APPLICATIONS OF HYBRID BAGASSE/KENAF FIBER REINFORCED WITH POLYPROPYLENE FOR AUTOMOTIVE COMPOSITES COMPONENT

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A report submitted
in fulfillment of the requirements for the degree of
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DECLARATION

I declare that this project report entitled “Application of Hybrid Bagasse/Kenaf Fiber Reinforced with Polypropylene for Automotive Component” is the result of my own work except as cited in the references.

Signature : ……..

Name : AHMAD SHAFIQ BIN MOHD SHUKRI

Date : FEBRUARY 2022

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

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ABSTRACT

Nowadays, material and manufacturing sustainability, cost and energy consumption, the environment and health issues, are factors affecting production rates in automotive sectors. Therefore, most companies use natural fibers to overcome these difficulties. In addition, hybrid bagasse/kenaf fiber reinforcement with polypropylene (PP) as a matrix for producing composite materials. This innovation of composite is to increase the uses of waste of natural fiber. To make this happen, the mechanical and physical properties of this composite material need to be identified. Fiber and PP will be combined with different fiber compositions in each sample. To begin with, the natural fiber from bagasse are extracted from the sugarcane while kenaf is imported from another region then undergoes alkaline treatment. The tube was cut to 1 cm and then mixed with PP into the mould and compressed with a hot press and cooler at the specified temperature, pressure and time parameters. Another composites is prepared by same method which is bagasse/kenaf with PP. After the sample is prepared, it will undergo several types of tests, namely the density test, hardness test and tensile test. According to the results of the tensile test, it shown that the maximum load on hybrid bagasse/kenaf PP decreased linearly with increasing fiber content. Besides, the density trend also decrease with increasing fiber content in the sample. The result of hybrid bagasse/kenaf PP and kenaf PP composites are thoroughly compared.

ACKNOWLEDGEMENT

First and foremost, praises and thanks to the God, the Almighty, I am so grateful for His showers of blessings I am given the strength to be able to complete my final year project titled 'Application of Hybrid Bagasse/Kenaf Fiber Reinforced with Polypropylene For Automotive Component' in the given period, through thick and thin in my final year.

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LIST OF ABBREVIATIONS

PP	Polypropylene
KF	Kenaf fiber
FRPC	Fiber reinforced polypropylene composite
UV	Ultra violet
ASTM	American Standard Testing Method
UTS	Ultimate tensile strength

CHAPTER 1

INTRODUCTION

1.1 Background

As manufacturing industry looks to reduce the dependence on products and commodities based on petroleum, there are increasing needs to look at more environmentally sustainable, long-lasting materials to substitute the ones already in use. Interest in lightweight products reinforced with natural fibers has soared lately as a result of new environmental policies and consumer demand, prompting manufacturers to search for alternatives to traditional synthetic materials. Natural fiber reinforced composites have seen a substantial growth in use during the last decade, owing to their low cost of manufacture, lower density, and biodegradable qualities, as well as the fact that they provide nearly similar mechanical properties to synthetic fiber reinforced composites such as glass fiber and carbon fiber (Manish Kumar Lila et al., 2018).

Natural fibers such as kenaf, bagasse, bamboo, coir, and jute are among those being investigated for use as composite reinforcement. The yield of these crops has shown significant increment in these years, due to their considerable advantages in terms of strength and durability, as well as their ease of handling. Paulo Pecas et al. (2018) state that natural fiber-based composites hold promising potential for the automotive market because the need for lightweight and ecologically acceptable materials is increasing. While research indicates that natural fiber composites can lead to a 20% cost reduction and a 30% weight reduction in an automotive part, this effect is offset by the cost of the components. Following those writers, light weight of components allows for lower fuel consumption, greater recycling capabilities, less trash disposal, and fewer greenhouse gas emissions which are a few of the primary reasons

for the application of natural fibers. For interior elements in automotive such as, door trims, front dashboards cushions, backrests, and cabin pillars, natural fiber reinforced composites are the dominant type of material used. On the other hand, in the application of exterior parts, natural fiber composite parts are rarely applied.

Different locations around the world develop and use a variety of natural fibers, and occasionally import or export them to other regions. For example, the European automotive sector primarily employs flax and hemp, whereas jute and kenaf are primarily imported from Bangladesh and India, banana fiber is largely imported from the Philippines, and sisal is imported from South Africa, the United States, and Brazil. For the German automotive manufacturing, flax fiber has been the most important natural fiber.

Specifically for this research, bagasse and kenaf fiber would be used as the main reinforcing materials since they are plentiful natural resources and simple to procure. Polypropylene will be utilised as a matrix and it is a popular thermoplastic medium used in the automobile industries. Hisham A. Maddah et al. (2016) demonstrated that polypropylene is a promising plastic due to its excellent chemical, thermal, and mechanical properties. Furthermore, researchers favour thermoplastic polymeric matrices over thermosets because thermoplastics have a shorter manufacturing time, lower recycling costs, and are more easily repaired (Quazi T. H. Shubhra et al., 2013).

1.2 Problem Statement

In today's world, industries are searching for environmentally sustainable materials extracted from natural energy to be used in their products, both to reduce their environmental footprint and to appeal to a growing number of environmentally aware customers. The automotive sector, in particular, is constantly looking for smaller, more environmentally sustainable materials that are nevertheless suitable for mass manufacturing at low cost without sacrificing material strength. (Samuel C.R. Furtado et al., 2014). Since academics and legislators are interested with greener automobile manufacturing and consumption solutions, they are highly engaged with how natural fibers may be used to these processes. Hence, using natural fiber composite materials as conventional materials for automotive component manufacturing is a reasonable assumption based on the research results.

The issues of existing materials are weighed down by their high weight, non-biodegradable, and high cost. In spite of the fact that natural fibers and synthetic fibers have a lot in common, a number of problems remain with regard to natural fibers. For example, there is a high degree of variability in mechanical characteristics, as well as reduced ultimate strength, reduced elongation, issues with nozzle flow circulation in injection moulding machines, and a lack of resistance to weathering.

1.3 Objective

This research aims to develop a natural fiber reinforced composite and examines the physical and mechanical properties of the composites utilising a variety of testing techniques, with an emphasis on the use of bagasse/kenaf natural fiber as reinforcement for polypropylene matrix. Throughout the study, there are a number of goals to be met.

1. To fabricate, perform testing and analyze the samples of bagasse and kenaf fiber reinforced polypropylene composites with various fiber composition using specific parameters and method.
2. To study the effect of density, hardness and tensile test on the fiber composite samples.

1.4 Scope of Study

The scope of this study is to fabricate bagasse/kenaf fiber reinforced polypropylene composites using structured methods and various composition ratios, as well as to examine the physical and mechanical properties of the those composites based on the data and results obtained from the conducted experiments. The scopes are as follows:

1. Preparation of fiber reinforced composites with different fiber percentage ratio at 7%, 14%, 21% and 28%.
2. Observation on the reaction of natural fibers and effect on the microstructure due to chemical treatment process.
3. Analysis to determine the mechanical properties of composites, including density, tensile, and hardness tests.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Natural fiber reinforced composites are made up of a polymer matrix with high-strength natural fibers such as jute, oil palm, sisal, kenaf, and flax incorporated in it. As for polymer, it is usually divided into two types: thermoplastics and thermosets. A thermoplastic, also called thermo-softening plastic, is a type of plastic polymer material that's can be mould at higher temperatures and then roll back their properties as they cool, due to their dimensional molecular framework. Thermoset polymers, on the other side, are strongly cross-linked polymers that cure utilising only fire, heat and strain, and/or light irradiation. Thermoset polymers with this structure have strong properties including high versatility for tailoring preferred ultimate properties, great strength, and modulus. The properties and efficiency of composites may be influenced by a variety of techniques. The hydrophilic composition of the natural fiber, as well as the fiber loading, have an effect on the composite properties. To achieve good composite properties, high fiber loading is usually needed. In general, as the fiber composition in the composites increases, the tensile properties of the composites improve. The method parameters used are yet another essential factor that has a significant impact on the composites' properties and surface properties. Moreover, natural fiber chemical structure has a huge impact on the physical and mechanical properties of the composite, which are expressed by the percentages of cellulose, hemicellulose, lignin, and waxes in the composite. As a result, suitable methods and criteria should be selected properly to achieve the best composite characteristics.

2.2 Natural Fiber

Fiber derived from nature animal fibers, vegetable fibers, and mineral fibers are the common forms of natural fibers. These fibers are a readily available, easy-to-find commodity in nature. They display high tensile strength, biodegradability, specific stiffness and low cost per unit volume as outstanding material properties. Natural fibers are regarded to be naturally present composites made up of cellulose fibrils that are embedded in a lignin matrix. To maximise its tensile strengths, as well as provide stiffness, the cellulose micro fibrils are aligned throughout the fiber length. Natural fiber reinforces well due to the crystalline structure of cellulose. The majority of global automotive manufacturers are using natural fibers composites, as well as conventional materials, in their products as indicated in **Table 2.1**.

Table 2.1: Applications of natural fibers in automotive industry

Natural Fibres	Component Description	Other Constituents
Bast fibres (flax, hemp, kenaf, jute, sisal, etc.)	Carrier for covered door panels, covered components for instrument panels, covered inserts, carrier for hard and soft armrests, seat back panels, door panels, door bolsters, headliners, side and back walls, seat backs, rear deck trays, pillars, centre consoles, load floors, trunk trim	Polypropylene (PP) and polyester
Abaca	Under-floor panel and body panels	-
Banana	Wrapping paper	-
Flax/Sisal	In the interior door linings and panels, door panels	Thermoset resin
Kenaf	Door inner panel	PP
Kenaf/Flax	Package trays and door panel inserts	-
Kenaf/Hemp	Door panel, rear parcel shelves, other interior trim, Lexus package shelves, door panels	-
Wood	Carrier for covered door panels, carrier for covered door panels, covered or foamed instrument panels, covered inserts and components, covered seat back panels, fibre in the seatback cushions, inserts, spare tire, covers	Acrylic resin and synthetic fibre

2.2.1 Kenaf Fiber

Kenaf (Hibiscus cannabinus) is an annual crop that looks a lot like theokra (Abelmoschus esculentus) and cotton (Gossypium hirsutum), both of which belong to the same family (Malvaceae). The kenaf plant originated in Africa, but India and China account for more than 75% of global kenaf supply, making kenaf the most important bast fiber source in these countries. In Malaysia, Kenaf was acknowledged as a new industrial crop in 2000, assisting the country's commodities industry in diversifying. Thus, between 1996 and 2005, MYR 5.8 million (USD 1.53 million) was dedicated to kenaf research and development (R&D) in order to attract investors. Kenaf was developed throughout a four-phase period. Between 2004 and 2005, the National Tobacco Board's workforce was first exposed to kenaf. The following phase (2006-2010) focused on introducing the kenaf crop to producers, developing a kenaf production plan, and farming. Between 2011 and 2015, the emphasis moved to commercialization of kenaf crops and their associated products. The current phase (2016-2020) focuses on the commercialization of new potential approaches and brand development for kenaf.

