's modulus of all the specimen including neat polypropylene.

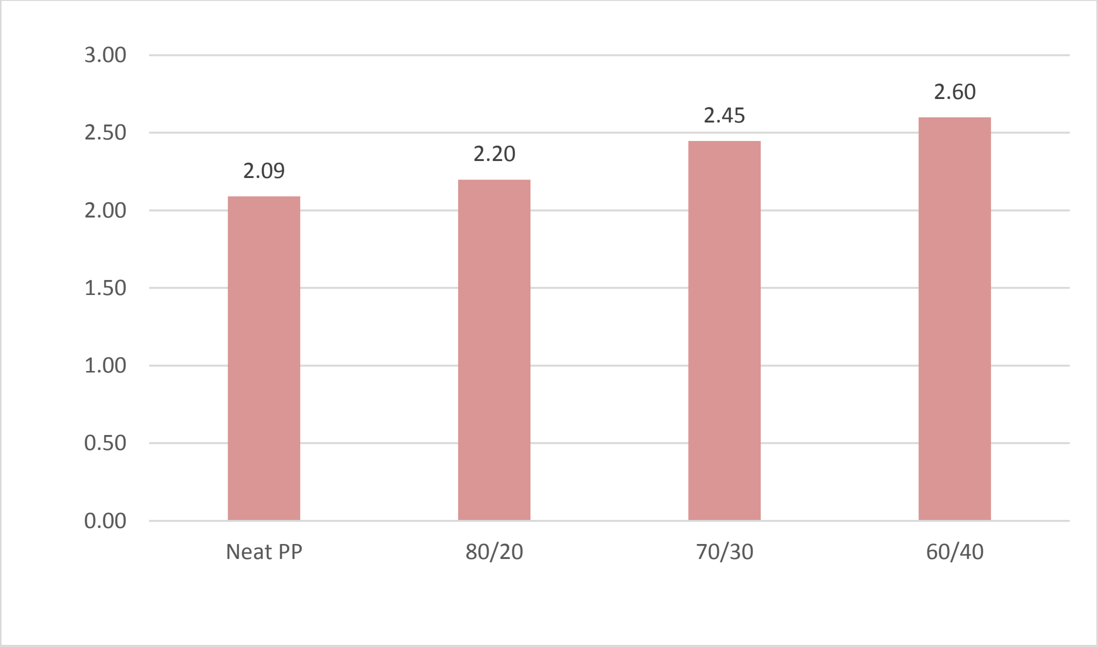


Figure 4 - 2: Bar Chart for Tensile Modulus of the specimen in GPa.

From the graph, we can observe that the graph is slightly increased for the tensile modulus compared to neat polypropylene and the best composition is 60/40 with a tensile modulus value of 2.6 GPa. The strength increased as the fiber content increased.

4.1.3 SEM for Tensile Specimen

Scanning Electron Microscopy (SEM) was done on tensile specimen to see the microstructure of the composite at the fractured surface.

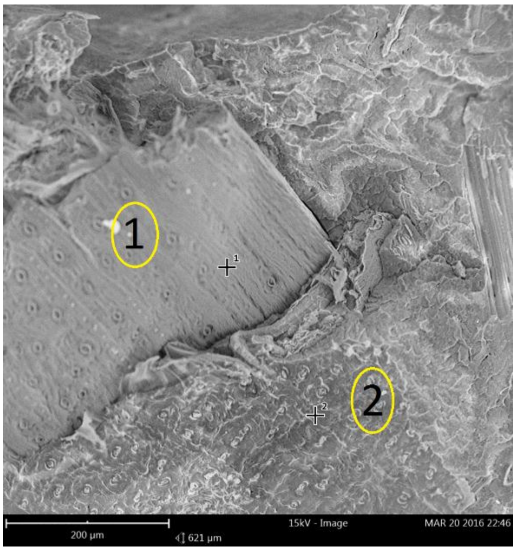


Figure 4 - 3: Microstructure of palas fiber and polypropylene at the fractured surface

Based on Figure 4-3, palas fiber was labelled as number 1 while the polypropylene was labelled as number 2. From observation, the author concluded that the palas fiber and polypropylene mixed well with each other due to the compounding process that have been done before undergo injection moulding.

Table 4-1 and 4-2 shows the amount of Carbon, Nitrogen and Oxygen in the composite.

Table 4 - 1 : Amount of element in the composite at spot 1 (Palas fiber)

Element Number	Element Symbol	Element Name	Weight Concentration	Error
6	C	Carbon	43.0	0.4
7	N	Nitrogen	30.8	0.3
8	O	Oxygen	26.1	3.1

Table 4 - 2: Amount of element in the composite at spot 2 (Polypropylene)

Element Number	Element Symbol	Element Name	Weight Concentration	Error
6	C	Carbon	80.4	0.4
7	N	Nitrogen	19.6	0.0

Figure 4-4 shows how the microstructure react towards the pulling force during the tensile test.

