INVESTIGATION ON FLEXURAL AND MORPHOLOGICAL CHARACTERISTICS OF NOVEL HYBRID OIL PALM EMPTY FRUIT BUNCH/ KENAF REINFORCED HIGH DENSITY POLYETHYLENE COMPOSITE FOR AUTOMOTIVE APPLICATION

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This report is submitted
in fulfillment of the requirement for the degree of
Bachelor of Mechanical Engineering (Automotive)

Faculty of Mechanical Engineering

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DECLARATION

I declare that this project report entitled "Investigation On Flexural And Morphological Characteristics Of Novel Hybrid Oil Palm Empty Fruit Bunch/ Kenaf Reinforced High Density Polyethylene Composite For Automotive Application" is the result of my own work except as cited in the references

Signature : .....

Name : .....

Date : .....

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 (Automotive).

Signature :. .....

Name of Supervisor : .....

Date : .....

DEDICATION

To my beloved mother and father

ABSTRACT

Natural fiber composites (NFC) are aggressively being adapted into production of components and products, especially in the automotive industry, to achieve better vehicle end-of-life performance as well as to reduce the dependency of non-renewable materials. In addition, extensive research have been conducted to improve the mechanical properties of both natural fibers and polymer matrix for better bonding and load carrying characteristic of the final composites. One of the efforts is through hybridization method, whereby two different types of fiber are combined within a single matrix. The hybridization offer desirable advantage of gaining a balance between cost and performance between the combined fibers. In this research, a novel hybrid oil palm empty fruit bunch (OPEFB) and kenaf fibers was formulated, using thermoplastic high density polyethylene (HDPE) as the matrix. The aim was to investigate the flexural performance of hybrid OPEFB/ kenaf reinforced HDPE composites at varying OPEFB to kenaf fiber ratio. All samples were prepared at fix fiber to matrix ratio of 40:60 wt%. Meanwhile, the OPEFB to kenaf fiber loadings ratio were varied 0:100, 25:75, 50:50, 75:25 and 100:0 wt%. The fibers were first crushed and sieved to size between 1 to 5 mm. Hybrid fibers were later mixed with HDPE using compounding and formed into thin plates using hot compression moulding process. Finally, the sample is cut to size and characterize in accordance to the ASTM D790 for the flexural test. Findings of the research revealed that the highest flexural modulus was achieved at hybrid OPEFB:kenaf formulation of 25:75 wt% (from the total 40 wt% total fiber loadings), an increase of 6.5% compared to flexural modulus using 100% OPEFB composites. Furthermore, all hybrid formulation showed lower tensile strength compared to 100% OPEFB/HDPE composites and 100% kenaf/HDPE composites. The lowest flexural strength property was found at hybrid OPEFB:kenaf formulation of 50:50 wt%, which represent a reduction up to 16.1% from the tensile strength recorded for 100% OPEFB composites. The reason is maybe due to poor interfacial bonding between the fiber and the matrix, as observed in the fiber pull-out failure images on the fractured samples. The overall findings suggested that the hybrid OPEFB/ kenaf reinforced HDPE composites was able to slightly improve the flexural modulus of the 100% OPEFB reinforced HDPE composites, despite showing lower performance in term of flexural strength as compared to 100% OPEFB reinforced HDPE composites.

ABSTRAK

Serat semula jadi sedang disesuaikan ke dalam pengeluaran komponen dan produk, terutamanya dalam industri automotif, untuk mencapai kenderaan akhir-kehidupan serta untuk mengurangkan pergantungan bahan yang tidak boleh diperbaharui. Di samping itu, banyak penyelidikan telah dijalankan untuk meningkatkan sifat-sifat mekanikal serat semula jadi dan matriks polimer untuk ikatan yang lebih baik. Salah satu usaha ialah melalui kaedah penghibridan, di mana dua jenis serat semula jadi digabungkan bersama-sama di dalam matriks tunggal. Penghibridan ini menawarkan keseimbangan antara kos dan prestasi antara gentian. Dalam kajian ini, 'Oil Palm Empty Fruit Bunch(OPEFB) dan gentian kenaf telah dirangka, menggunakan 'High Density Polyethelyne' (HDPE). Tujuannya adalah untuk mengkaji prestasi lenturan OPEFB/kenaf diperkukuh komposit HDPE dengan perbezaan nisbah OPEFB kepada nisbah gentian kenaf. Semua sampel telah disediakan pada serat:matriks dalam nisbah 40:60wt%. Sementara itu, OPEFB kepada nisbah beban gentian kenaf telah diubah 0:100, 25:75, 50:50, 75:25 dan 100:0wt%. Gentian dihancurkan dan disaring saiz antara 1-5mm kemudiannya dicampur dengan HDPE menggunakan pengkompaunan dan dibentuk plat nipis menggunakan proses pengacuan mampatan panas. Akhir sekali, sampel dipotong kepada saiz mengikut ASTM D790. Ujian lenturan mendedahkan bahawa modulus lenturan tertinggi dicapai pada OPEFB:kenaf pada 25:75 wt% (daripada jumlah 40% berat jumlah beban serat), peningkatan sebanyak 6.5% berbanding dengan modulus lenturan menggunakan 100% komposit OPEFB. Tambahan pula, semua rumusan hibrid menunjukkan kekuatan tegangan yang lebih rendah berbanding dengan 100% komposit OPEFB / HDPE dan 100% kenaf / HDPE komposit Kekuatan lenturan terendah ditemui di OPEFB:kenaf 50:50 wt%, di mana pengurangan sehingga 16.1% daripada kekuatan tegangan yang dicatatkan bagi 100% komposit OPEFB. Sebabny mungkin kerana ikatan antara muka yang lemah antara gentian dan matriks, seperti yang berlaku di tarik-keluar gentian imej kegagalan pada sampel patah. Hasil dapatan menunjukkan bahawa hibrid OPEFB / kenaf diperkukuh komposit HDPE dapat meningkatkan modulus lenturan daripada 100% OPEFB diperkukuh komposit HDPE, walaupun menunjukkan prestasi yang lebih rendah dari segi kekuatan lenturan berbanding 100% OPEFB diperkukuh komposit HDPE.

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LIST OF ABBREVIATIONS

CMCs	-	Ceramic Matrix Composites
MMCs	-	Metal Matrix Composites
PMCs	-	Polymer Matrix Composites
NFC	-	Natural Fiber Composites
CO_2	-	Carbon Dioxide
HDPE	-	High Density Polyethylene
OPEFB	-	Oil Palm Empty Fruit Bunch
L_C	-	Critical Length
NaOH	-	Sodium Hydroxide
SEM	-	Scanning Electron Microscopy
SiC	-	Silicon Carbide
Al_2O_3	-	Aluminum Oxide
SiN	-	Silicon Nitride
RPM	-	Rotation per Minute
PP	-	Polypropylene
MAPE	-	Maleic Anhydride–G–Polyethylene
OPPF	-	Oil Palm Press Fiber
NMT	-	Natural Fiber Mat Thermoplastic

LIST OF SYMBOLS

E - Flexural Modulus/ Young's Modulus

Ơ - Stress

ε - Strain

CHAPTER 1

INTRODUCTION

1.1 Background

In the material world, the current trend is using of bio-fibers as fillers and/or reinforcers in the plastics composites. The flexibility of natural fibers during processing, high specific stiffness, and low cost makes them an attractive alternative for the manufacturers. There is an increasing demand on plastics as an important raw material which is up to 80% made up of thermoplastics. Bio-composites are gaining popularity for structural applications (Faruk et al., 2012).

Bio-composite materials are advanced and flexible engineering materials. Combination of a plastic polymeric matrix with reinforcing natural fibers produces composites with corresponding properties of each material. Natural fiber reinforced composite refers to the natural fibers in any polymeric matrix which can either be thermoset or thermoplastic; natural or synthetic. Furthermore, bio-composites are environmentally friendly. With different combination of natural fibers and plastic polymer, different strength and toughness are achievable (Saba et al., 2014).

Oil palm empty fruit bunch (OPEFB) fibers are classified as natural fibers which are environmental friendly. These fibers are renewable, abundance, non-toxic, and low cost making them popular. However, the disadvantages of OPEFB fibers are the moisture absorption properties, and incompatibility with some polymer matrix. Polyethylene (PE) is the most frequently used thermoplastic in the production of natural fiber plastic composites due to its general availability, low melting point and low cost (Ewulonu & Igwe, 2012).

Kenaf is an industrial crop in Malaysia. It is one of the popular plants which is harvested for its fibers globally, after cotton. Kenaf has potential in the automotive market as well as the construction industries due its long fibers nature at the outer bark, bast. Kenaf is gaining popularity from researchers and industries for utilization in different polymer composites. In many research, kenaf fibers are reinforced with polymer matrix to form fiber reinforced polymeric composites which further improve the properties of the polymers. The kenaf fibers is comparable to existing materials in terms of mechanical properties, thus them a suitable replacements to glass fibers in polymer composites as reinforcing materials (Saba et al., 2015).

Issues arisen in composites are the thermal instability of natural fibers, the moisture adsorption of natural fibers, fiber matrix adhesion surface, bio degradation and photodegradation of fibers, processing for thermoplastic/thermoset composite and the modification of natural fibers (Saheb & Jog, 1999).

1.2 Problem Statement

As the automotive industries strive for improve in environment sustainability, remarkable achievements in green technology via the development of natural fiber composites (NFC) or bio-composites are achieved. Development of NFC are increasing, therefore making it a suitable replacement for synthetic composites which are non-biodegradable and required the use of non-renewable and non-recyclable resources. Furthermore, the final mechanical properties of the composites are influenced by many factors such as the fiber type, fiber size, fiber orientation, matrix type, fiber and matrix modification process and the composites processing methods. This allows a wide combination of composites architecture, which result in different mechanical properties for different needs. In this research, a novel hybrid NFC using the combination of oil palm empty fruit bunch (OPEFB) fiber and kenaf fiber are developed. Recyclable thermoplastic

high density polyethylene (HDPE) is also used as the matrix for the hybrid composites. OPEFB/kenaf reinforced HDPE is a new and unknown composite. Up to date, there is very limited research on the characterization of hybrid OPEFB with other type of natural fibers, especially kenaf fiber. More limited source of information is also presence with regards to the performance of OPEFB composites produced using high density polyethylene (HDPE) thermoplastic matrix. This research was focused to investigate the flexural and morphological characteristics of hybrid OPEFB/kenaf reinforced HDPE composites for automotive application. Varying OPEFB to kenaf fiber loadings were used to prepare the hybrid samples. Hybrid fibers in short fiber form were selected for the composites construction while sample preparation involved compounding and compression moulding processes. The samples were later cut to size and subjected to flexural test based on ASTM D790 to obtain its flexural mechanical properties. In addition, morphology examination on the fracture samples using optical microscopy technique was also employed to determine the failure mechanism for the hybrid OPEFB/kenaf reinforced HDPE composites.