Figure 2.1: Kenaf fiber before treatment

Each of kenaf growing season lasts around 75–120 days from planting to harvest. Due to kenaf's ability to flourish in hot regions with moderate rainfall, it is best planted in Malaysia between March and June, with crop harvesting occurring in July. The stem of the kenaf plant has up to 40% useable fiber, approximately double that of jute, hemp, or flax. In compared to other plants, this yield percentage improves the cost-effectiveness of the fiber. Furthermore, it takes only short period of time for a kenaf plant to grow from seed to a height of 3.6m - 4.3m. In the past, kenaf fiber was usually extracted from the plant's bast and processed using a variety of methods. The extraction method entails soaking the stalks and manually removing the fibers, and it has been found to provide superior reinforcement efficiency.

The kenaf plant consists of several beneficial components, including leaves, seeds, and stalks. And each of these components contains useful components such as fibers and fiber strands, oils, proteins and allopathic substances. Numerous variables, including cultivating process, planting date, photosensitivity, growing season duration, plant population, and plant maturity, may alter the productivity and content of various plant components. **Figure 2.1** illustrates a schematic representation of the kenaf plant cell wall. This structure is referred to as a micro fibril, microfiber, or elementary fiber. **Table 2.2** summarises the micro fibril size and chemical composition of the kenaf stem.

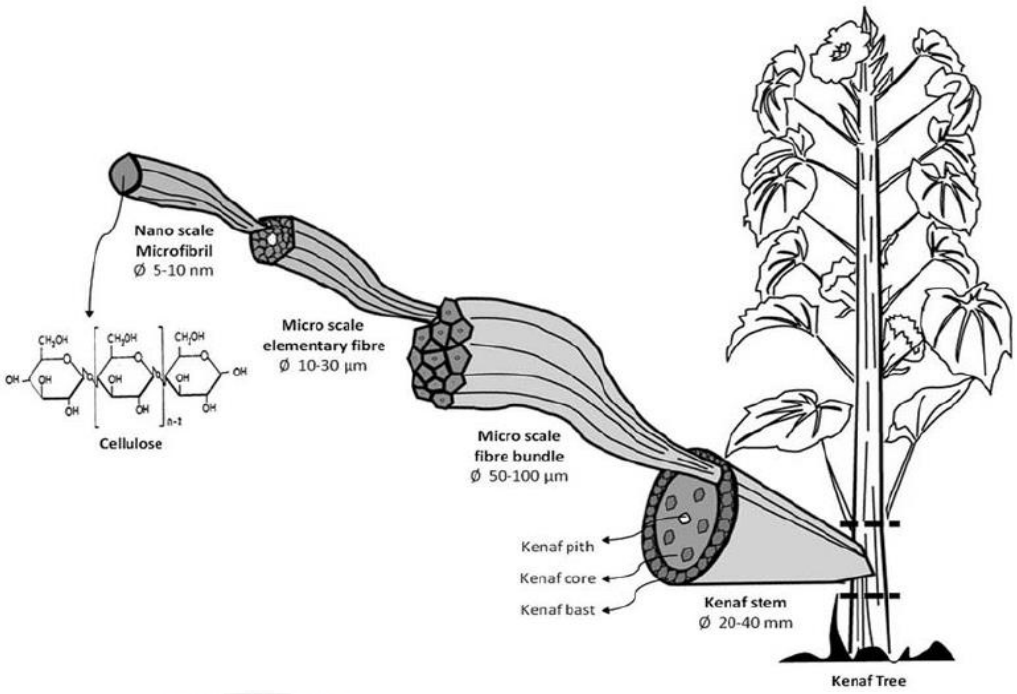

Figure 2.2: Schematic diagram of micro fibril in kenaf plant

Table 2.2: Chemical content of kenaf stem

	Bark	Core
Fibril length, *L* (mm)	2.22	0.75
Fibril width, *W* (µm)	17.34	19.23
L/*W*	128	39
Lumen diameter (µm)	7.5	32
Cell wall thickness (µm)	3.6	1.5
Cellulose (%)	69.2	32.1
Lignin (%)	2.8	25.21
Hemicellulose (%)	27.2	41
Ash content (%)	0.8	1.8

Natural fibers, such as kenaf fibers, comprise around 60-80% cellulose, 5-20% lignin (pectin), and up to 20% moisture. The cell wall is a hollow tube composed of four unique layers: one main cell wall, three secondary cell walls, and a lumen, which is an open channel running through the centre of the micro fibril. Each layer is made up of cellulose contained in a matrix of hemicellulose and lignin, mimicking composites

reinforced with artificial fibers. Hemicellulose is a network of polysaccharides with a high degree of branching, such as glucose, mannose, galactose, and xylose. Lignin is a polymer made up of aliphatic and aromatic hydrocarbons that forms a protective coating on fibers. Through hydrogen bonds and other connections, the cellulose components of the fibers supply the fibers with strength and stiffness. Hemicellulose is responsible for the biodegradation, moisture absorption, and thermal breakdown of fibers. Unlike lignin (pectin), which is thermally stable but contributes to UV destruction, lignin (pectin) is photodegradable.

The majority of natural fibers are made of cellulose and lignin. The cellulose content dictates the mechanical properties, which are influenced by a range of parameters, including fiber length, fiber loading or percent volume of fibers, fiber vertical alignment, fiber orientation, and interfacial adhesion between fibers and matrix.

According to a study (Nishino et al., 2010), the form, scale and strength of natural fibers are largely determined by the cultivation method. Kenaf fiber is subjected to a variety of treatments and surface changes in order to improve its condition and properties. Alkaline treatment with sodium hydroxide (NaOH) solution is the most common chemical treatment, followed by silane treatment and other mixed treatments like alkaline-silane, alkaline-bleaching, alkaline-steam and alkaline-electron irradiation. As fibers are treated in a variety of ways, they provide excellent mechanical properties when incorporated into composites. Chemical treatments have been shown to improve fiber-matrix interface adhesion by chemically bonding the adhesive to the material. Overall, each treatment has a different effect on fiber strength, suitability, and fiber-matrix adhesion, which is also dependent on the fiber composition.

The figure below illustrates the example of research results that been obtained using kenaf fiber involving different composition of alkaline treatment. These qualities will have an effect on the mechanical properties of the manufactured fiber reinforced composites.

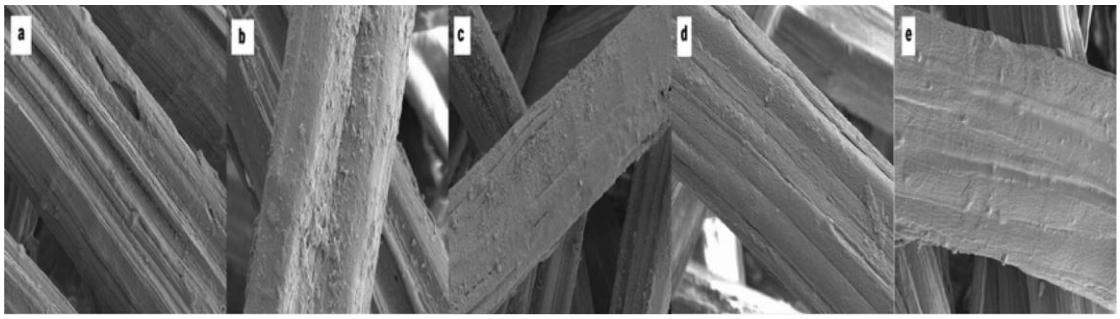

Figure 2.3: SEM micrograph of kenaf fiber (a) untreated fiber, (b) 2% NaOH, (c) 4% NaOH, (d) 6% NaOH and (e) 8% NaOH

2.2.2 Bagasse

Sugarcane (Saccaharum officinarum) is a readily available and plentiful source of lignocellulosic biomass. The solid residue remaining after juice extraction is referred to as sugarcane bagasse or bagasse in general. Sugarcane is an agricultural crop that provides several advantages to humans and other living creatures. Bagasse accounts for around 32% of each tonne of the sugarcane output. Malaysia has a total sugarcane bagasse planting area of roughly 34 500 acres. Due to the fact that around 1.1 million tonnes of sugarcane were produced in 2002, bagasse is readily available in Malaysia (Lee and Mariatti, 2008). Bagasse is a renewable agricultural product that is underutilized. Bagasse ranges in colour from grey-yellow to pale green. It is dense and quite disorganised in terms of particle size. Bagasse is utilised as fuel in power plants since it is produced at sugar mills. This is a low-efficiency method due to its poor caloric

content. However, whenever sugarcane is produced on a big scale, extra bagasse must be disposed of through other means such as burning, dumping, or land burial. Thus, an economically viable use of leftover bagasse might help the sugar mill enhance revenues while also resolving an environmental issue.

Figure 2.4: Bagasse fiber

Sugarcane bagasse is typically composed of 50% cellulose, 25% hemicellulose, and 25% lignin. The high content of cellulose in bagasse fiber makes it an excellent composite reinforcing material. Numerous researchers have identified a variety of chemical compositions for bagasse, as mentioned in **Table 2.3**. The molecular structure of bagasse fiber are shown in **Figure 2.5**.