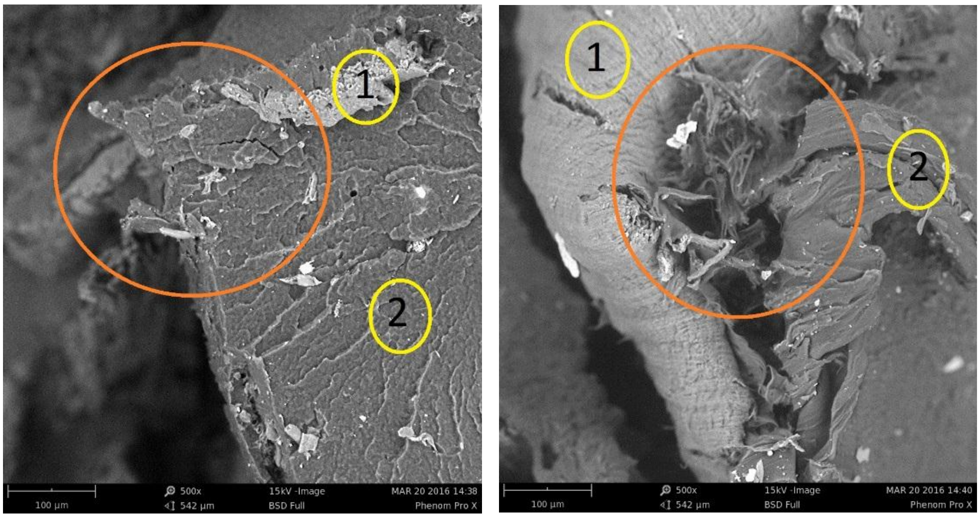


Figure 4 - 4: Microstructure of the palas fiber being pulled out and damaged matrix (void).

Based on Figure 4-4, the region marked with orange shows that the composite was pulled upward due to the pulling force from the tensile test. The microstructure of palas leaf was labelled as number 1 while polypropylene was labelled as number 2.

4.2 Flexural Properties

For the flexural test, the author obtained the flexural strength and flexural modulus of the neat polypropylene and also for all of the specimens from different composition. 5 best specimens were selected to undergo the test and the average value was taken.

4.2.1 Flexural Strength

Figure 4-5 shows the histogram for flexural strength of all the specimens including neat polypropylene.

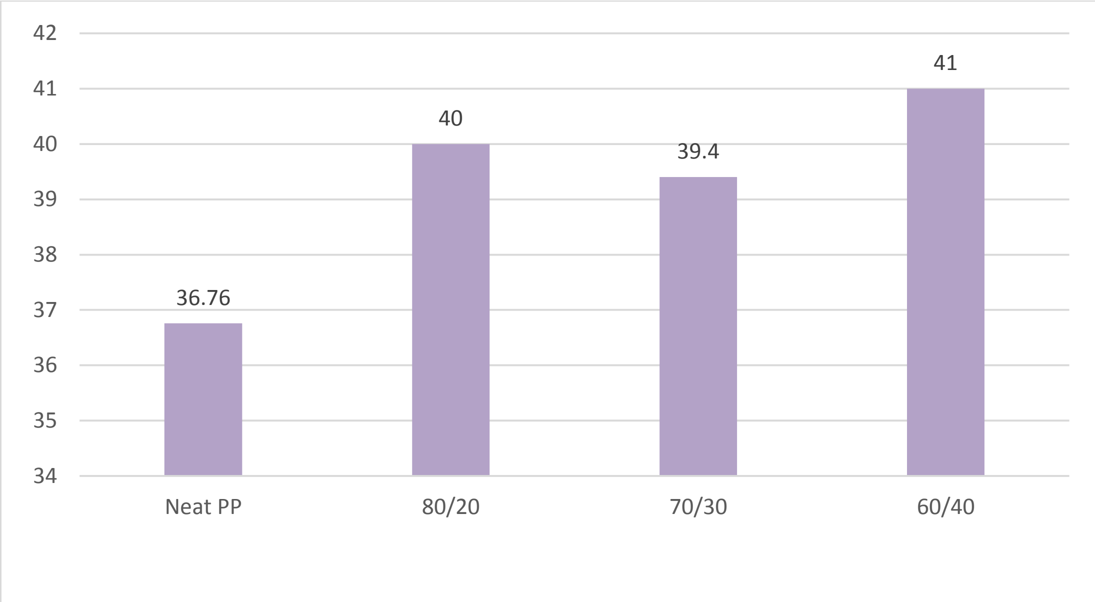


Figure 4 - 5: Flexural Strength of the specimen in MPa.