1.3 Objectives

The objectives of this project are as follow:

i. To identify the flexural properties of the hybrid OPEFB/kenaf reinforced HDPE with varying weight percentage of OPEFB and kenaf.

ii. To study the morphological characteristic of the hybrid OPEFB/kenaf reinforced HDPE with varying weight percentage of OPEFB and kenaf.

1.4 Scope of Project

The scopes of this project are:

i. Formulation of the bio-composite samples are fix at 40wt.% natural fibers and 60 wt.% HDPE.

ii. To conduct flexural tests for hybrid OPEFB/kenaf reinforced HDPE samples at varying weight percentage of OPEFB and kenaf fibers.

iii. To perform morphological examination on the fractured samples using optical microscope

iv. Report Writing.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Composites are defined as a combination of two different types of materials, which are the reinforcing phase and the matrix phase. Reinforcing and matrix phases can be ceramic, metal or polymers in nature. The matrix acts as a protection layer for the fibers before, during and after the processing. Furthermore, the matrix acts as a load distributor during loading between the fibers. With the flexibility of the combination of reinforcing phase and matrix phase, it is possible to create new composites with different properties. Composites can be design to suit different needs such as for thermal, electrical, structural and environmental applications (Kumar et al., 2014).

2.2 Types Of Composites

Composites are classified to into 3 different groups as shown below:

i. Ceramic Matrix Composites (CMC) : CMCs are composed of a ceramic matrix (i.e., SiC, Al_2O_3, SiN) and embedded fibers of other ceramic materials.

ii. Metal–matrix composites (MMC) : MMCs are used widely in the industry.

iii. Polymer Matrix Composites (PMC) : PMCs are thermoset or thermoplastic matrix bonded with reinforcement phases such as glass, carbon, Kevlar fibers and metal (Haghshenas, 2015).

2.2.1 Ceramic Matrix Composites (CMCs)

Ceramics are materials which demonstrates good mechanical properties in terms of its hardness/stiffness, melting point, resistivity to corrosion and low density). However, ceramics are brittle and perform poorly under loading. With reinforcement of ceramics with other material, its properties can be enhanced. This leads to a new composite material known as ceramic matrix composites(CMCs). CMCs are ceramic materials consisting of ceramic fibers either oriented unidirectional or arranged in nD architectures (n = 2, 3, 4…) and are combined in a ceramic matrix of different or same chemical composition (Zamawiany, 2005).

2.2.2 Metal–matrix composites (MMCs)

Generally, metallic materials are ductile, metallic bond, crystalline structure, good conductivity and chemically unstable. With the reinforcement of lighter metals, it is possible to create composites which are light weight making it suitable for weight reduction applications. Metal matrix composites are classified by its reinforcement and type of components in particle/layer/fiber and penetration composite materials. Furthermore, fiber materials can be classified into continuous fiber which are, multifilament or monofilament composite materials and short fibers or whisker composite. Currently, MMCs are used in aluminum crankcase with strengthened cylinder surface, fiber-reinforced engine piston, and particle strengthened disc brake (Kainer, 2006).

2.2.3 Polymer Matrix Composites (PMCs)

PMCs consist of a variety of short or continuous fibers bind using an organic polymer matrix, whereby the reinforcing phase provide stiffness and strength. The reinforcing phase functions to support the load whereas the matrix is to bond the fibers together and to transfer the loads evenly to the fibers. PMCs are favorable due to their low costing and simple

manufacturing. The use of non-reinforced polymers is limited by its low mechanical properties. Besides that, polymers material possesses relatively low strength and low impact resistance. The desired mechanical properties is generally optimized through trial and error testing (Awalellu, 2016).

The most important manufacturing methods for polymer-based composites are gravity casting, under pressure casting, contact molding, simultaneous spray forming, bag molding, vacuum injection, cold pressing and hot pressing (Florea & Carcea, 2012).

2.3 Matrix

Matrix of composites mainly polymers can be classified into 2 types of materials which are thermosets and thermoplastics (Mohammed et al., 2015). Both are long chain-like molecules but differs in their bonding. In thermoplastics, long chain molecules are held by weak Van Der Waal forces as for thermosets, the long chain molecules held by strong bonds (Haider et al., 2012).

Matrix properties determines the overall resistance of the PMCs. The resistance includes the water absorption ability, chemical reaction, impact, delamination and high temperature creep. Therefore, matrix in the PMCs are the are more prone compare to the reinforcing phase as matrix provides a barrier against adverse environments, protects the surface of the fibers from mechanical abrasion and it transfers load to fibers (Pickering et al., 2016).

2.3.1 Thermosets

Thermosets consist of several types mainly, polyesters, epoxies, vinyl esters, bismaleimides, and polyamides. It is widely used in the formation of fiber-reinforced plastics. However, epoxies are more favorable in the advanced composites resin category. Thermoset resins undergo chemical treatment which crosslink the polymer chains, which

results in connecting all the matrix together to form a 3D network. This chemical treatment process is known as curing and is irreversible. Thermosets, due of their 3D crosslinked structure, thermosets possess high dimensional stability, high temperature resistance, and good resistance to solvents (U.S. Congress, 1988).

2.3.2 Thermoplastics

Thermoplastic consist of materials such as polyesters, polyphenylene sulfide, liquid crystal polymers and many more. Thermoplastic have long and discrete molecule which melts to forms a viscous liquid. After forming, thermoplastics are then cooled to a semi crystalline, amorphous, or crystalline solid. The crystallinity of the thermoplastics affects it matrix properties. The processing of thermoplastics is reversible through a reheating process and thermoplastics, in general are inferior to thermosets at chemical stability and high temperature strength. Thermoplastic however are more resistant compared to thermosets in terms of cracking and impact. Thermoplastics are more favorable from a manufacturing point of view due to its ability to heat and cool quicker compare to curing a material for manufacturing (U.S. Congress, 1988).

2.4 Reinforcing Fibers

2.4.1 Natural Fibers

Natural fibers are defined as fibers that are not manmade or synthetic. Natural Fibers are sources from animals or plants. The use of natural fiber from renewable and non-renewable is becoming more favorable (Mohammed et al., 2015).

Natural fibers which are from plants or animals are used as reinforcement in polymer composites. Usage of natural fibers in products will lead to an eco-friendly environment, as these fibers are biodegradable as well as renewable. This demonstrates that natural fibers are easily produced and won't pollute the environment by releasing greenhouse gases

(Jayachandran et al., 2016). Natural fibers are CO_2 neutral and the amount of energy needed for production is lesser compare to that of glass fibers (Garkhail et al., 1999).

The plants, which produce cellulose fibers classified into categories, mainly consisting of bast fibers (flax, ramie, kenaf, jute, and hemp), seed fibers(kapok, cotton and coir), leaf fibers (sisal, abaca and pineapple), grass and reed fibers (rice, wheat and corn), and core fibers (hemp, jute and kenaf)as well as all other kinds (roots and woods) (Faruk et al., 2012).

The common natural fibers and its respective production is shown in Table 2-1.

Table 2-1 : Natural Fibers in the World and their World Production

Fiber Source	World production (10^3ton)
Bamboo	30,000
Sugar cane bagasse	75,000
Jute	2,300
Kenaf	970
Flax	830
Grass	700
Sisal	375
Hemp	214
Coir	100
Ramie	100
Abaca	70

2.4.1.1 Kenaf

Natural fiber, kenaf is inexpensive and widely available. Kenaf fiber is obtained from the stem of plant genus Hibiscus, which is classified under the family of Malvaceae and the species of Hibiscus cannabinus. This plant is common in the subtropical and tropical Africa and Asia (Salleh et al., 2012).

Kenaf, a warm season fibrous plant growing in tropical areas. It is related with the cotton, okra, and hibiscus due to its systematic make up. Kenaf consist of an inner core fiber with a 60-75% which result in a low quality pulp, and an outer bast fiber 25–40%, which results in a high quality pulp, in the stem. The kenaf's core with a larger cross sectional area and a higher dry weight when compared to the bast. Thus, this indicates the core portion produces more fiber (Abdul Khalil et al., 2010).

Based on Yusoff & Mohamad (2015) kenaf improves the tensile and flexural strength of polyprolylene composite through special treatment and composition which gives better bonding between kenaf and polymer matrix. Reinforcement using epoxy with the treated kenaf has increased flexural strength due to the chemical treatment, NaOH on the interface of the fibers and the porosity of the composites. This has prevented the bond from breaking detachments or pulling out of the kenaf fibers.

2.4.1.2 Oil Palm Empty Fruit Bunch (OPEFB)

OPEFB natural fibers are available widely, renewable, nontoxic, and low in cost. However, OPEFB main limitation for application as reinforcing polymers is the processing temperature. High temperature causes fiber degradation and the possibility of volatile emissions would affect the composite. Therefore, precaution such as limiting the processing temperature of natural fiber components to about 200 $°C$ are taken into account (Ewulonu & Igwe, 2012).

2.4.2 Synthetic Fibers

Synthetic fibers, are defined by the International Organization for Standardization (ISO) as fibers manufactured from polymers built up from chemical elements or compounds. Common synthetic fibers which are widely used are polyester, acrylic, nylon and polyolefin (East, 2005).

2.4.3 Fiber Length

Fiber length is an crucial factor which affects the mechanical properties of the composite. Short fiber composite subjected to tensile load is transferred into a fiber from the matrix through shear at the fiber/matrix interface. At the fibers end, the tensile stress is zero and increase along the fiber length. Thus, the fibers needs to have a length of greater than critical length (L_C) in order for the fiber to be able to be broken during tensile loading of a composite. At the critical length, just before fracture, the fiber would theoretically only have been carrying half of the load compared to a continuous fiber at the same composite strain. Ideally, fiber length should be greater than the critical fiber length to allow efficient reinforcement to the composite (Pickering et al., 2016).

2.5 Natural Fiber Composites (NFCs)

Composites are named as bio composite materials when one of its phase either matrix polymer or reinforcement/filler fibers is sourced from a natural source (Hassan et al., 2010). With emphasis on environment as well as well managed allocation of natural resources, NFCs have become valuable in various industries. NFCs are used in various industries which includes the packaging, furniture, disposable accessories, automotive industries, building, and insulation materials. Natural fibers in NFCs act as fillers or reinforcing materials in the polymer matrices. With proper allocation of natural fibers, it reduces environmental pollution. NFCs are used in producing recyclable and bio-degradable products and act as an

alternative to the traditional glass/carbon polymer composites which maybe not be safe to the environment as NFCs. Besides that, natural fibers have advantages over glasses due to its availability, carbon dioxide(CO_2) sequestration enhanced energy recovery, reduced tool wear during processing, and reduction in irritation. However, natural fibers suffer in certain properties such as durability, water resistance, and poor bonding with the matrix phase. The weak bond leads to undesired characteristics which affects their performance severely. Thus, various solutions are used to further improve their compatibility and bonding via chemical, mechanical, or physical modifications with the usage of surface treatments and coupling agents (Al-Oqla et al., 2015).