Table 2.3: Chemical composition of bagasse fiber

Cellulose	Hemicellulose	Lignin	Protein	Fat and waxes	Ash	Saccharose	Silica	Glucose	References
50	25	25							Huang *et al.* 2012, Xu *et al.* 2010
40	24.4	15	1.8	0.6	5	14		1.4	Vazquez *et al.* 1999
40–43	28–30	9–11	8–9	2–2.5	5–6				Ramaraj 2007
46	24.5	19.5		3.5	2.4		2		Mulinari *et al.* 2009a
69.4	21.1	4.4		5.5	0.6				Habibi *et al.* 2008
41.8	28	21.8							Bilba *et al.* 2003
55.2	16.8	25.3			1.1				Trindade *et al.* 2005
56	6	29			7				Maldas and Kokta 1991
36.32	24.7	18.14							Vilay *et al.* 2008

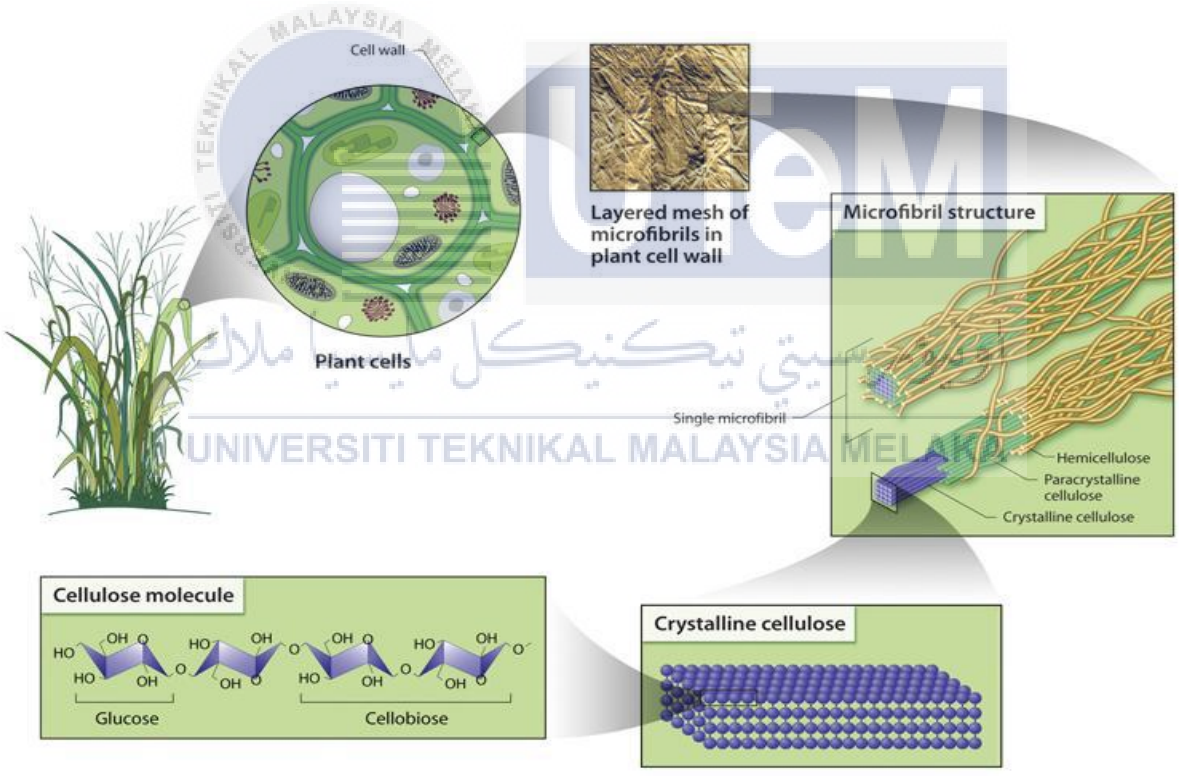

Figure 2.5: Molecular structure of bagasse fiber

Bagasse fiber has a high tensile strength and modulus of elasticity, making it a suitable reinforcing material for composites. Sugarcane bagasse has a tensile strength of around 20–290 MPa and a Young's modulus of around 19.7-27.1 GPa (Wirawan et al., 2011), as properties of natural fibers are shown in **Table 2.4**. Bagasse fibers, like kenaf fibers, may be treated chemically with alkaline, acetylation, or silane. During the alkaline treatment procedure, the hydroxyl group in bagasse is ionised to alkoxide by adding aqueous sodium hydroxide. This procedure eliminates a portion of the lignin, wax, and oils that coat the fibers and promotes defibrillation by exposing more contact area between the fiber and the matrix, as well as possible response sites. Additionally, when hydrogen bonds are broken, surface roughness increases, resulting in enhanced mechanical interlocking between the fiber and matrix, resulting in greater mechanical resistance of the composites. Acetylation is a process that converts the hydroxyl group in bagasse fiber to an acetyl group, increasing the hydrophobicity and decreasing the polarity of the fibers.

Table 2.4: Physical and tensile properties of natural fiber

Type of fibers	Density (g/cm^3)	Tensile strength (MPa)	Young's modulus (GPa)	Elongation at break (%)
Kenaf (bast)	1.2–1.4	295–930	53	1.6–6.9
Flax	1.4	800–1500	60–80	1.2–1.6
Hemp	1.48	550–900	70	1.6
Jute	1.46	400–800	10–30	1.8
Ramie	1.5	500	44	2
Coir	1.25	220	6	15–25
Sisal	1.33	600–700	38	2–3
Cotton	1.51	400	12	3–10
Bagasse	1.2	20–290	19.7–27.1	1.1
Pineapple	1.5	170–1627	82	1–3
Banana	1.35	355	33.8	5.3
Sugar palm	1.26	190.29	3.69	19.6

2.3 Polypropylene

Polypropylene (PP) was developed in 1954 and immediately acquired widespread acceptance owing to its low density compared to other commodity polymers. PP has great chemical resistance and may be converted using a variety of processes, including injection moulding and extrusion. Polypropylene is a colourless polymer with superior mechanical qualities that outperforms polyethylene for a variety of reasons.

PP is an excellent material for strengthening and filling. Thus, a research conducted by Vincenzo Busico and Roberta Cipullo (2000) examines the influence of fiber reinforcement on the mechanical characteristics of fiber reinforced polypropylene composites (FRPCs). A composite material is a polymer matrix reinforced with glass or carbon fibers. FRPCs provide superior durability, moisture resistance, and strength, making them excellent for use in construction, sports equipment, and automobiles. Synthetic fibers provide superior mechanical qualities versus natural fibers. Glass fibers are often utilised as a synthetic reinforcement in conjunction with PP to make composites with exceptional mechanical characteristics. The mechanical properties of composites, on the other hand, are determined by a variety of fiber treatments and coupling agents. The diameter of the fibers is another critical component in the construction of composite materials. A particular value for the diameter of the fibers should not be surpassed; otherwise, the fibers would weaken the composite.

Due to its strength, hardness, and high melting point, PP is an excellent structural polymer. When designed properly, PP resins may demonstrate exceptional processability. It is a vinyl polymer in which each carbon atom is connected to a methyl group, as shown in **Figure 2.6**.

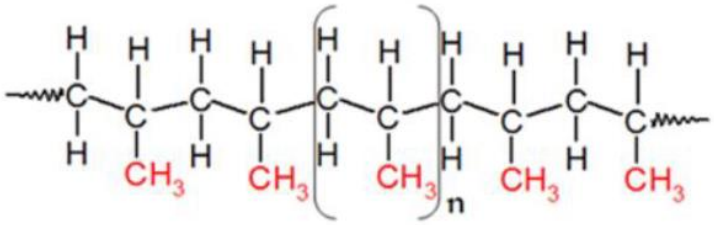

Figure 2.6: Structure of polypropylene polymer

Polypropylene is paving the way for this exciting transformation in plastics technology; it is a strong but lightweight material with a wide range of industrial, automotive, and daily applications. This space-age substance is tougher and more durable than a wide variety of other resin compounds and is the lightest of the major polymers. Polypropylene's exceptionally low specific gravity enables the portability of a wide variety of durable items. PP is a polymer that is exceedingly durable. Unlike concrete and steel, PP does not corrode or react with water, acid, detergents, or non-oxidizing organic substances. This chemical resistance ensures the strength's dependability. While PP is a lightweight material, it nevertheless has an unexpected level of strength and durability. Products manufactured of PP are about three times as strong as those made of steel. The table below shows the properties of polypropylene fiber.

Table 2.5: Physical properties of polypropylene

Composition	100% Virgin polypropylene
Fiber length	18mm
Specific gravity	0.91
Melting point	160°C
Tensile strength	(137-689) MPa
Young's modulus	(5500-7000) MPa
Fiber thickness	18-30 microns
Elongation	25-40 %

Polypropylene is produced by polymerizing propylene gas with the help of a catalyst, most often Ziegler-Natta or metallocene. The temperature, pressure, and reactant concentrations used during polymerization are determined by the polymer grade being produced. Numerous manufacturing techniques exist, all of which have certain fundamental commonalities. They are either gas-phase processes (fluidized bed or stirred reactor) or liquid-phase processes (slurry or solution). The pictures below demonstrate a flow diagram for each of the two kinds of processes. Gas-phase polymerization is inexpensive and versatile, allowing for the use of a wide range of catalysts. It is the most often used technique in current polypropylene manufacturing facilities.

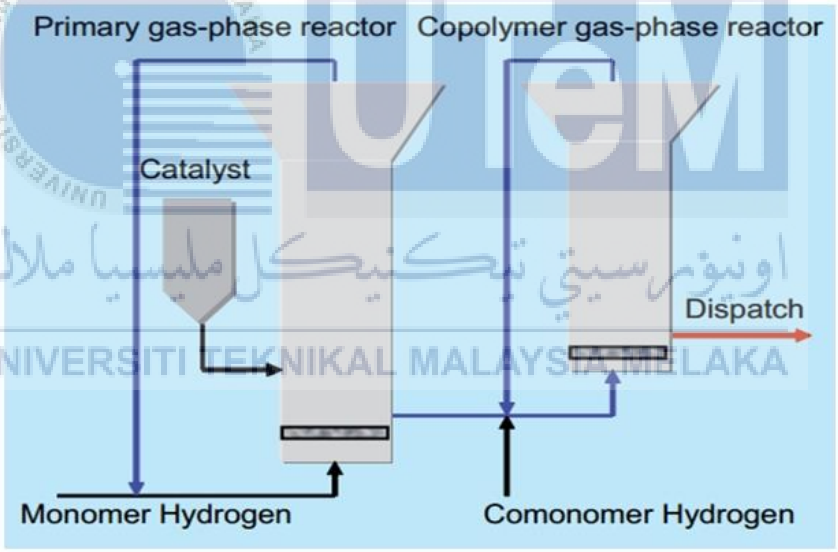

Figure 2.7: Gas-phase process

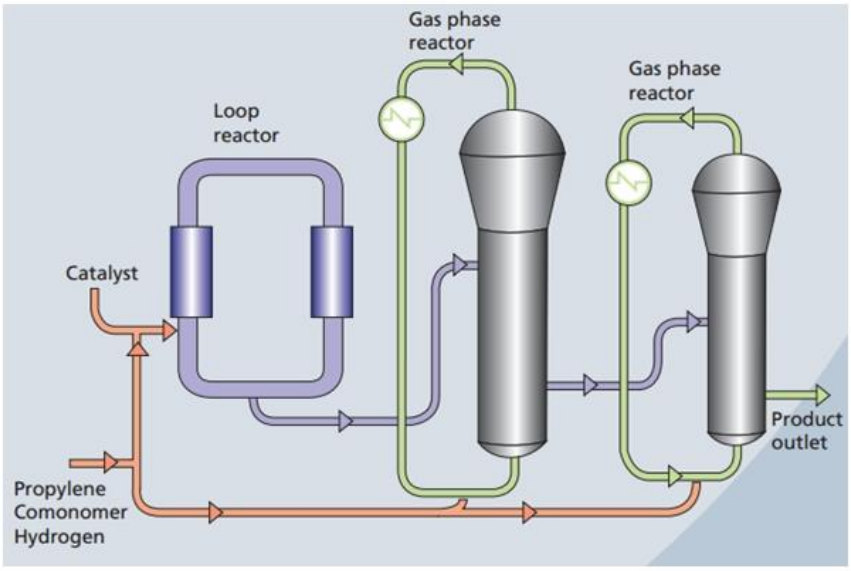

Figure 2.8: Liquid-phase process

Polypropylene is widely used in automobiles. For instance, one of the first applications was in battery cases and air conditioning ducting. Due to PP's low density of 0.91 g/cm^3, it accounts for a large portion of the polymers in modern automobiles, as automakers strive to minimise the total weight of their vehicles in order to save consumers money on petrol. Additionally, interior trim and a number of external parts are fully composed of PP or PP composites. All interior components, including door trims, cabin pillars and dashboard consoles are made of PP. Due to the need of weight reduction, PP became a popular material for vehicle components both internal and external applications.