From the graph, the flexural strength drastically increased compared to the neat polypropylene and the best composition is 60/40 with a flexural strength value of 41.0 MPa. The strength increased as the fiber content increased.

4.2.2 Flexural Modulus

Figure 4-6 shows the histogram for flexural modulus of all the specimens including neat polypropylene.

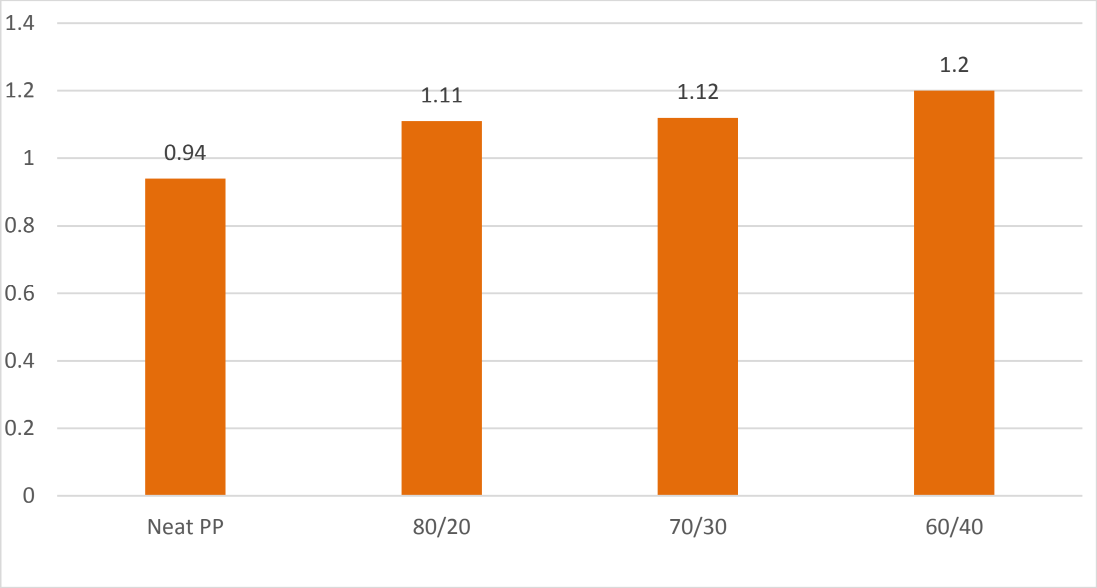


Figure 4 - 6: Flexural Modulus of the specimen in GPa.

From the graph, the flexural modulus slightly increased compared to the neat polypropylene and the best composition is 60/40 with a flexural modulus value of 1.20 GPa. The flexural modulus increased as the fiber content increased.

4.3 Impact Properties

For the impact test, the author obtained the impact strength of the neat polypropylene and also for all of the specimens from different compositions. 5 best specimens were selected to undergo the test and the average value is taken to construct the grah.

4.3.1 Impact Strength

Figure 4-7 shows the histogram for impact strength of all the specimens including neat polypropylene.