Furthermore, use of natural fibers as reinforcement for low melting point thermoplastic matrix are prioritize. Injection molding is a process to form molded parts using thermoplastic. Short natural fibers reinforced composites is favorable due to its ability to be shaped into complex shapes using standard thermoplastic injection molding equipment (Farsi, 2012).

2.6 Previous Findings

Bio composites are widely studied and past researches have proved that different mechanical properties are achievable via different method. Research by Kumar and his team on Kenaf + Unsaturated Isopthalic Polyester Resin + 2% Catalyst-Methyl Ethyl Ketone Peroxide shows that flexural strength increases compared to neat resin and surface treatment significantly effect flexural strength. From Abdul Aziz, research on Kenaf + HDPE + 0.06 M NaoH + 0.06 M $MgCl_2$, treatment with chemical enhances the flexural properties.

Wambua and his team proved that flexural strength increases with wt% of fibers between 30wt% to 50 wt%. As for Obasi and his team, his research on Oil palm press fibers (OPPF) + epoxy resin CY-230 + hardener HY-951+ NaOH shows that flexural strength

increased with increasing fiber wt% up to 20%. Flexural modulus increases linearly with fiber content up to 30wt%. Alkali treatment OPPF/epoxy have higher flexural properties than untreated.

Table 2-2 : Past Result from Previous Research

No	Material	Test Method	Summary of the results	Reference (Author)
1	Kenaf + Unsaturated Isopthalic Polyester Resin + 2% Catalyst-Methyl Ethyl Ketone Peroxide	ASTM D790 ASTM D 638	*flexural strength increase compared to neat resin *Surface treatment has significant effect on flexural strength	(Kumar et al., 2014)
2	Kenaf + HDPE + 0.06 M NaoH + 0.06 M $MgCl_2$	ASTM D7264-07	*10wt% bast fiber treated with 0.06 M $MgCl_2$ has the highest flexural properties *treatment with 0.06 M NaoH or 0.06 M $MgCl_2$ enhanced flexural properties	(Abdul Aziz et al., 2016)
3	Kenaf + Silica (hydrophobic silica) + Epoxamite 100 with 103 SLOW Hardener	ASTM D790	*Silica nanoparticles with epoxy decreases flexural strength *flexural strength of 2 vol% hydrophobic silica nanoparticle's loading same as without any silica nanoparticle *2 vol% silica nanoparticles inducing the highest flexural modulus	(Bajuri et al., 2016)
4	Kenaf + Polypropylene (PP)	ASTM D790-71	*Flexural strength increases with increasing wt% of fiber, 30wt% to 50wt%	(Wambua et al., 2003)
5	Kenaf + Polypropylene	ASTM D790	*Flexural strength not reported	(Rajappan et al., 2015)
6	OPEFB + Epoxy	ASTM D790	* Flexural properties decrease as the fiber content is increased	(M. Yusoff et al., 2010)

7	Oil palm press fibers (OPPF) + epoxy resin CY-230 + hardener HY-951+ NaOH	ASTM D790	*flexural strength of OPPF/epoxy composite increased with increasing fiber content up to 20 wt. % * Flexural modulus on the other hand increased linearly with increasing fiber content up to 30 wt. % *Alkali treated OPPF/epoxy have higher flexural properties than untreated	(Obasi et al., 2014)

Table 2-3 : Findings on Applications of Natural Fibers in Automotive Industry

No	Title	Summary of the Findings	Reference (Author)
1	The Cost of Automotive Polymer Composites: A Review and Assessment of DOE's Lightweight Material Composites Research	Fiber reinforced thermoplastics for example, carbon fiber reinforced thermosets have twice the weight reduction of a glass fiber-reinforced thermoset. Fiber-reinforced thermoplastics are recyclable, long shelf life, and suitable in high volume processing making it relatively cheap for fabrication	(Das, 2001)
2	Sustainable Bio-Composites From Renewable Resources: Opportunities And Challenges In The Green Materials World	Bio composites can/may replace petroleum based composite in many applications, offering new agricultural, environmental, manufacturing, and consumer benefits. Several factors which require addressing are surface treatment on the natural fibers to make it more reactive, and development of appropriate processing techniques, depending on the type of fiber form. Bio composites are an alternative to glass reinforced	(Mohantry et al., 2002)

		composites due to bio composites being a renewable resource. Genetic engineering offer opportunities to improved support of global sustainability. Natural fibers are biodegradable Bio composites properties would allow new market development and opportunities for a greener world.	
3	Role of Fiber Adhesion in Natural Fiber Composite Processing for Automotive Applications	Limiting factors in natural fiber composites are moisture uptake and limits in high temperature process	(Holbery et al., 2004)
4	Sheet-Molded Polyolefin Natural Fiber Composites for Automotive Applications	Natural fibers as reinforce in thermoplastic has potential in replacing glass fiber composites in automotive. Film stacking was used as the method of preparation. The results show that hemp based natural fiber mat thermoplastic (NMT) have comparable strength properties when compared to conventional flax based thermoplastics. Increase in strength is observed with increment of compression with a more uniform density profile. The results indicate that hemp-based NMT are suitable as high stiffness is required for automotive application	(Pervaiz & Sain, 2003)
5	Applications of Natural Fibers and Its Composites: An Overview	Natural fiber composites demonstrate good mechanical properties, as well as highly variable in properties. Natural fibers weakness can be solved with development of advance processing of natural fiber and their composites. Natural fibers properties can generate new bio composites which is greener to the environment. Natural fiber as reinforcement focused the attention towards environmental and hybrid composite is a combination of two or more fibers to obtain	(Sanjay et al., 2016)

		good properties from both fibers. Natural fiber polymer composites are alternative to synthetic fiber polymer composites often used in automotive parts such as armrests, parcel shelves, door panels, seat shells, headrests instrument panels and many more. Banana fiber reinforced composites are gaining attention because of its application in under floor protection cars Automotive parts which are billion seat cover, visor in two-wheeler, cover L-side, rear view mirror, name plate and indicator cover, were made using sisal/roselle fibers hybrid composites	
6	Natural Fiber Reinforced Polymer Composites In Industrial Applications Feasibility Of Date Palm Fibers For Sustainable Automotive Industry	Properties such as values of elasticity, tensile strength and elongation to break are crucial in selection of reinforcing fibers. Date palm fibers demonstrates good value of elongation to break compared with others. Generally natural fibers have low mechanical properties, they have desired ones, most notably, the specific modulus of elasticity. Modulus of elasticity with respect to cost influence the selection of natural fibers. The higher this value is, the more desired fiber type in most of applications	(Al-Oqla & Sapuan, 2014)
7	Natural Fiber As A Substitute To Synthetic Fiber In Polymer Composites A Review	Natural fibers composite is a proven alternative to synthetic fibers composite in many automotive industry, transportation, construction and packaging industries. Natural fibers result in lighter composite materials as compared to synthetic fibers. Natural fibers are biodegradable and have lower	(Begum K & Islam MA, 2013)

		emission compared to production of synthetic fiber.	
8	Developement Of Natural Fiber Reinforced Polymer Composites	Natural fiber composites are being used in manufacturing components in the automotive sector. Specification in natural fiber composites include the flexural properties breaking force, impact strength, elongation, suitability for processing, acoustic absorption and crash behavior. Natural fiber are being used in automotive because of its reduction in weight, production energy and cost. The reason natural fibers are being use widely are its cost and weight, with consideration on vehicle component recycling to meet the requirements of the end of life vehicle.	(Aková, 2013)
9	Industrial Fibres: Recent And Current Developments	Cotton-polymer composites were reported to be the first fiber reinforced plastic used by the military. However, suitability of natural fibers as a reinforcement is reduced because of its hydrophilic nature. Insufficient adhesion between untreated fibers with polymer matrix results in poor impact, which can be solved through effective surface treatments. High concentration of fibers defects during intensive harvesting and processing must also be solved to improved product performance	(Suddell, 2008)

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the methodology used in this project to obtain the best sample based on its flexural performance. The flow chart is shown in the Figure 3.1. This project starts by selection of the reinforcing fiber and the polymer matrix. The composite is then made and tested with reference from ASTM D790. Results of the test are then analyse.

3.2 General Experimental Setup

The natural fibers are firstly washed and dried using an oven. This is to ensure minimal or no moisture content in the fiber as it will affect the bonding between the polymer matrix. The selected fiber length for the experiment is set at 1-5mm and it is classified as short fiber. This process is done using a crushing machine which cuts the natural fiber.

Next, the natural fibers and the polymer matrix are mixed together using a mixer machine. The composition of the composite is set at 60wt% HDPE and 40wt% natural fiber. The natural fiber consists of 2 different source which are kenaf and OPEFB. The mixer machine is set at 160 ℃ due to the melting point of the HDPE is at 132℃ (PETRONAS Chemicals Group Berhad, 2015). Any higher in the temperature, it may cause the natural fiber to burnt. The mixed compound is then set to cooled to room temperature before putting it into the crushing machine which crushes the compound into fragments.

The completed samples are then tested according to the ASTM D790 which is a 3 point bending test. Based on ASTM INTERNATIONAL (2016), Molding Materials (Thermoplastics and Thermosets)—The preferred specimen dimensions for molding materials is 12.7 mm (0.5 in.) wide, 3.2 mm (0.125 in.) thick, and 127 mm (5.0 in.) long. They are tested flatwise on the support span, resulting in a support span-to-depth ratio of 16:1 (tolerance ±1).