2.4 Hybrid Composite

Hybrid composites are reinforced composites with two or more different kinds of fibers and a single matrix polymer. In principle, several different fiber types may be incorporated into a hybrid, but it is more likely that a combination of only two types of fibers would be most beneficial. The primary goal of this hybridization is to increase the mechanical characteristics of the fibers. Hybrid composite materials are becoming more prevalent in variety of engineering applications due to their increased qualities over standard composites. The mechanical characteristics of hybrid composites are generally superior in terms of tensile strength, Young modulus, and tensile stress compared to single fiber composites.

The physical and mechanical properties of a composite generally depends on two factors, which is the composition, and the properties of fiber reinforcement and the matrix. To find the most suitable natural fiber to be used as a reinforcement, several experiments should be conducted to identify the properties of the samples and their behaviour whether it satisfy and fulfil the objectives of the design and required performances. A study carried out by Jawaid and Abd Khalil (2011) states that the strength of hybrid composites depends on the properties of fibers, fiber content ratio, fiber length, fiber arrangements, fiber to matrix interface bonding and the fiber configuration. Typically, the mechanical characteristics of a composite will improve as fiber length and fiber loading in the composite increase. The figure below shows the three main hybrid configurations used in manufacturing industries.

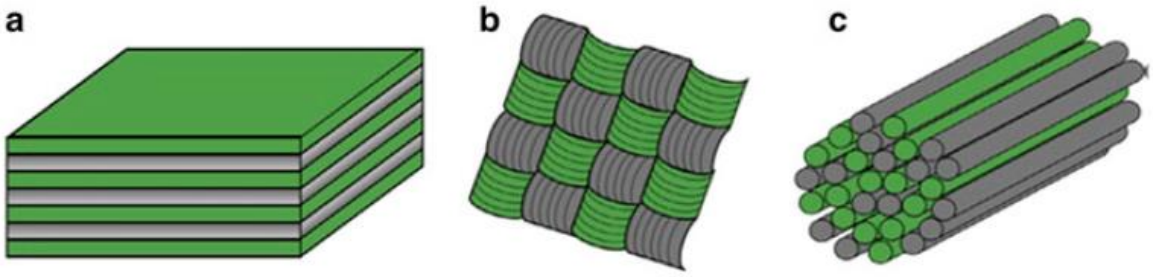

Figure 2.9: Hybrid configurations: (a) interlayer, (b) intralayer, and (c) intrayarn

CHAPTER 3

METHODOLOGY

3.1 Overview

The unique features of manufacturing components of fiber reinforced composite structures is that the mechanical properties of the materials can be customised to meet the needs of a specific application. Depending on the intended end product, the substance may be engineered to display isotropic or extremely anisotropic properties by adjusting the direction or location of the fibers. One of the main disadvantages of this customization is the potential financial costs involved with this manufacturing system. Although customising individual parts can be sufficient when dealing with low-volume parts, the customising procedure becomes prohibitively expensive when applied to higher-volume parts. The use of thermoplastic sheets with pre-existing fiber orientation for higher output pieces is a cost-effective option.

This chapter would include an overview of the analysis methods. **Figure 3.1** depicts a flowchart and description of the methods used in this study. The steps that must be taken in order to accomplish the goals begin with a literature review in order to collect relevant results for this project. Following that, raw material preparation, sample fabrication, and final tests on the samples will be conducted to determine the mechanical properties of the composites samples.

This chapter will be divided into three subsections, which are:

i. Preparation of raw materials
ii. Fabrication of hybrid composite samples
iii. Testing methods and processes

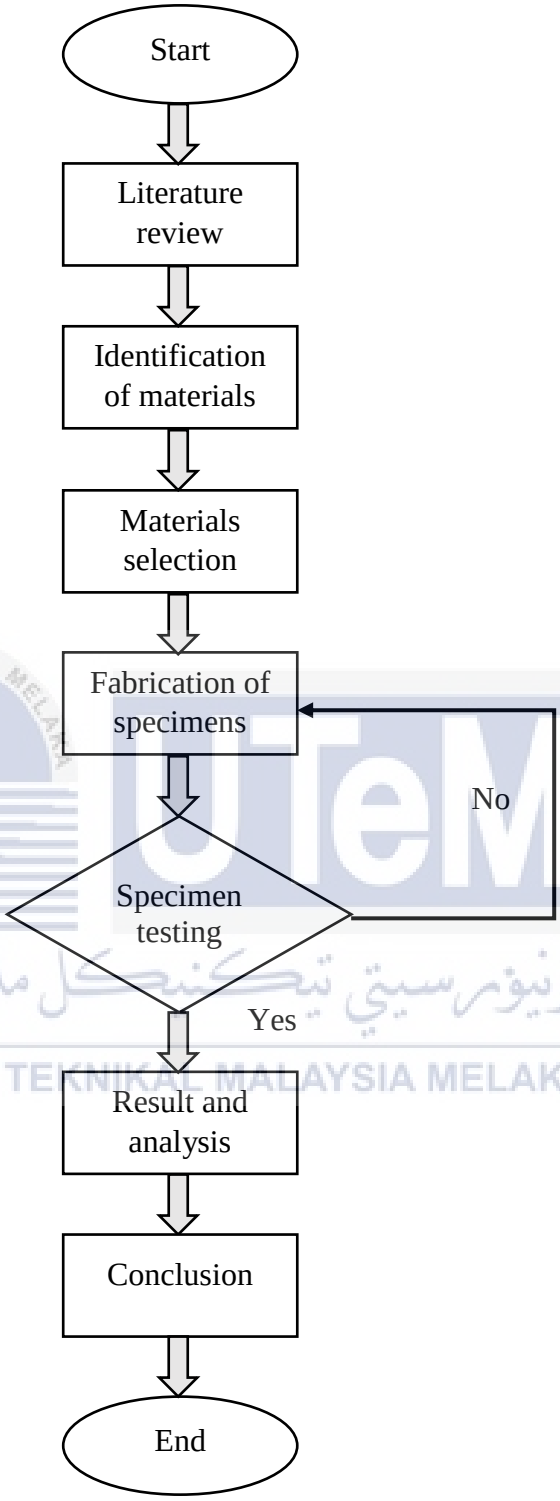

Figure 3.1: Flowchart of methodology

3.2 Preparation of raw materials

There are three main materials that will be extracted and modified before being mixed together to form a fiber composite. Materials used in the production of the composite include kenaf fiber, bagasse fiber and polypropylene. It was decided to prepare two sets of samples, one with hybridization and one without hybridization. The process of all materials will be discussed further.

3.2.1 Preparation of kenaf fiber

The process of obtaining kenaf fiber begins with the extraction of the fiber from the kenaf stalk. The kenaf stalk will first be cleaved with a length of 10 mm using a fiber decorticating machine, as illustrated in **Figure 3.2**. It will then be rinsed with distilled water to ensure that any pollutants or dirt stuck to the kenaf are completely removed. Due to moisture content in kenaf, it will be dried in the sun for 24 hours to achieve total moisture elimination.

Figure 3.2: Decorticating machine

Treatment of the kenaf fiber with an alkaline solution is the next stage in the preparation process. Preparation of sodium hydroxide (NaOH) solution is required for this procedure. The 5% aqueous NaOH solution was prepared using the stirrer machine as shown in **Figure 3.3**. For the next 24 hours, the fiber will be immersed in the NaOH solution at room temperature. The purpose of this step is to improve the physical properties of the fiber. After that, it will be baked for around 24 hours at 60° C to be completely dried.

Figure 3.3: NaOH solution with 5% concentration stirred by stirrer machine

Figure 3.4: Kenaf fiber soaked in NaoH solution

3.2.2 Preparation of bagasse fiber

For bagasse, it is easier to obtain the fibers due to the crushed cane stalk as a result of juice extraction. Basically, wet bagasse with 50% moisture content was collected at the nearby stall the end process of juice extraction. Utilizing a fiber decorticating machine, bagasse fiber will be chopped into 10 mm lengths similar to kenaf fiber. Then, it will be dried in oven at 105° C for 24 hours to totally remove the moisture.

Alkali treatment will be used to extract the lignin and other binding materials from the rind structure to free the fiber. Bagasse fiber will undergo an alkali treatment by immersing the fiber in a NaOH solution with 5 wt. % concentration fixed at 1 hour of treatment time. This is considered the optimum concentration to obtain the best fiber strength.

3.2.3 Preparation of polypropylene

Polypropylene resin are used in fabricating the samples because of its outstanding thermoforming and low-density qualities, PP has become the primary source of matrix polymer raw materials. **Figure 3.5** displays the resin in form of pellets before the process. To begin with, an electronic weighing scale will be used to weigh an estimated quantity of polypropylene resin of up to 20 grams. It will next be crushed into powder form for around 50 minutes using a pulverizer machine. Each of crushing process is set to 500 seconds (total 3000 seconds) to avoid the machine overheat and eventually melt the PP resins. To make fine powdered PP, further mixing using a blender machine was done.

Figure 3.5: Polypropylene resin

Figure 3.6: Pulveriser machine (set at 500 seconds per process)

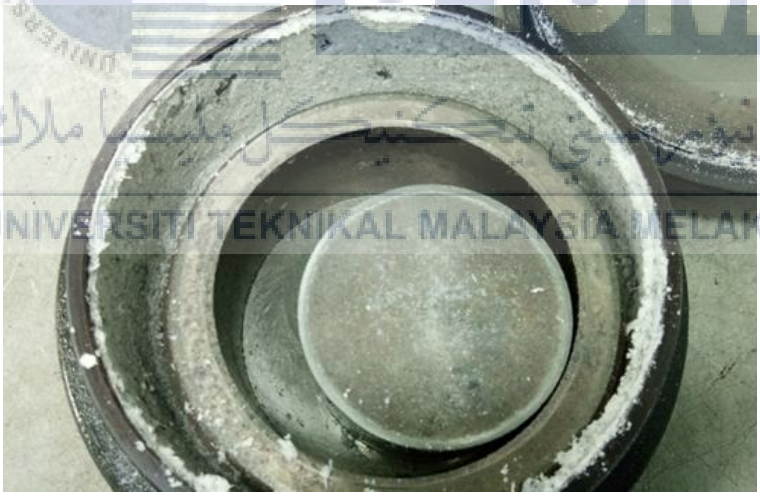

Figure 3.7: PP in form of powder

3.3 Fabrication of specimens

Fabrication will consist of fabrication of nine test specimens using three different fiber reinforcement compositions: one PP monomer, four kenaf reinforced PP composites and four hybrid bagasse/kenaf reinforced PP composites with different composition ratios. At first, the equal weight percentages of kenaf and bagasse fibers will be mixed. After that, test specimen composites will be manufactured in accordance with the weight ratio that has been obtained, as shown in **Table 3.1**. The total weight of each sample composite is set at approximately 30 grams. The combination of fiber and matrix polymer will be put in a mould and compressed using a hot press machine, at 180°C and 10kg/cm^2 pressure.