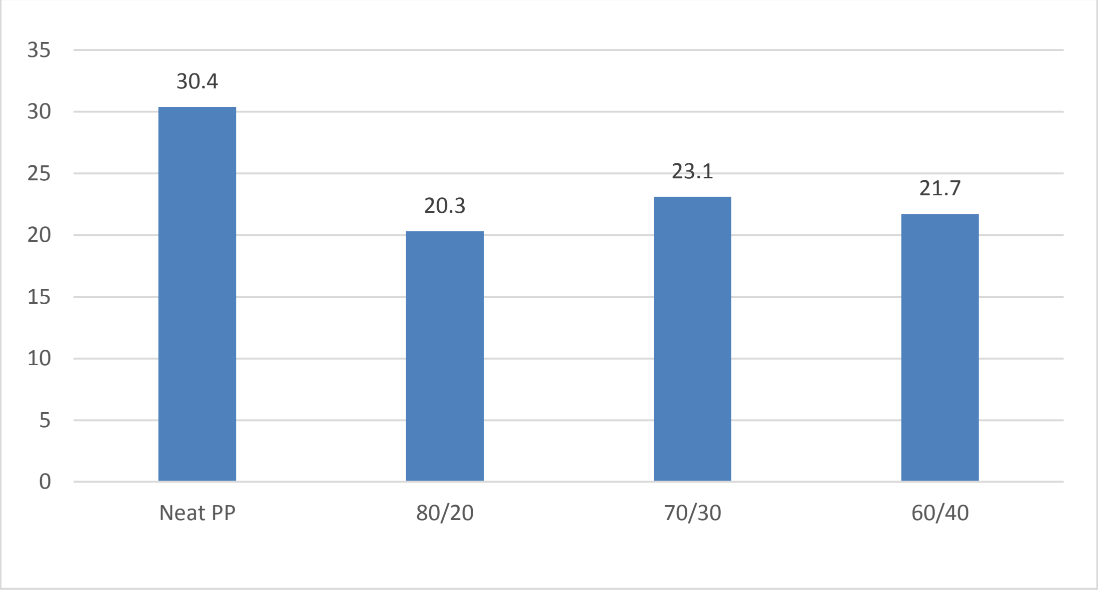


Figure 4 - 7: Impact Strength of the specimen in J/m.

From the graph, there is no improvement for impact strength. The graph decreased compared to the neat polypropylene as expected. The strength decreased as the fiber content increased.

4.3.2 SEM for Impact Specimen

Scanning Electron Microscopy (SEM) was also been done on impact specimen to see the microstructure of the composite at the fractured surface. Figure 4-9 shows the microstructure of the impact specimen.

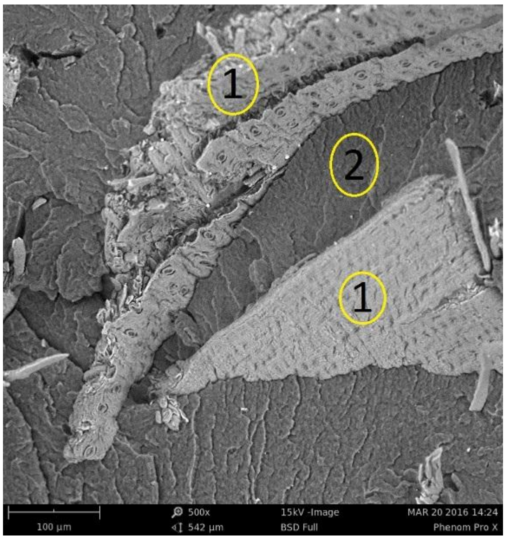


Figure 4 - 8: Micrograph of the composite for impact specimen.

Based on Figure 4-8, the palas fiber microstructure was labelled as number 1 while the polypropylene microstructure was labelled as number 2. From observation, the author concluded that the palas fiber and polypropylene mixed well with each other due to the compounding process undergo injection moulding process. Figure 4-10 shows the microstructure of the composite at the fractured surface after impact test.

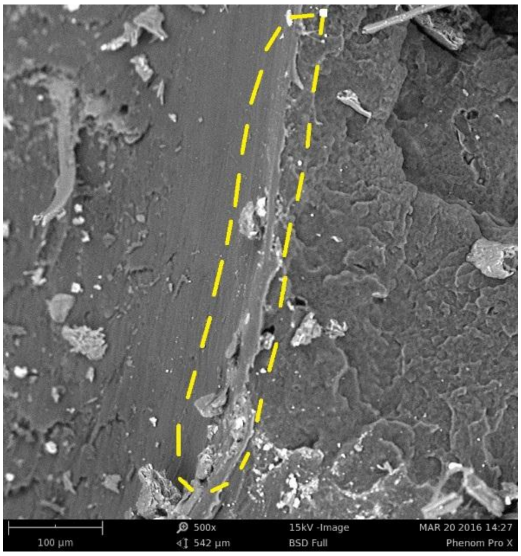


Figure 4 - 9: Microstructure of the composite at fractured surface from the impact test.

Based on Figure 4-9, dotted region shows the fractured surface of the specimen from impact test. We can observe that the microstructure at the breaking region (left region) differ with the microstructure at normal region (left region).

CHAPTER 5

CONCLUSIONS

The aims of this project are to evaluate the mechanical behaviour of palas leaf reinforced composite, to conduct and investigate the tensile, impact and flexural testing of the composite. As a conclusion, there is no significant improvement on the tensile strength and impact strength over neat polypropylene. For the tensile modulus, flexural strength and flexural modulus, the value increased as the fiber content increased. 60% of polypropylene and 40% of palas fiber is the optimum composition to produce the best tensile modulus, flexural strength and flexural modulus. The objective of this project is to conduct tensile, flexural and impact properties and evaluate the suitability of palas leaf as a reinforcement material in polymer composites to replace conventional materials or synthetic fiber. The tensile modulus, flexural strength and flexural modulus of palas leaf reinforced composite have higher value than the neat polypropylene. Palas leaf is also low cost, environmental friendly and recyclable. Hence, the objective of this project is achieved.

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APPENDIX