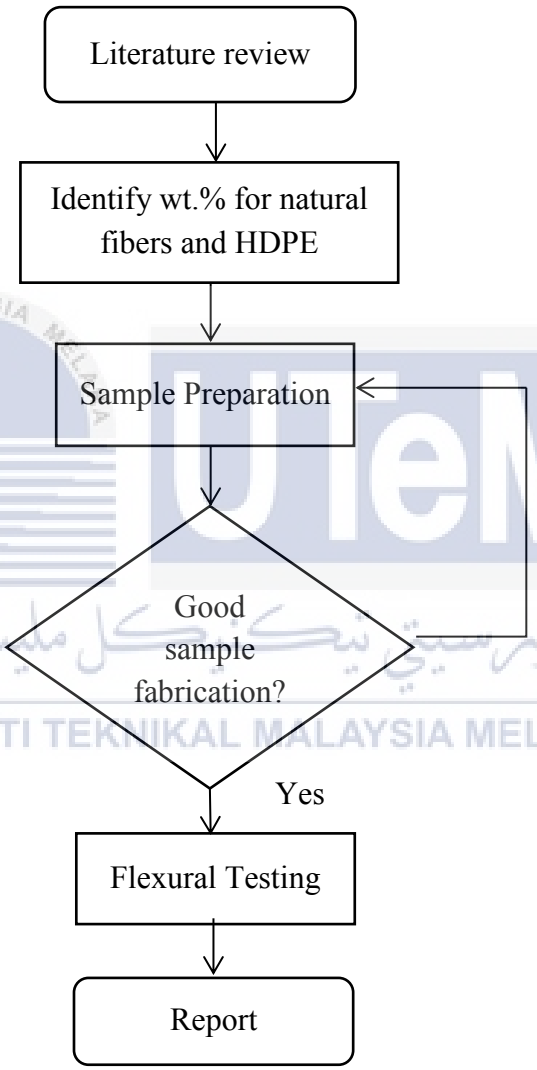

Figure 3-1 : Flow Chart of the Methodology

3.3 Fabrication Process

In this process, natural fiber which are OPEFB and Kenaf act as the reinforcement is collected from local sources. The HDPE (matrix material) from ETILINAS by PETRONAS Chemicals Group Berhad. Natural fibers at 40wt% and HDPE at 60wt% are mixed using an internal mixer at 160 ℃ at 50RPM for 8 minutes. Composites with random fiber orientation are fabricated using hot pressing. The mold (200 x 100 x 3mm) is put under load at 160 ℃ for a set time and cool to room temperature. After cooling, the specimens are cut into dimension as stated in the ASTM D790 for flexural tests. The composition and designation of the composites prepared for this study are listed in Table 3-1.

Table 3-1 : Composition of Composites

Composites	Composition
C1	40wt% OPEFB + 60wt% HDPE
C2	30wt% OPEFB + 10wt% Kenaf + 60wt% HDPE
C3	20wt% OPEFB + 20wt% Kenaf + 60wt% HDPE
C4	10wt% OPEFB + 30wt% Kenaf + 60wt% HDPE
C5	40wt% Kenaf + 60wt% HDPE

Note :

Process consist of 15 minutes of plate pre-heating + 15 minutes of hot press at 90kgf/cm^2 + 5 minutes cooling at 90kgf/cm^2.

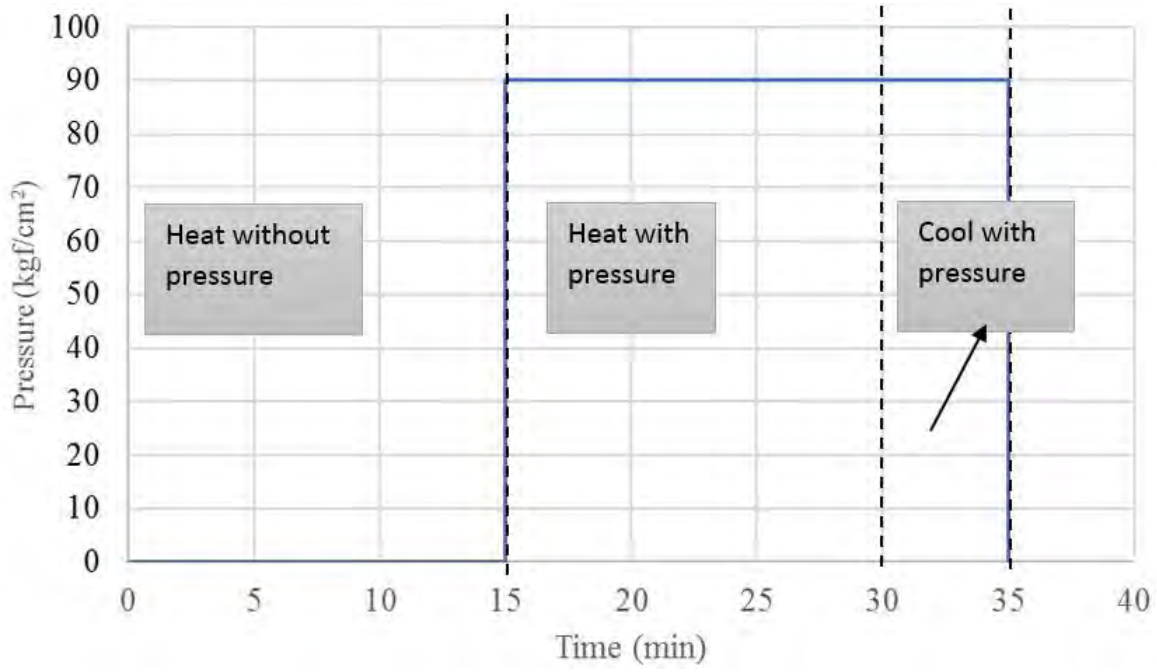

Figure 3-2 : Hot Press Process

3.4 Internal Mixer

The internal mixer is in Faculty of Manufacturing Engineering, UTeM Main Campus is used to mix the natural fibers and the polymer matrix which is the HDPE. This process takes 10 minutes for every cycle. Each cycle output is only at a maximum of 50g. The parameters set for the internal mixer is at 50 RPM at 160 ℃ for 10 minutes. The product obtained from the internal mixer is shown in Figures 3-3

Figure 3-3 : Example of Internal Mixer Product, 40wt% Kenaf + 60wt% HDPE

3.5 Crusher Machine

The product obtained from the internal mixer must be crushed into smaller bits before being hot pressed. The crusher machine is in Faculty of Manufacturing Engineering, UTeM Main Campus. The crusher machine is as shown in Figure 3-4. Safety precaution is to be taken. Googles, safety boots and face mask is to be worn. The crusher is a rotating blade which crushes the product obtained from the internal mixer.

Figure 3-4 : Crusher Machine

Figure 3-5 : Product Obtained After Crushing Process, 40wt% OPEFB + 60wt% HDPE

3.6 Hot Press Machine

After the composite is crushed to smaller bits, it is ready to be hot pressed. The machine used is the hydraulic hot molding machine located in Faculty of Manufacturing Engineering, UTeM Main Campus. The parameters set for this process os as shown in Figure 3-2. The Figure 3-6 shows the hydraulic hot molding machine.

Figure 3-6 : Hydraulic Hot Molding Machine

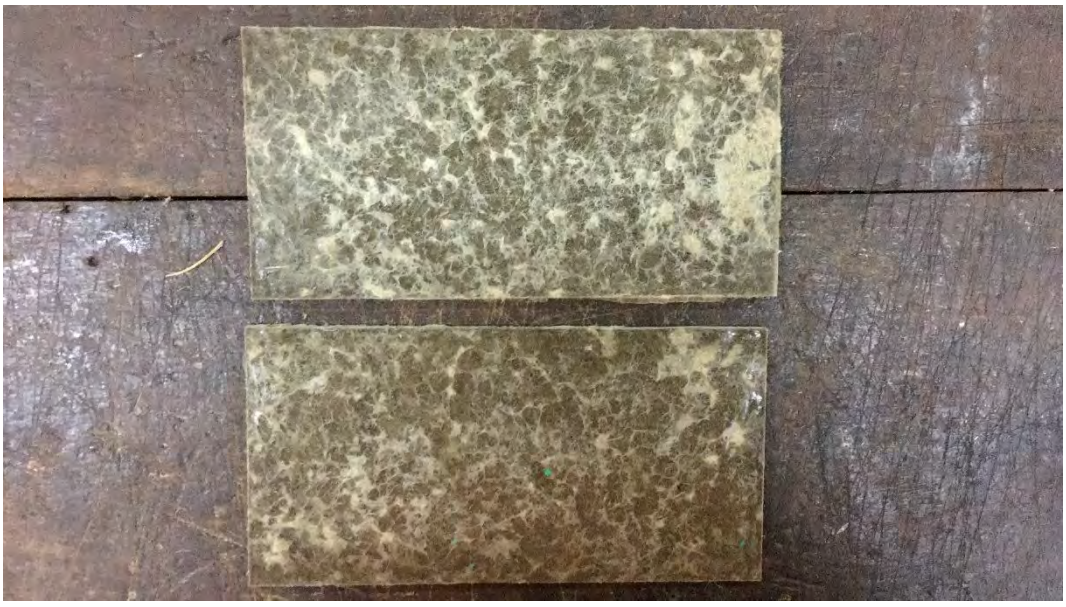

Figure 3-7 : Composite Plate Obtained After Hydraulic Hot Molding with Mold Size 200 mm x 100mm x 3.2mm

3.7 Dimensions of Test Samples

5 bio- composites of different wt% of natural fibers were made. All 5 composites are cut to size as stated by the ASTM D790 standard which is 12.7 mm wide, 3.2 mm thick, and 127 mm long for it to undergo flexural testing. The vertical bench saw as shown in Figure 3-8. An example of cut sample size is shown in the Figure 3-9. When using, the vertical bench saw, protection attire must be worn. The vertical guide on the machine is to be locked in place to ensure a straight line is cut, else the sample may be misaligned and the size will not correspond to the ASTM D790 standard.

Figure 3-8 : Vertical Bench Saw

Figure 3-9 : Dimensions of Cut Sample Size, 127mm x 12.7mm x 3.2mm

3.8 Flexural Testing

The flexural testing is conducted using the Universal Testing Machine located in Faculty of Manufacturing Engineering, UTeM Main Campus. The test is conducted with support span of 51.2mm. The support span is obtained via the 16:1 span to depth ratio. The depth of the sample is at 3.2mm. Furthermore, the cross-head speed is set to 2mm/min. The Figure 3-10 shows the flexural testing in progress.