Table 3.1: Composition ratio of specimens

Specimen composition (%)		Weight composition of fiber/matrix polymer (gram)
Kenaf fiber/PP reinforced composite (Kenaf/PP)	Hybrid Bagasse/kenaf fiber PP composite (Bagasse/Kenaf/PP)	
7/93	3.5/3.5/93	2.1/27.9
14/86	7/7/86	4.2/25.8
21/79	10.5/10.5/79	6.3/23.7
28/72	14/14/72	8.4/21.6
PP monomer		
0/100		0/30

The fabrication procedure involves filling a rectangular aluminium mould with a size of 140mm x 60mm with a combination of fiber reinforcement and matrix polymer. After that, the combination will be squeezed using a hot press machine, as indicated in **Figure 3.8**. At a temperature of 180°C, the samples will be preheated for 12 minutes. Then they will go through a full press for 6 minutes at 180°C, followed by a cold press for 6 minutes at 25°C. During pressing, around 10kg/cm^2 of pressure is applied. Following the heating and chilling procedure, the mould is put on the mould opener as shown in **Figure 3.9** to remove the sample from the mould. The composite samples are then been cut into 140mm x 20mm size, which is the required dimensions based on the standards of the testing, resulting in three samples for each composition.

Table 3.2: Parameter for hot press machine

Temperature	180 ℃
Preheat	12 minutes
Hot press	6 minutes
Pressure	10kg/cm^2

Figure 3.8: Hydraulic hot press machine

Figure 3.9: Aluminium mould (140mm x 60mm)

Figure 3.10: Mould opener machine

After the specimens are cut into desired size, they will be labelled to ease the process of testing for each specimen composition. Each composition consist of three specimens, each will be used for different testing which is density, tensile and hardness test.

Table 3.3: Specimen of PP monomer

Sample	PP (%)
A	100

Table 3.4: Specimens of kenaf fiber PP composites

Sample	Kenaf fiber (%)	PP (%)
B	7	93
C	14	86
D	21	79
E	28	72

Table 3.5: Specimens of hybrid bagasse/kenaf fiber PP composites

Sample	Bagasse fiber (%)	Kenaf fiber (%)	PP (%)
F	3.5	3.5	93
G	7	7	86
H	10.5	10.5	79
I	14	14	72

3.4 Testing

Testing will be carried out to examine and compare the mechanical and physical characteristics of different compositions of bagasse/kenaf fiber reinforced PP composites and kenaf/PP composites. There will be four test conducted consist of density test, tensile test and hardness test. All four testing will be carried out according to American Standard Testing Method (ASTM) to obtain most accurate result.

Table 3.6: ASTM Testing

Testing	ASTM Code
Density Test	ASTM D792
Tensile Test	ASTM D3039
Hardness Test	ASTM D2240

3.4.1 Density Test

The density test will be conducted based on ASTM D792. There are two types of test methods available, which is Method A for testing solid in water, and Method B for testing solid in liquid other than water. These methods describe on how to determine the specific gravity (relative density) and the density of solid polymer plastics in forms of rods, tubes, sheets, or moulded items. For this specimens, we will only be using Method A to determine the density and specific gravity. A digital electronic densimeter (MD-300S) as shown in **Figure 3.11** will be used. Mass of the samples will be determined at first by putting them on the densimeter. Water is then filled into the

container until it reaches a particular level of, then the container will be placed on the densimeter. In the meanwhile, when the samples are submerged in water, the specific gravity and volume values will be obtained.

Figure 3.11: MD-300S Digital electronic densimeter

3.4.2 Tensile Test

The tensile test will be done according to ASTM D3039. The purpose of this test is to determine how much force is necessary to break a polymer composite specimen, as well as how far the specimen stretches or elongates to reach that breaking point. Specimens will be put in the grips of Instron Universal Test Machine at a pre-set grip separation and pulled with a constant head speed of 5mm/min until failure is achieved. The elongation and tensile modulus will be determined using a strain gauge attached to the test machine. From the obtained results, the ultimate tensile strength

(UTS), percent of elongation and maximum load for each specimens will be identified and recorded.

Figure 3.12: Instron universal testing machine

3.4.3 Hardness Test

For hardness test, we will be following ASTM D2240 standard which allows for an assessment of initial hardness, or indentation hardness, after a certain amount of time. The test necessitates the application of force in a steady, shock-free way while measuring the hardness. The specific hardness of the materials, such as polymer or rubber, is measured with an analogue shore scale D-type durometer. The value of

hardness is frequently used to identify a certain hardness of the specimen, as well as a method to control the quality measure on batches of materials.

The specimen will first be placed on a firm flat surface, and the instrument's indenter will be pressed onto it, and making sure the specimen is parallel to the surface. Within one second of firm contact with the specimen, the hardness is read and will be recorded on the scale. This test determines how deeply an indenter penetrates a material under defined force and time parameters.

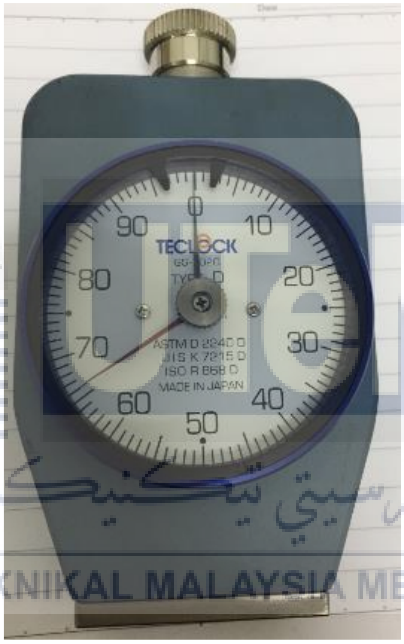

Figure 3.13: Analogue Shore Scale D-type Durometer

CHAPTER 4

RESULT AND DISCUSSION

4.1 Overview

This chapter will focused on result of mechanical properties, physical properties and analysed the microstructure of hybrid bagasse/kenaf with PP and kenaf with PP. It will further discussed on every result mentioned.

4.2 Effect of physical test

One of the objective in this research was to study the physical properties of hybrid bagasse/kenaf fiber with PP composite. Type of test involve in this section are density test and microstructure test. Moreover, it is compare the physical properties with kenaf reinforced PP.

4.2.1 Density

Table 4.1 and **Figure 4.1** show the results of density (g/cm^3) based on weight percentage (%) for hybrid bagasse/kenaf PP and kenaf PP composites. Based on the table below, the result of both type of composites show reduction in the value of density as the weight percentage of fiber increase. Even with the same weight percentage between hybrid bagasse/kenaf PP and kenaf PP composites, the density of kenaf PP composite is higher than the density of hybrid bagasse/kenaf PP except for 21% fiber composition which shows higher density in hybrid bagasse/kenaf PP.

For the 0% of weight percentage of fiber (sample A) recorded the highest value of density which is 0.904 g/cm^3 and the 28% of weight percentage for both composites has the lowest value of percentage which is 0.867 g/cm^3 and 0.864 g/cm^3 respectively. Specifically, the value of density shows the same reduction with increment of weight

percentage of fiber. The highest density value with fiber is 0.891 g/cm^3, which is for 7% fiber composition of kenaf, followed by 7% of hybrid bagasse/kenaf with 0.887 g/cm^3. Comparing the 28% of weight percentage between the density of hybrid bagasse/kenaf PP and kenaf PP composites, the latter still has the higher value. This is because the bond between single type of fiber and matrix are much stronger and pack compared to the bond of the two combined fibers and matrix.

Table 4.1: Density properties of hybrid bagasse/kenaf PP and kenaf PP composites.

Samples		Mass m (**g**)	Volume V (cm^3)	Density ρ (g/cm^3)
A	Pure PP	9.18	10.152	0.904
B	Kenaf-PP 7/93	9.56	10.734	0.891
C	Kenaf-PP 14/86	9.23	10.467	0.882
D	Kenaf-PP 21/79	8.34	9.574	0.871
E	Kenaf-PP 28/72	8.62	9.942	0.867
F	Hybrid-PP 7/93	8.57	9.656	0.887
G	Hybrid-PP 14/86	8.72	9.923	0.879
H	Hybrid-PP 21/79	9.21	10.546	0.873
I	Hybrid-PP 28/72	9.01	10.432	0.864

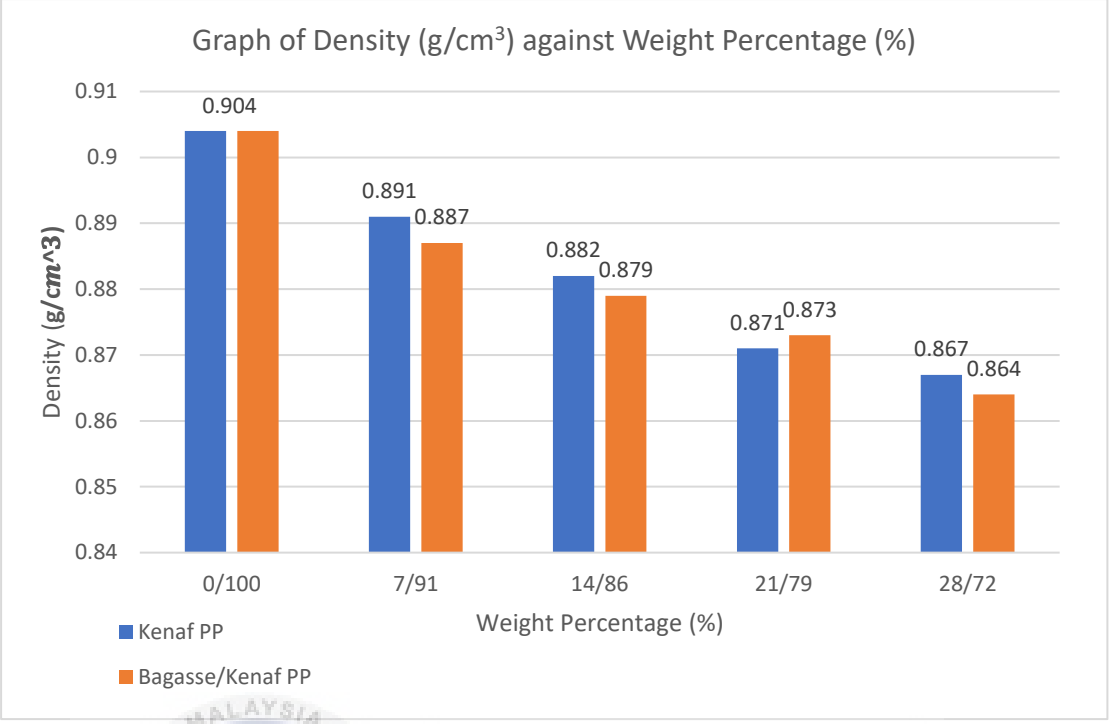

Figure 4.1: Graph of density (g/cm^3) against weight percentage (%) of bagasse/kenaf PP and kenaf PP composites