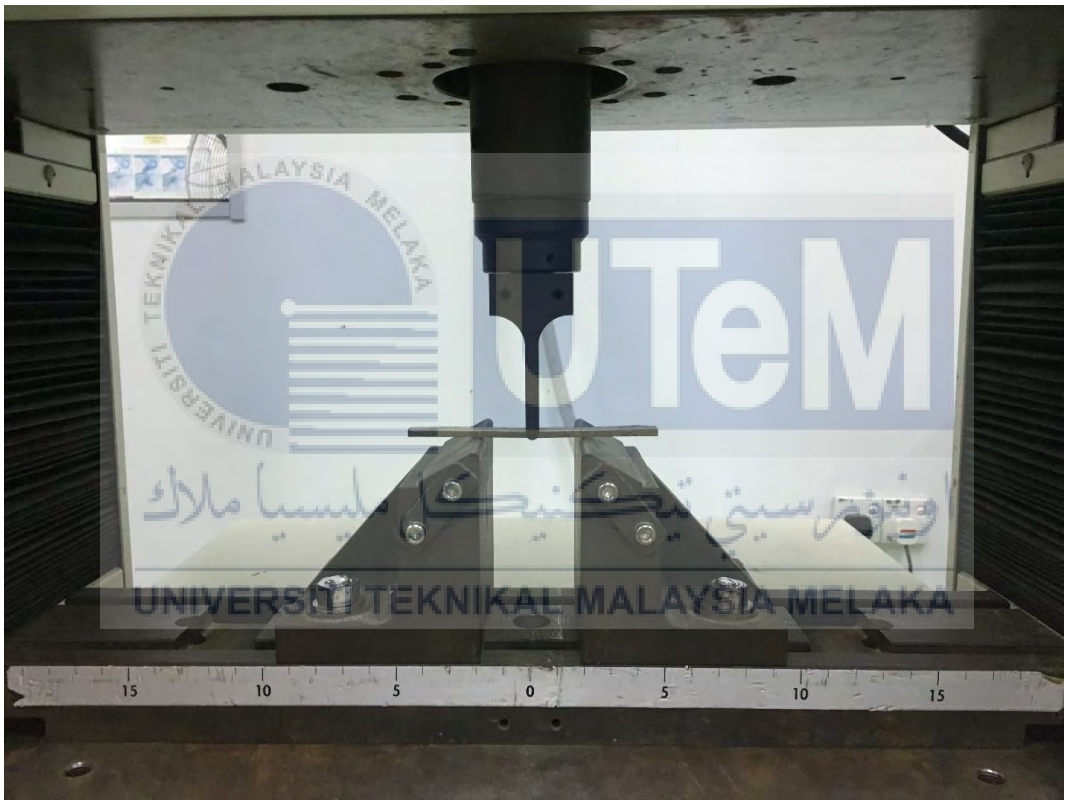

Figure 3-10 : Flexural Testing in Progress

3.8.1 Test Samples After Flexural Testing

Each sample is tested till the stroke strain is at 5% or till breakage occurs as stated in ASTM INTERNATIONAL, (2016). The sample did not undergo breakage but only cracking in the middle of the sample. The fracture failure is identified using a low power microscope located in the Advanced Material Laboratory in Faculty of Mechanical Engineering.

Figure 3-11 : Test Samples with Composition of 40wt% OPEFB + 60wt% HDPE

Figure 3-12 : Test Samples with Composition of 30wt% OPEFB + 10wt% Kenaf + 60wt% HDPE

Figure 3-13 : Test Samples with Composition of 20wt% OPEFB + 20wt% Kenaf + 60wt% HDPE

Figure 3-14: Test Samples with Composition of 10wt% OPEFB + 30wt% Kenaf + 60wt% HDPE

Figure 3-15 : Test Samples with Composition of 40wt% Kenaf + 60wt% HDPE

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Flexural Testing Results

The composites are cut into pieces as stated in ASTM790. Each piece is labeled 1 to 5 Flexural testing is done using the Universal Testing Machine located in Faculty of Manufacturing Engineering , UTeM.

The raw data are extracted from the flexural testing machine and then used to plot a graph of Force vs Deflection. Due to the large volume of data which will cause noise in the graph, MATLAB was used to plot the graph. A smooth line was obtained from the large data. At the elastic region, 2 points in the graph were obtained via MATLAB data tool. Thus, the gradient is calculated. This is used to obtain the flexural elasticity of the composite.

4.1.1 40wt% OPEFB + 60wt% HDPE

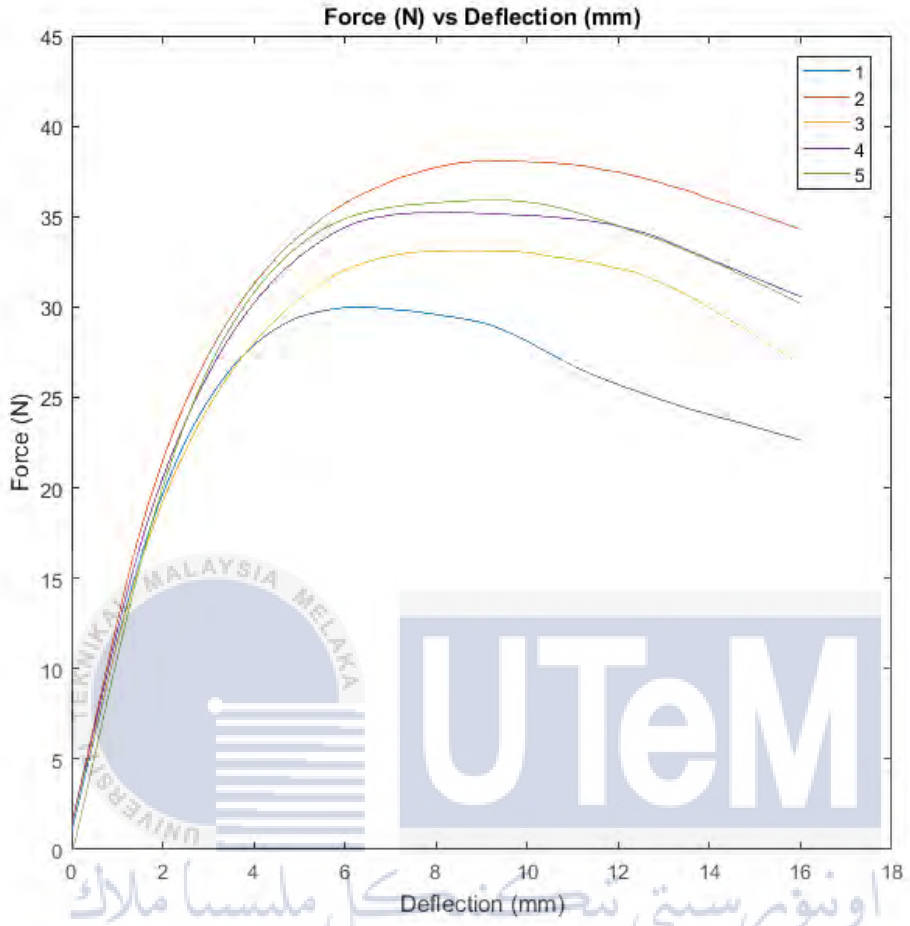

Figure 4-1 : Force vs Deflection Graph for 40wt% OPEFB + 60%wt HDPE

Table 4-1 : Coordinate of 2 Points and Maximum Force for 40wt% OPEFB + 60%wt HDPE

Sample	Point 1		Point 2		Gradient	Maximum Force (N)
	X	Y	X	Y		
1	0.401	5.178	1.031	11.74	10.416	30.0
2	0.395	5.828	1.037	12.903	11.020	38.06
3	0.315	4.544	0.966	11.04	9.978	33.12
4	0.427	5.931	1.026	12.31	10.649	35.22
5	0.356	3.508	1.204	12.62	10.745	35.9

4.1.2 30wt% OPEFB + 10wt% Kenaf + 60wt% HDPE

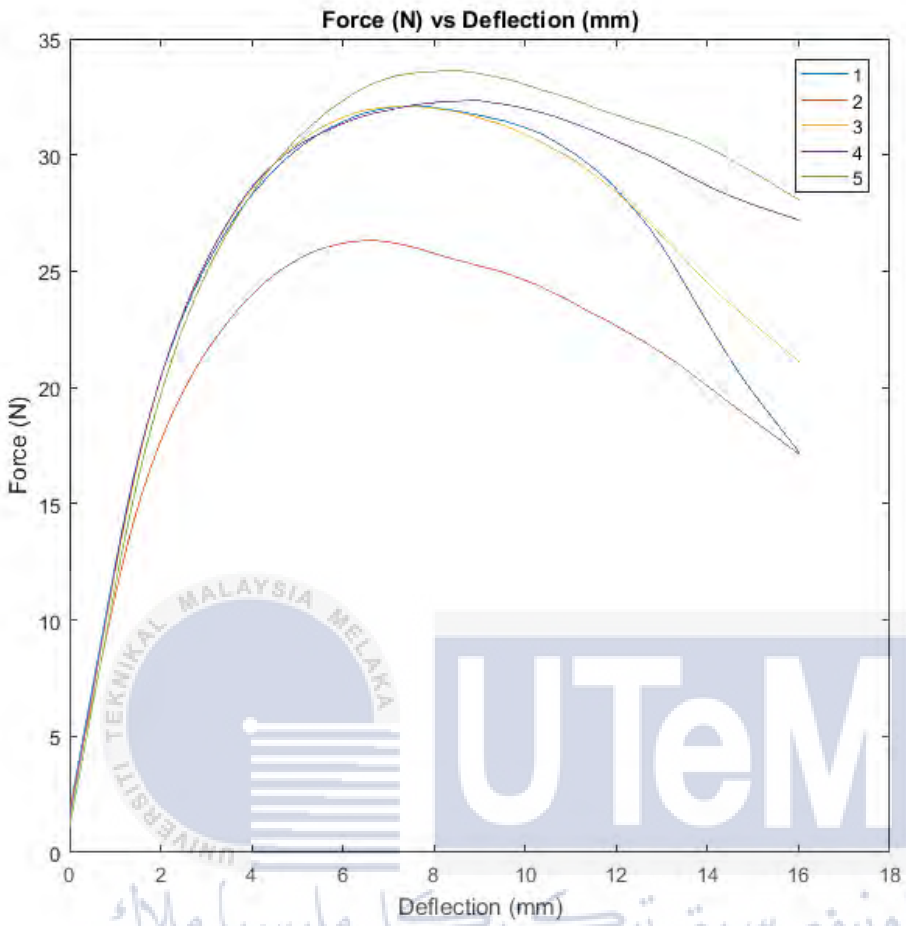

Figure 4-2: Force vs Deflection Graph for 30wt% OPEFB + 10wt% Kenaf + 60%wt HDPE

Table 4-2 : Coordinate of 2 Points and Maximum Force for 30wt% OPEFB + 10wt% Kenaf + 60%wt HDPE

Sample	Point 1		Point 2		Gradient	Maximum Force (N)
	X	Y	X	Y		
1	0.405	6.077	1.041	12.75	10.492	32.09
2	0.432	5.824	1.111	11.97	9.052	26.32
3	0.426	5.916	1.066	12.75	10.678	32.08
4	0.427	6.061	1.054	12.77	10.700	32.34
5	0.446	5.683	1.044	11.87	10.346	33.61

4.1.3 20wt% OPEFB + 20wt% Kenaf + 60wt% HDPE

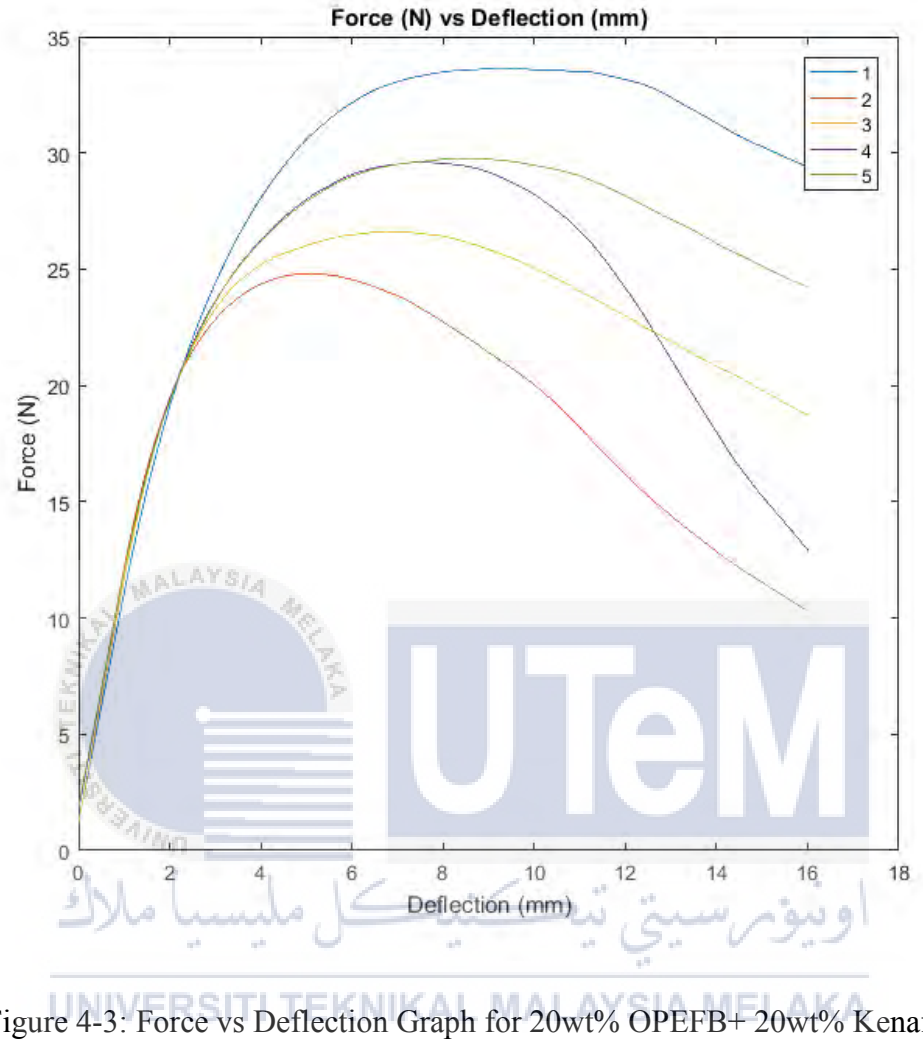

Figure 4-3: Force vs Deflection Graph for 20wt% OPEFB+ 20wt% Kenaf + 60%wt HDPE

Table 4-3 : Coordinate of 2 Points and Maximum Force for 20wt% OPEFB+ 20wt% Kenaf + 60%wt HDPE

Sample	Point 1		Point 2		Gradient	Maximum Force (N)
	X	Y	X	Y		
1	0.615	7.276	1.262	13.55	9.697	33.61
2	0.619	8.146	1.23	14.28	10.039	24.81
3	0.617	7.656	1.255	14.13	10.147	26.62
4	0.618	8.061	1.244	14.27	9.919	29.61
5	0.617	8.084	1.232	14.12	9.815	29.77

4.1.4 10wt% OPEFB + 30wt% Kenaf + 60wt% HDPE

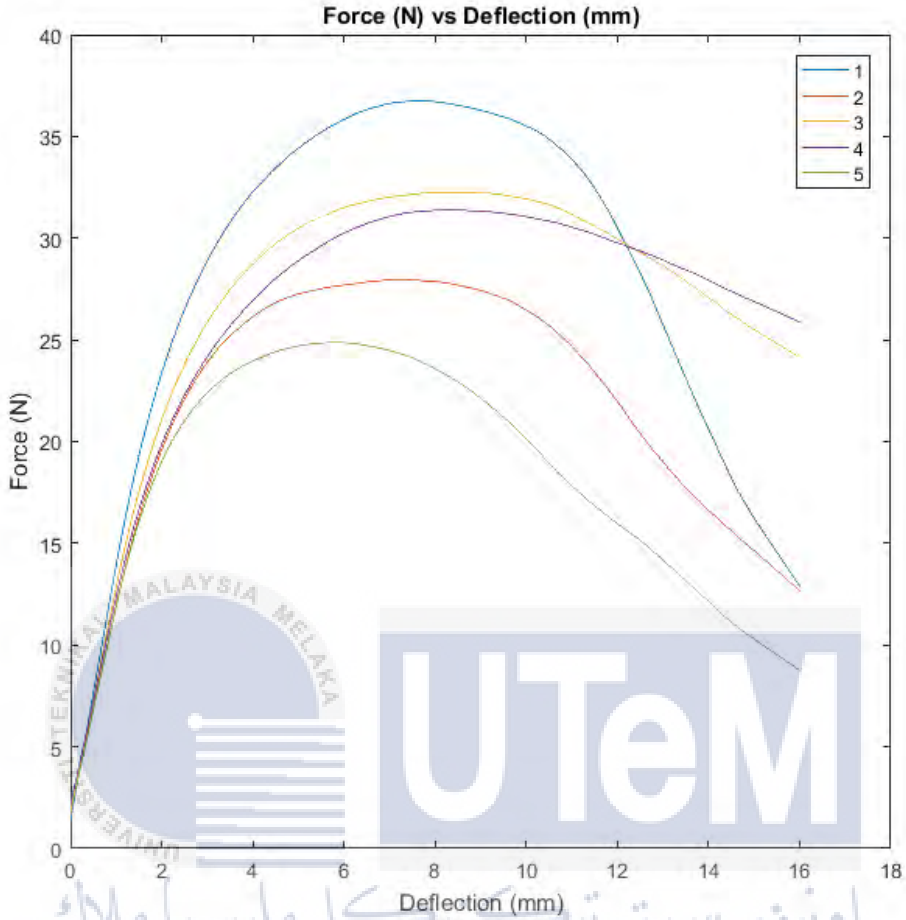

Figure 4-4: Force vs Deflection Graph for 10wt% OPEFB + 30wt% Kenaf + 60%wt HDPE

Table 4-4 : Coordinate of 2 Points and Maximum Force for 10wt% OPEFB + 30wt% Kenaf + 60%wt HDPE

Sample	Point 1		Point 2		Gradient	Maximum Force (N)
	X	Y	X	Y		
1	0.622	9.176	1.207	16.31	12.195	36.75
2	0.625	8.159	1.2	13.83	9.863	27.98
3	0.624	8.642	1.201	14.9	10.846	32.25
4	0.627	8.526	1.117	14.24	11.661	31.38
5	0.623	8.033	1.118	13.81	11.671	24.87

4.1.5 40wt% Kenaf + 60wt% HDPE

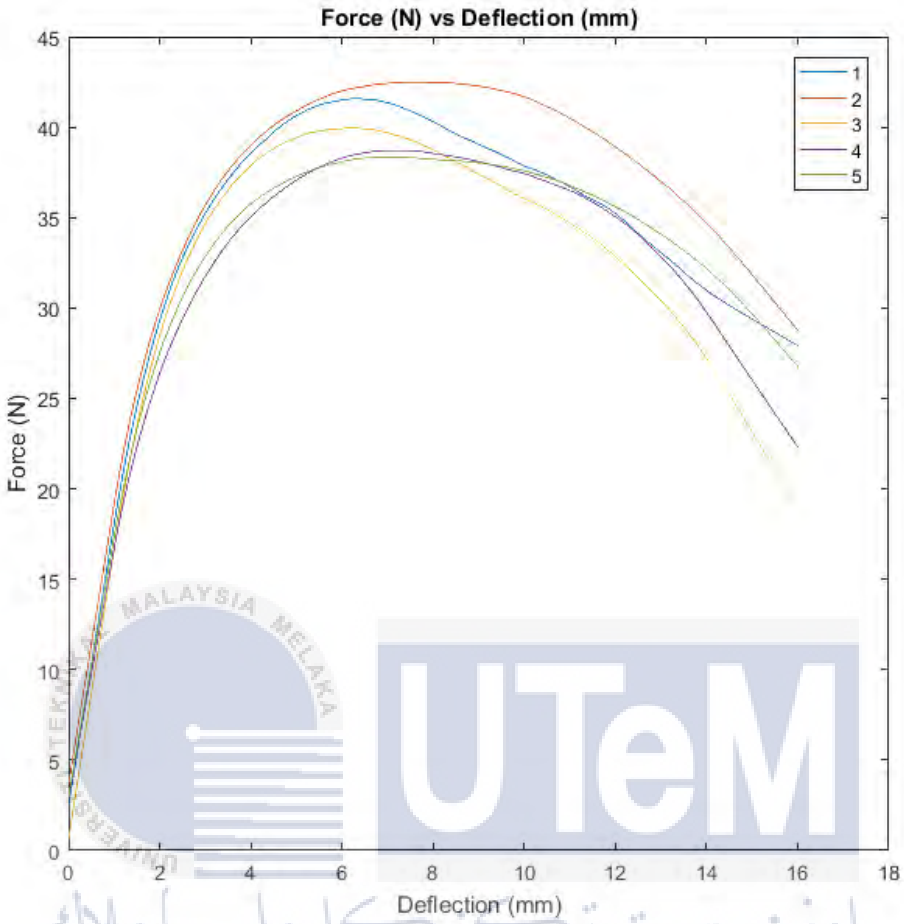

Figure 4-5 : Force vs Deflection Graph for 40wt% Kenaf + 60%wt HDPE

Table 4-5 : Coordinate of 2 Points and Maximum Force for 40wt% Kenaf + 60%wt HDPE

Sample	Point 1		Point 2		Gradient	Maximum Force (N)
	X	Y	X	Y		
1	0.208	5.687	0.933	17.01	15.618	41.57
2	0.203	6.798	0.944	18.27	15.482	42.49
3	0.205	5.952	0.951	16.61	14.287	39.95
4	0.206	5.738	0.931	15.72	13.768	38.72
5	0.206	5.975	0.938	16.44	14.296	38.32

4.2 Analysis

From the gradient obtained from the graph, the flexural elasticity can be calculated using formula which is obtained from ASTM INTERNATIONAL, (2016).

$$E_f = \frac{L^3 m}{4bd^3}$$

where L is the support span, m is the gradient, b is the width and d is the thickness.

Whereas, flexural strength can be calculated using the formula which is obtained from ASTM INTERNATIONAL, (2016).

$$\sigma_f = \frac{3PL}{2bd^2}$$

where P is the force, L is the support span, b is the width and d is the thickness.