4.2.2 Hardness

The test followed by the hardness testing to analyse the hardness properties of the samples according to the weight percentage of fiber. **Table 4.2** indicates the test results of the hardness for hybrid bagasse/kenaf PP and kenaf PP composite. The pure polypropylene monomer sample (sample A) with 0% fiber composition recorded the lowest reading of hardness value from the hardness test which is 57.4 while the highest data obtained recorded by hybrid bagasse/kenaf PP composite with 28% of fiber (sample I) which is 65.4 and followed by sample H with hardness value of 64.2. Based on the analysis, the hardness of the fiber reinforced composite increases as the ratio of fiber composition increases, which results in the value of hardness for sample B, C, D and E are 60.2, 61.6, 62.8 and 63.2 respectively. For the hybrid bagasse/kenaf PP composite which is sample F, G, H and I, the hardness values recorded are 61.8, 62.6,

64.2 and 65.4 respectively. Both composites recorded an increase in value with the increment of fiber composition. Overall, there is a slight difference in hardness value between hybrid bagasse/kenaf and kenaf PP composites which shows higher value in hybrid composite compared to kenaf PP. However, both composites shows the same trend in the graph according to the weight percentage.

Table 4.2: Hardness properties of the samples

Samples		Hardness					
		1	2	3	4	5	Average
A	Pure PP	57	57	58	56	59	57.4
B	Kenaf-PP 7/93	62	60	61	58	60	60.2
C	Kenaf-PP 14/86	63	61	60	61	63	61.6
D	Kenaf-PP 21/79	65	62	61	64	63	62.8
E	Kenaf-PP 28/72	65	65	63	61	62	63.2
F	Hybrid-PP 7/93	62	62	61	63	61	61.8
G	Hybrid-PP 14/86	61	63	64	63	62	62.6
H	Hybrid-PP 21/79	65	65	66	62	63	64.2
I	Hybrid-PP 28/72	64	67	66	66	64	65.4

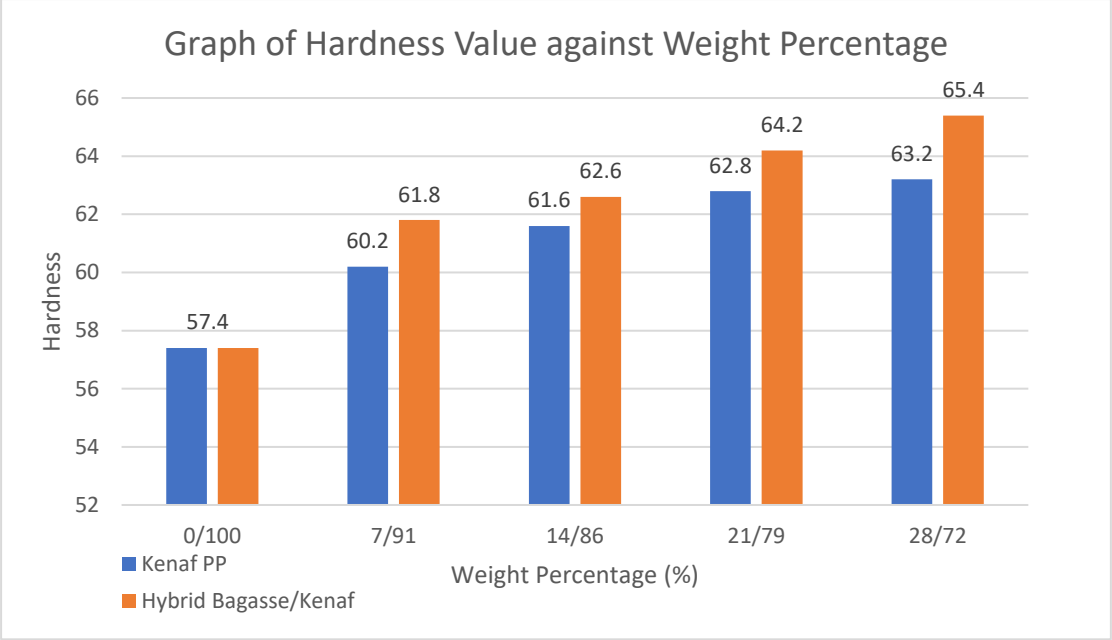

Figure 4.2: Graph of hardness value against weight percentage (%) of hybrid bagasse/kenaf PP and kenaf PP composites

4.3 Effect of mechanical test

The testing on the samples which is the tensile tests are done using Instron Universal Testing Machine. The results are automatically generated from the machine into a desktop. Based on the generated graph, the value of maximum load on sample, tensile stress and tensile strain are obtained and tabulated into following tables.

4.3.1 Tensile

Table 4.3 and **Table 4.4** shows the result for tensile test of hybrid bagasse/kenaf PP and kenaf PP composite samples according to weight percentage of fiber composition. The value of maximum load, tensile stress and tensile strain were identified from this tensile test. All the values are different according to the ability of the composites based on weight percentage when undergone elongation or stretched.

Figure 4.3 shows the diagram of maximum load against weight percentage in hybrid bagasse/kenaf PP and kenaf PP composites from the tensile test. Based on the graph, the maximum load for 0% of fiber composition (sample A) has the highest value among others, at 1192.80 N while the 28% fiber composition of bagasse/kenaf PP composite (sample I) is the lowest at 353.24 N. For sample B, C, D and E, the maximum loads are 1077.42 N, 743.93 N, 651.79 N and 459.60 N respectively. Meanwhile, the value of maximum load for sample F, G, H and I are 709.05 N, 435.03 N, 393.84 N and 353.24 respectively.

By comparing the value of maximum load of hybrid bagasse/kenaf PP and kenaf PP composites, both composites showing similar decreasing trend in graph. Each value of maximum load of kenaf PP is higher than hybrid bagasse/kenaf PP composites. The trend for this graph indicates that the lesser the fiber content, the higher the maximum load can be withstand by both composites. The maximum load of 0% fiber composition (sample A) is the highest because the sample does not consist fiber and the bond between the polypropylene polymers are stronger. So, this sample can withstand higher maximum load to fracture due higher elasticity compared to other samples. Whereas, the sample of 28% of fiber weight percentage hybrid bagasse/kenaf PP (sample I) which has lowest maximum load due to excessive of fiber in the composite and causing PP matrix unable to flow through the fiber and producing a good bonding. Therefore, the composite sample having composition difficulty and become brittle.

Based on **Figure 4.4**, it is shown the result of tensile stress at maximum load (MPa) against weight percentage of hybrid bagasse/kenaf PP and kenaf PP composites. At 0% weight percentage (sample A), the value is 23.86 MPa which is the highest tensile stress value. However, at 28% of weight percentage of hybrid bagasse/kenaf PP composite (sample I) shows lowest value of tensile stress at maximum load at 7.06 MPa.

For sample B, C, D and E, the tensile stress value at maximum load are 21.55 MPa, 14.88 MPa and 13.04 MPa and 9.19 MPa respectively. Meanwhile, the value of tensile stress at maximum load for sample F, G, H and I are 14.18 MPa, 8.70 MPa, 7.88 MPa and 7.06 MPa respectively. By comparing both sample of composites and overall tabulated data, kenaf PP composite has higher value of tensile stress at maximum load than hybrid bagasse/kenaf PP composites. The trend of both graphs shows decrement in tensile stress value due to increasing of the fiber composition in composites. As a result of discussion, it can be said that the less the fiber content in the composite, the higher the elasticity and tensile stress value of the composites. Moreover, the presence of fiber are affecting the PP segment mobility. Thus, making the composite brittle.

Table 4.3: Tensile properties of kenaf PP samples.

Weight percentage	Maximum Load (N)	Tensile stress at maximum load (MPa)	Tensile strain (Extension) at Maximum Load (mm/mm)
0	1192.80	23.86	0.05923
7	1077.42	21.55	0.01417
14	743.93	14.88	0.00732
21	651.79	13.04	0.01298
28	459.60	9.19	0.01453

Table 4.4: Tensile properties of hybrid bagasse/kenaf PP samples

Weight percentage	Maximum Load (N)	Tensile stress at maximum load (MPa)	Tensile strain (Extension) at Maximum Load (mm/mm)
0	1192.80	23.86	0.05923
7	709.05	14.18	0.01357
14	435.03	8.70	0.01351
21	393.84	7.88	0.00661
28	353.24	7.06	0.00514

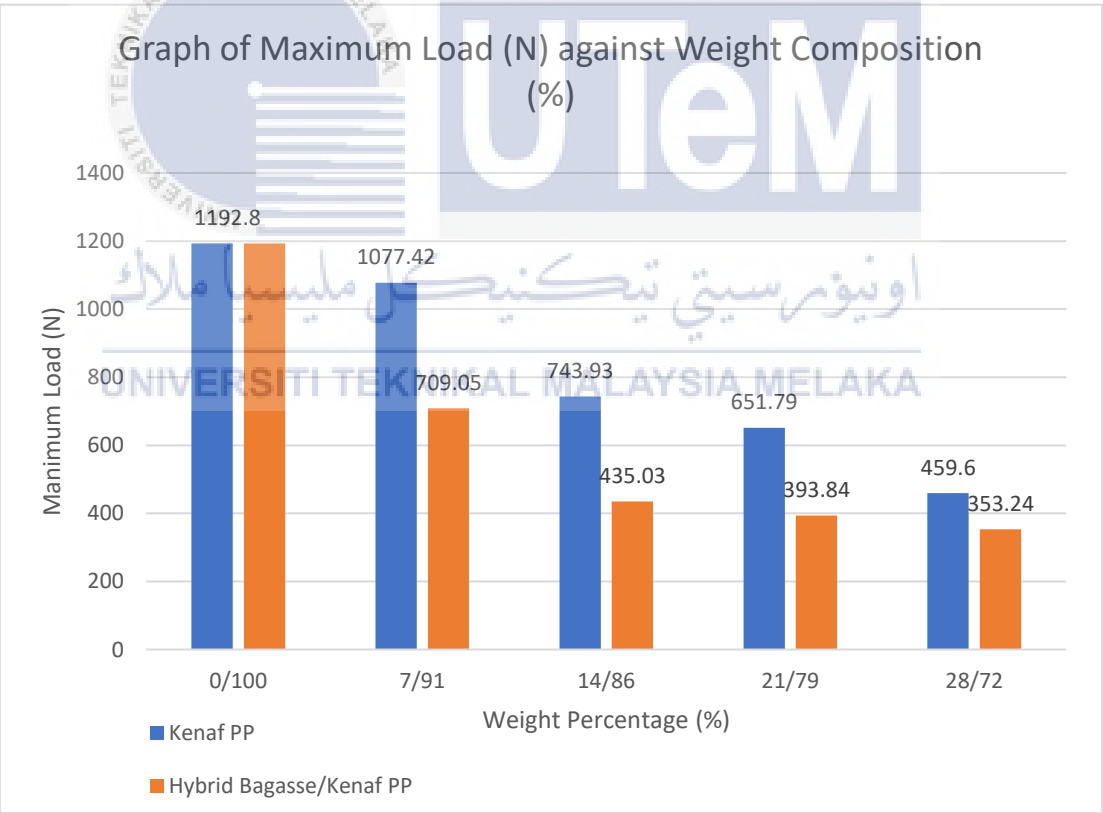

Figure 4.3: The graph of maximum load (N) against weight percentage (%) of hybrid bagasse/kenaf PP and kenaf PP composites