4.2.1 40wt% OPEFB + 60wt% HDPE

Table 4-6 : Flexural Modulus and Maximum Strength for 40wt% OPEFB + 60%wt HDPE

Sample	Flexural Modulus, E_f (MPa)	Maximum Strength, σ_f (MPa)
1	839.83	17.72
2	888.56	22.48
3	804.57	19.56
4	858.66	20.80
5	866.39	21.20
Average	851.60	20.35
Std Dev	31.57	1.8

4.2.2 30wt% OPEFB + 10wt% Kenaf + 60wt% HDPE

Table 4-7 : Flexural Modulus and Maximum Strength for 30wt% OPEFB + 10wt% Kenaf + 60%wt HDPE

Sample	Flexural Modulus, E_f (MPa)	Maximum Strength, σ_f (MPa)
1	845.98	18.95
2	729.83	15.54
3	860.98	18.94
4	862.75	19.10
5	834.21	19.85
Average	826.75	18.48
Std Dev	55.42	1.68

4.2.3 20wt% OPEFB + 20wt% Kenaf + 60wt% HDPE

Table 4-8 : Flexural Modulus and Maximum Strength for 20wt% OPEFB+ 20wt% Kenaf + 60%wt HDPE

Sample	Flexural Modulus, E_f (MPa)	Maximum Strength, σ_f (MPa)
1	781.87	19.85
2	809.47	14.65
3	818.18	15.72
4	799.73	17.49
5	791.35	17.58
Average	800.12	17.06
Std Dev	14.35	1.99

4.2.4 10wt% OPEFB + 30wt% Kenaf + 60wt% HDPE

Table 4-9 : Flexural Modulus and Maximum Strength for 10wt% OPEFB + 30wt% Kenaf + 60%wt HDPE

Sample	Flexural Modulus, E_f (MPa)	Maximum Strength, σ_f (MPa)
1	983.27	21.70
2	795.22	16.52
3	874.49	19.05
4	940.24	18.53
5	941.01	14.69
Average	906.85	18.10
Std Dev	73.54	2.65

4.2.5 40wt% Kenaf + 60wt% HDPE

Table 4-10 : Flexural Modulus and Maximum Strength for 40wt% Kenaf + 60%wt HDPE

Sample	Flexural Modulus, E_f (MPa)	Maximum Strength, σ_f (MPa)
1	1259.27	24.55
2	1248.29	25.09
3	1151.95	23.59
4	1110.13	22.87
5	1152.72	22.63
Average	1184.47	23.75
Std Dev	65.69	1.06

4.2.6 Comparison of Flexural Modulus and Maximum Flexural Strength

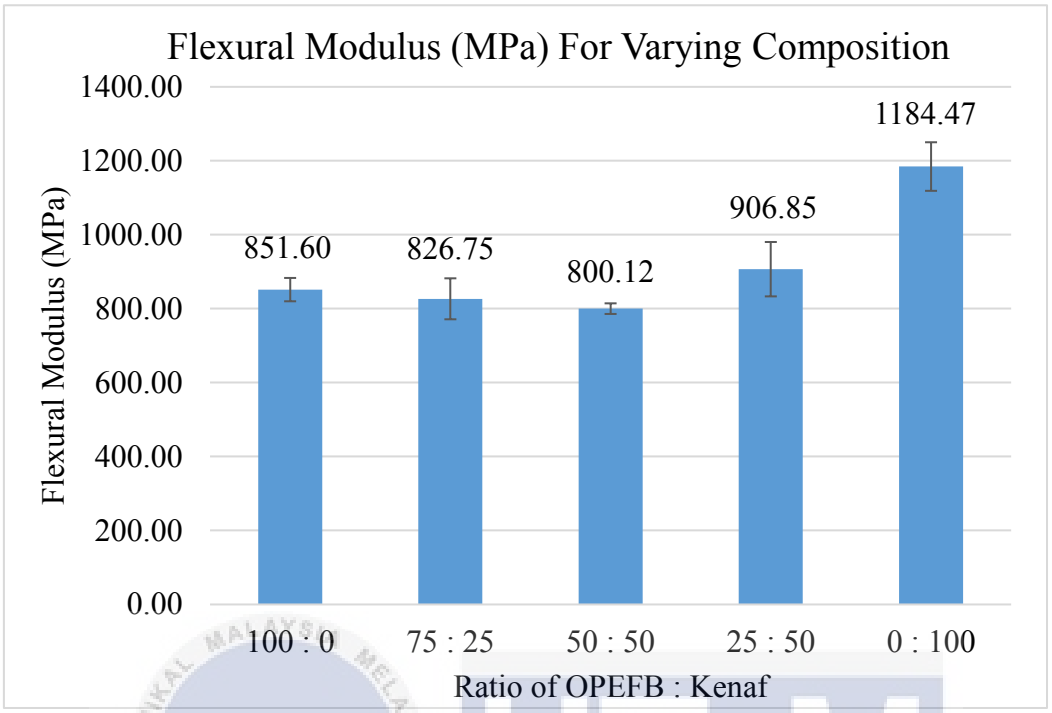

Figure 4-6 : Graph Of Flexural Modulus (MPa) For Varying Composition

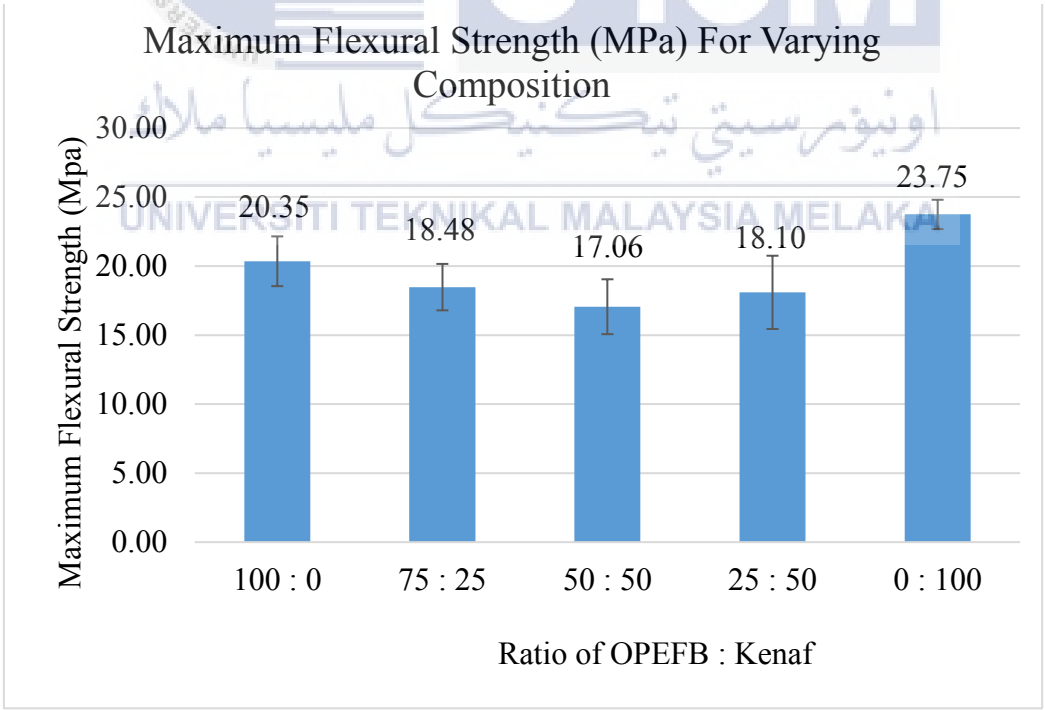

Figure 4-7 : Graph Of Flexural Strength (MPa) For Varying Composition

4.3 Microscope Image on Fracture

4.3.1 40wt% OPEFB + 60wt% HDPE

Figure 4-8 : Microscope Image for 40wt% OPEFB + 60wt% HDPE

Via the naked eyes, for the 40wt% OPEFB + 60wt% HDPE, the fracture is not deep. Using the low power microscope, the image obtained demonstrated why the fracture is not deep. Looking at the purple circle, the polymer matrix, HDPE demonstrates ductile characteristic. The HDPE has undergone plastic deformation and break. However, looking at the black circle, the OPEFB fiber has neither undergo fiber breakage nor fiber pull out. The OPEFB fiber has hold the composite and preventing it from breaking. Besides that, the orientation of the fiber is perpendicular to the fracture line. Therefore, it can hold the load and prevent breakage.

4.3.2 30wt% OPEFB + 10wt% Kenaf + 60wt% HDPE

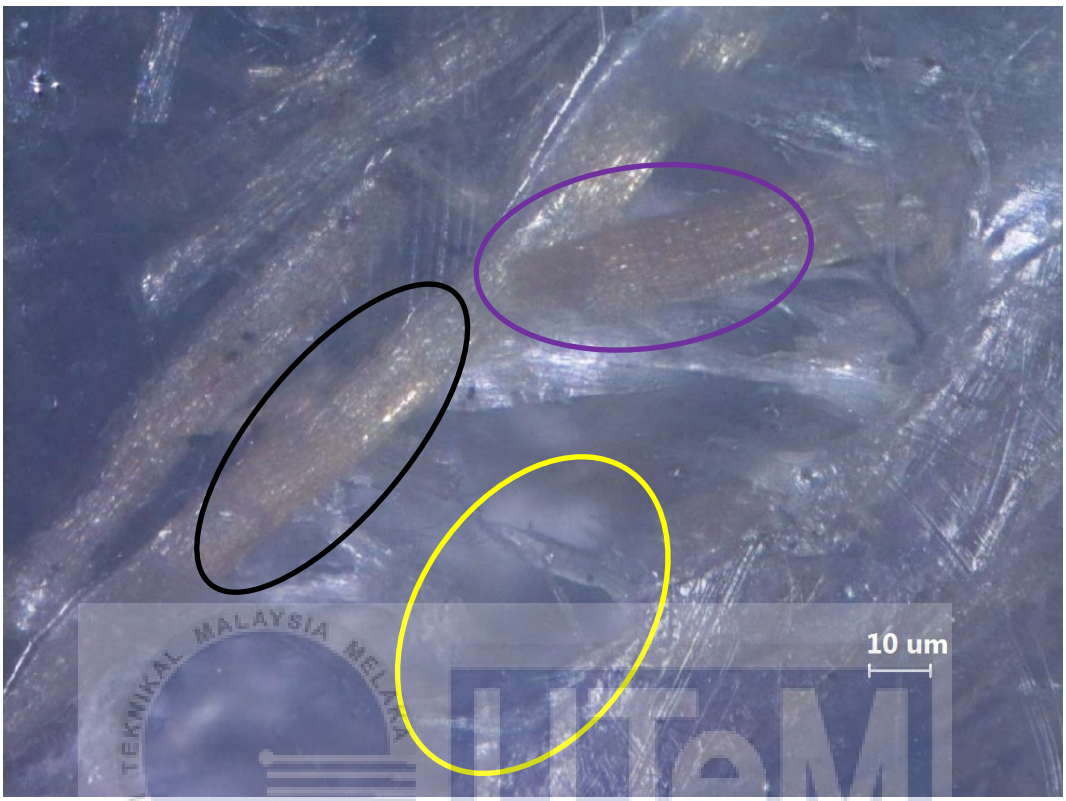

Figure 4-9 : Microscope Image for 30wt% OPEFB + 10wt% Kenaf + 60wt% HDPE

Based on the microscope image obtained for 30wt% OPEFB + 10wt% Kenaf + 60wt% HDPE, the purple circle shows OPEFB fiber pull out. This demonstrates poor adhesion between the natural fiber with the polymer matrix, HDPE. In the black circle, the orientation of the fibre is parallel to the fracture. Therefore, the load is not being carried by the fibers. The HDPE which is in the yellow circle demonstrates plastic ductility properties and has undergo plastic deformation.