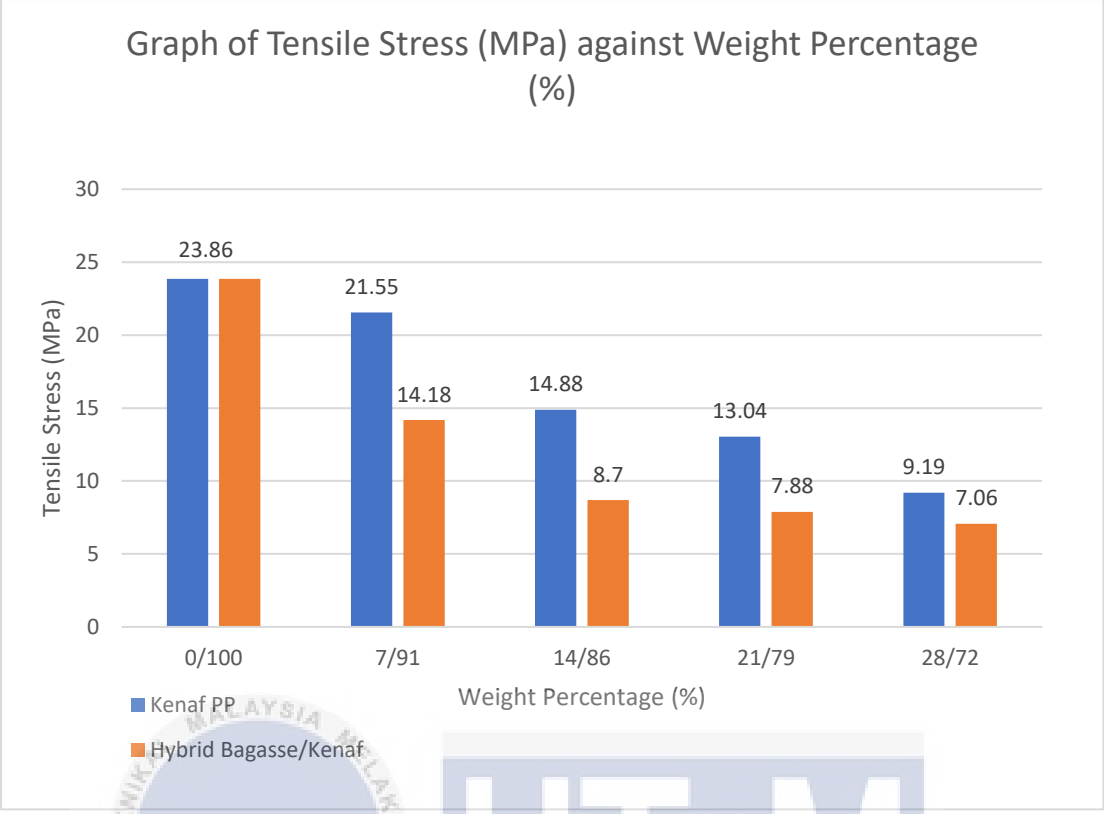

Figure 4.4: The graph of tensile stress at maximum load (MPa) against weight percentage (%) of hybrid bagasse/kenaf PP and kenaf PP composites.

Figures below illustrate that the result of maximum load against extension with different weight percentage of hybrid bagasse/kenaf PP and kenaf PP composites. The testing were done using three samples for each fiber composition. The results showed that the trend according to different weight percentage of both composites are in increasing trend. For 0 % of weight percentage (sample A), it shows the steepest pattern for this graph, followed by sample I with the lowest value. This result shows that the ductility level is the lowest on 28 % of fiber content. The reasons why higher composition of fiber has lower mechanical properties was the amount of PP resin not enough to wet the fiber. Brittle materials absorb lesser energy to fracture than the ductile material. Therefore, it leads to weak interface between the fiber and PP matrix.

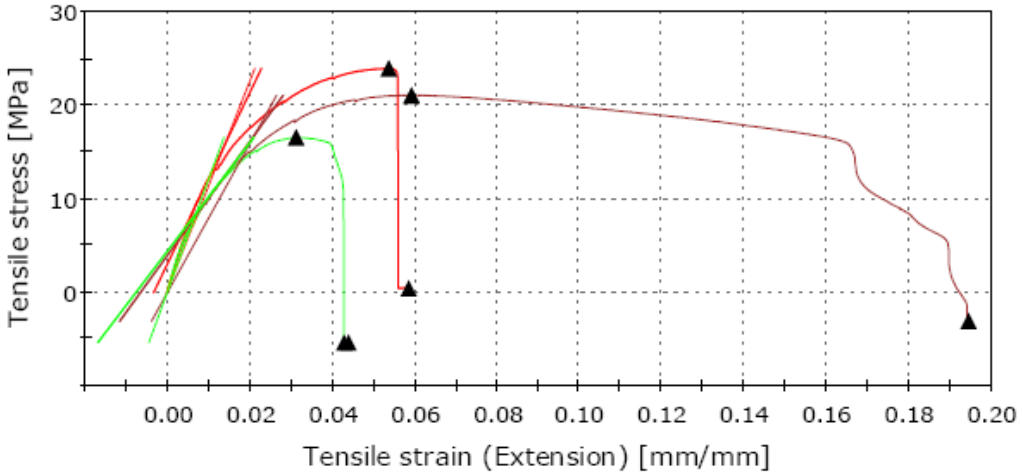

Figure 4.5: Sample A

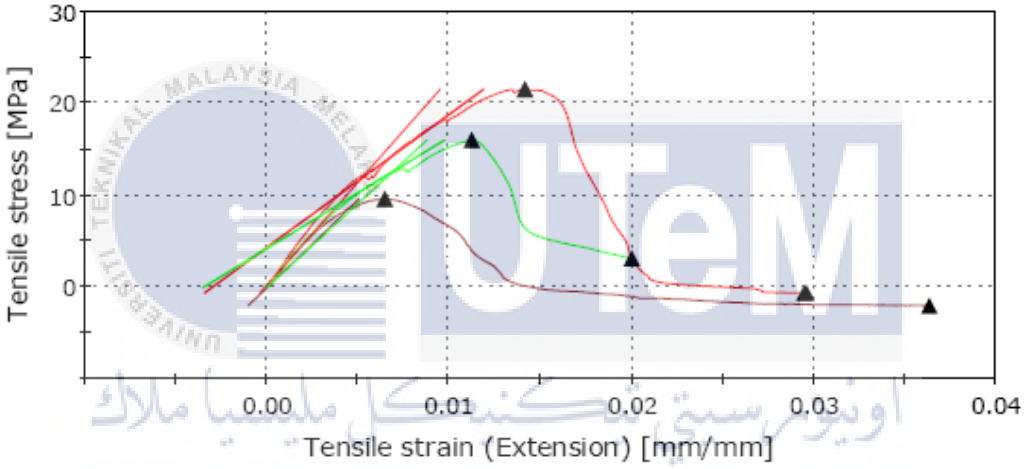

Figure 4.6: Sample B

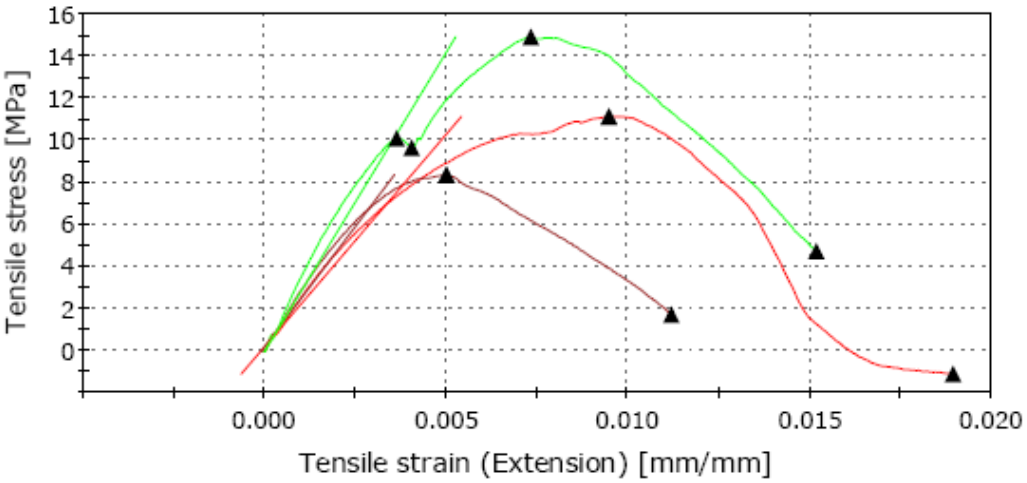

Figure 4.7: Sample C

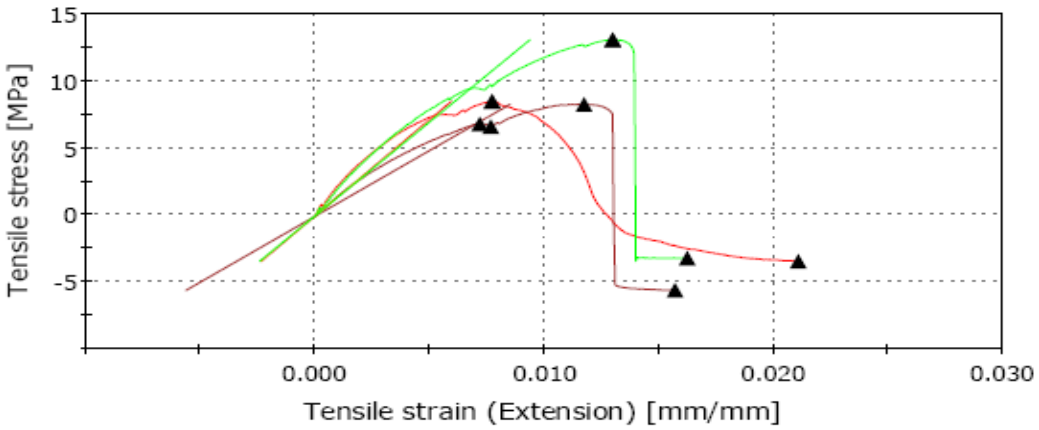

Figure 4.8: Sample D

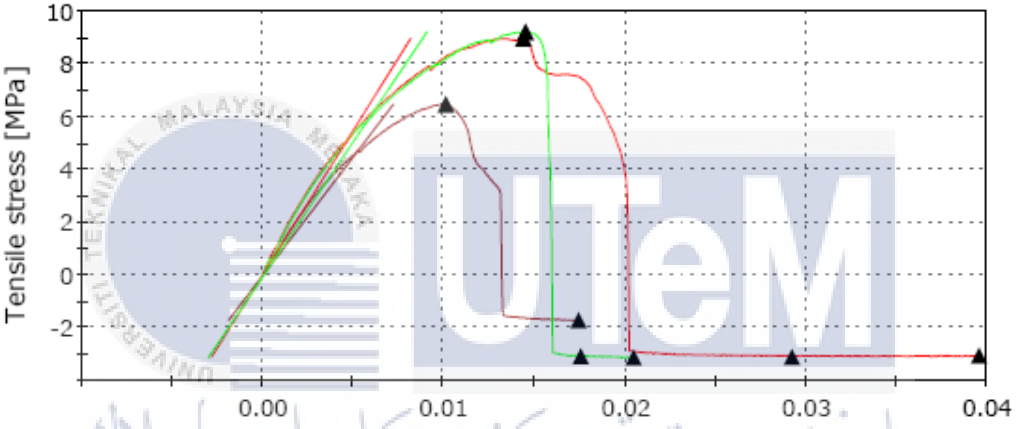

Figure 4.9: Sample E

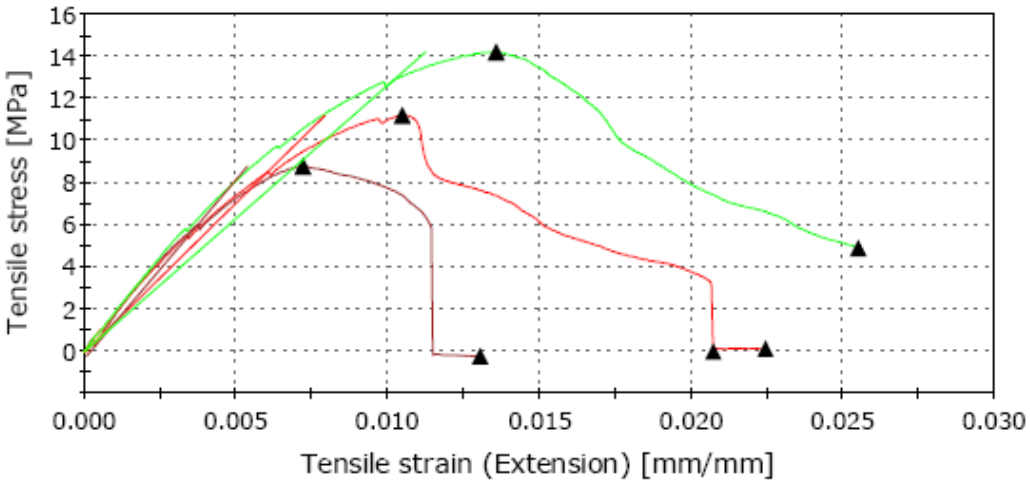

Figure 4.10: Sample F

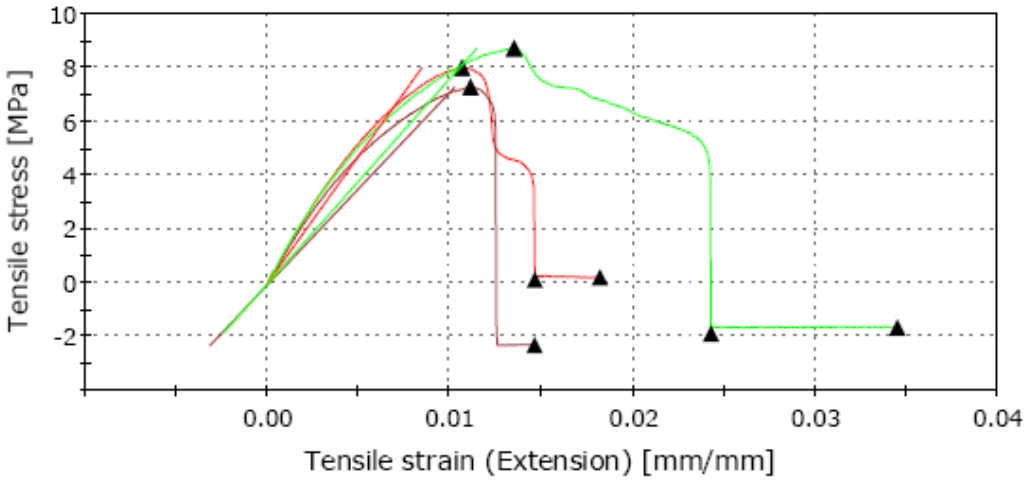

Figure 4.11: Sample G

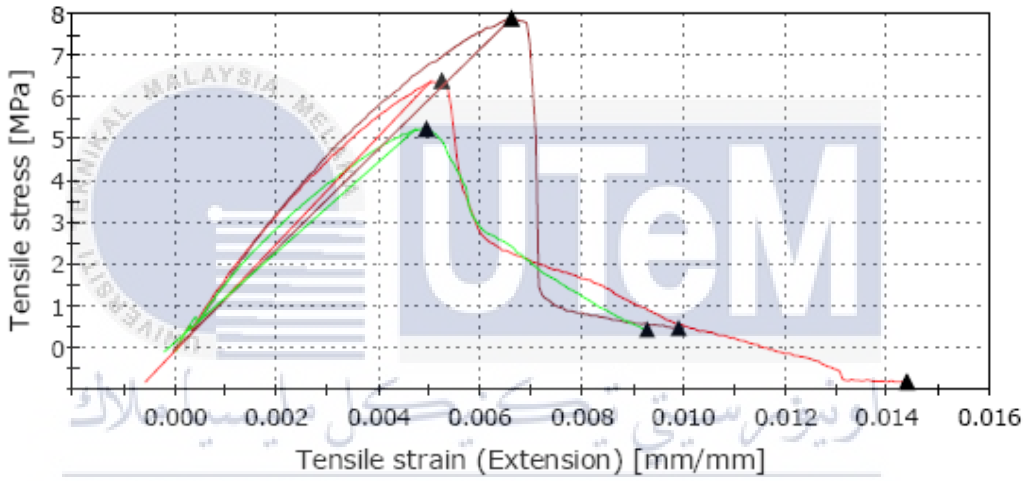

Figure 4.12: Sample H

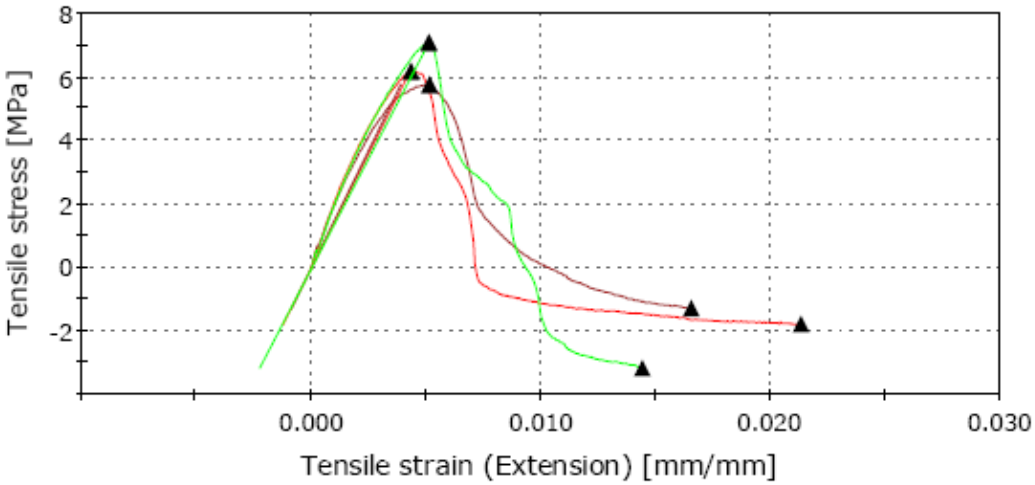

Figure 4.13: Sample I

As can be seen in the figures, the graph shows the result of tensile stress (MPa) against tensile strain which are to define the mechanical properties of the composites. The straight lines in the graph indicates the strain range between fiber and matrix facing elastic deformations or elastic region. While the rest of the curve is a range which fibers deform elastically while the matrix deformed plastically. After a few moment, the fibers show a brittle failure due to low ductility. By comparing the all the graphs, the elastic range of graph for kenaf PP composite is longer than hybrid bagasse/kenaf PP composite. This is the most important aspect because it measure how much the stress can be apply to the material before it starts to deform. Overall, the hybrid bagasse/kenaf PP shows better properties than kenaf PP composite.

Based on the tensile test, it can be conclude that the hybrid bagasse/kenaf PP composite is higher in tensile strength than kenaf PP composite. The composite strength depends on the fiber composition, fiber strength and interfacial strength between the fiber and the matrix. Moreover, tensile properties of composite is about interfacial bonding between fiber and matrix.

CHAPTER 5

SUMMARY

This research presents a literature review to examine the influence of volume proportion between reinforcement and matrix polymer on hybrid composites. In this study, the varied percentages of composition fraction between reinforcement and matrix polymer were established as manipulated variables.

An initial investigation has been conducted based on previous research on the effect of hybridization between two types of fiber and their relative characteristics. The different types of parameters, such as an ideal fiber length and temperature for the manufacture of composites, have been chosen, and the total weight of all the test samples, composites, has been set at 30g. The testing of hybrid composites will be carried out using appropriate standards for testing methods according to American Standard Testing Method (ASTM), which include ASTM D792 (density test), ASTM D3039 (tensile test) and ASTM D2240 (hardness test).

The next experimental effort will comprise the manufacture of test samples of hybrid composites and the mechanical testing of the test samples in accordance with the standards that have been established.

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