4.3.3 20wt% OPEFB + 20wt% Kenaf + 60wt% HDPE

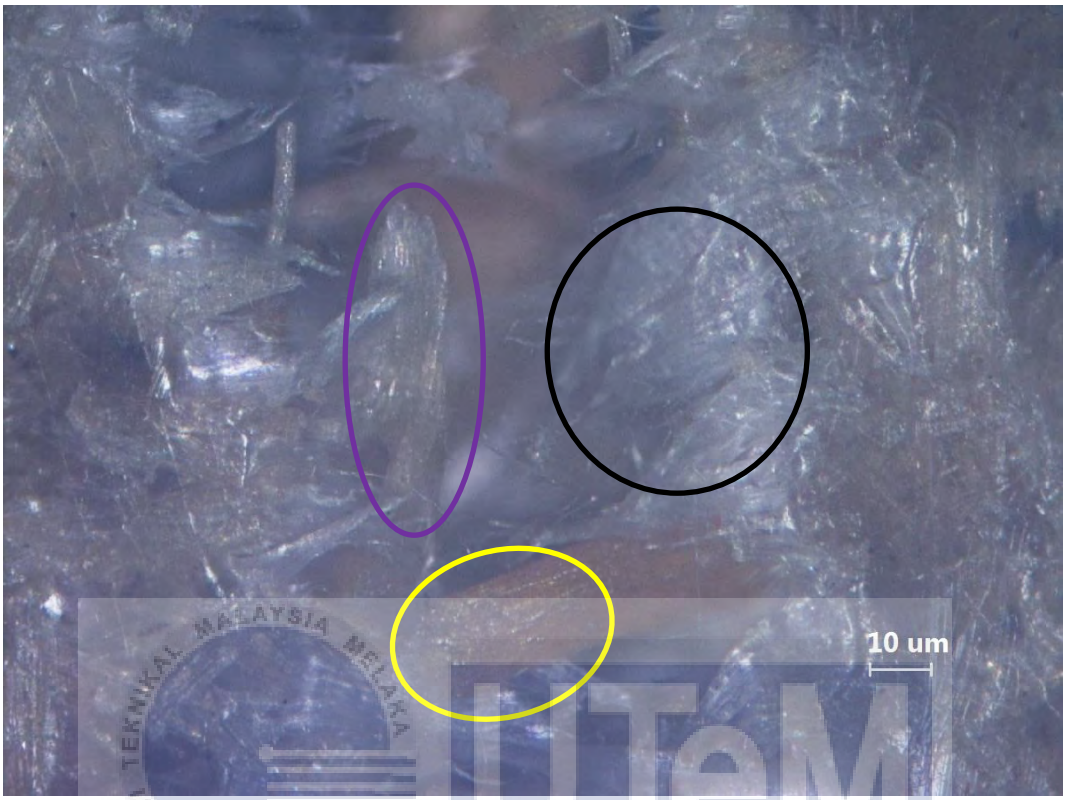

Figure 4-10 : Microscope Image for 20wt% OPEFB + 20wt% Kenaf + 60wt% HDPE

From the obtained microscope image for 20wt% OPEFB + 20wt% Kenaf + 60wt% HDPE, in the yellow circle, the OPEFB fibres has undergo fiber pull out. This shows the poor adhesion between the OPEFB fibers with the polymer matrix, HDPE. At the purple circle, the kenaf fiber is parallel to the fracture. This indicates that the load is not carried by the fiber. Therefore, fracture failure occurs at this point. The black circle shows HDPE has undergo plastic deformation and demonstrates ductility properties.

4.3.4 10wt% OPEFB + 30wt% Kenaf + 60wt% HDPE

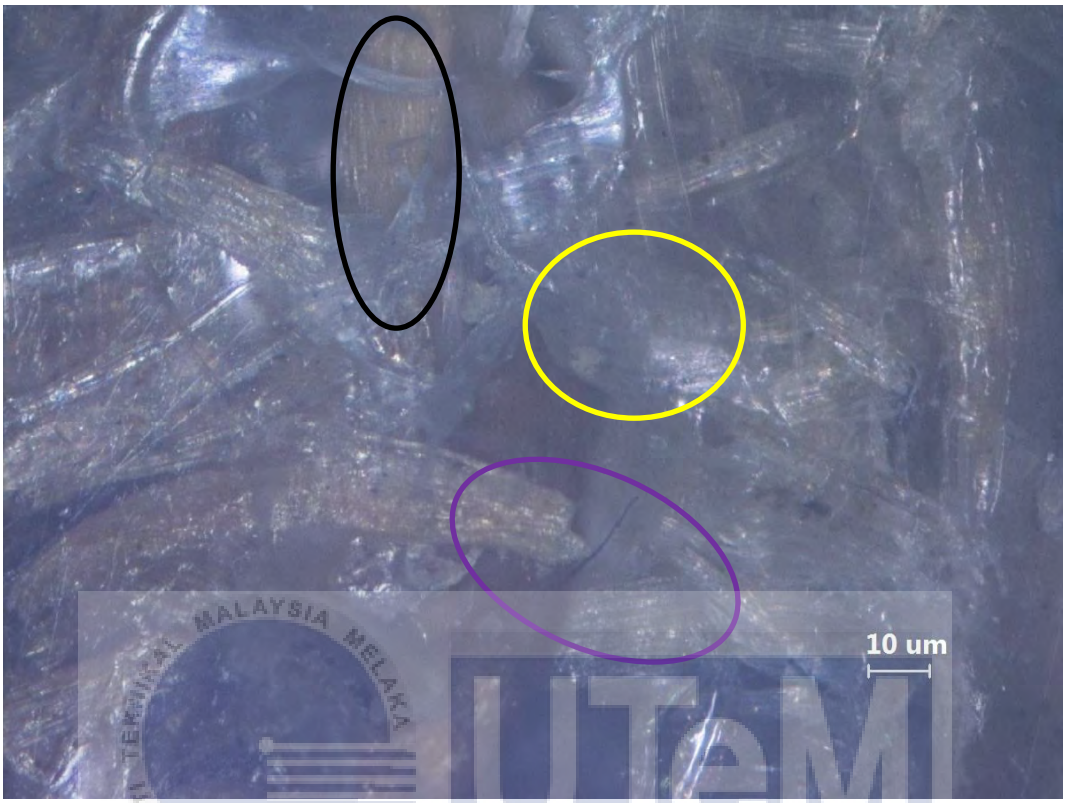

Figure 4-11 : Microscope Image for 10wt% OPEFB + 30wt% Kenaf + 60wt% HDPE

Based on the obtained microscope image for 10wt% OPEFB + 30wt% Kenaf + 60wt% HDPE, in the black circle the OPEFB fibers is aligned parallel to the fracture and thus it does not carry the load. Looking at the purple circle, the kenaf fiber has undergo fiber breakage. The demonstrates that the kenaf fiber has good adhesion with the polymer matrix, HDPE. In the yellow circle, The HDPE demonstrates plastic deformation and ductile properties.

4.3.5 40wt% Kenaf + 60wt% HDPE

Figure 4-12 : Microscope Image for 40wt% Kenaf + 60wt% HDPE

From the obtained image for 40wt% Kenaf + 60wt% HDPE using the low power microscope, it is observed that most of the fibers are aligned perpendicular to the fracture. This allows the kenaf fibers to hold the load. In the purple circle, the kenaf fiber has undergo fiber breakage. This demonstrates that the adhesion between kenaf and the polymer matrix, HDPE, is very good. At the black circle, it is clearly shown the kenaf fiber is holding the composite intact without the fiber breaking. In the yellow circle, the HDPE demonstrates plastic deformation and ductility properties.

4.4 Discussion

Research on OPEFB by Razak & Kalam (2012), indicate that flexural modulus is at 1100-1700MPa. Those obtain in my research is at 851.60MPa. This difference may be cause by several factors such as the fiber size used in their research are 180-355μm. This is significantly smaller than those used in my research. The OPEFB fibers in my research are at 1-5mm. Besides that, the polymer matrix used in their research is Polypropylene, PPnanoclay and MAPP pellets. In addition, Razak & Kalam has treated the OPEFB fibers with NaOH which increases the adhesion properties of the fiber via removal of natural and artificial impurities. For my research, the OPEFB fibers has not undergo any acid/alkali or properties enhancing treatment.

For the case of kenaf, based on Abdul Aziz et al. (2016) and Wambua et al. (2001), the obtained flexural modulus for their research on kenaf and HDPE lies in the range of 2.0-2.5 GPa, whereas in my research the flexural modulus obtain is at 1184.47MPa. A few factors may contribute to this difference. In Abdul Aziz in research, the composite is made up for 2 different parts of kenaf, which are the kenaf core at 80-100 mesh sizs and kenaf bast fiber at 40 mesh size mixed with HDPE and 3% compatibilizer which is Maleic Anhydride–G–Polyethylene. However, the size of natural fibers used in my research is at a range of 1-5mm. This is significantly larger than those used in Abdul Aziz research. Besides that, Abdul Aziz used the MAPE which may have improved the flexural modulus of the composite. The kenaf fibers used in my research has not undergo any acid/alkali or properties enhancing treatment.

In the case of Wambua, the composite if made using stack layers. This method is very different from the method used in my research. Besides that, the polymer matrix used in Wambua research is PP. PP has different mechanical properties compared to HDPE. This explains the difference in the flexural modulus obtain in my research.

In my research, there are a few causes of failure in the composite such as the orientation of the natural fibers. The orientation of the natural fibers which is parallel to the fracture, plays no part in carrying the load, whereas natural fibers which are perpendicular to the fracture are responsible to carry the load. Therefore, my research involves natural fibers in random orientation, thus the performance of the composite is not uniform across the composite. This causes the different flexural modulus and strength obtained.

Furthermore, the composite with higher OPEFB wt% demonstrates lower flexural modulus. This is due to the poor adhesion of the OPEFB with the polymer matrix, HDPE, thus demonstrating fiber pull out when observed in the microscope image, whereas those composites with higher kenaf wt% has higher flexural modulus and strength due to better adhesion of kenaf fibers with the polymer matrix HDPE.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS FOR FUTURE RESEARCH

5.1 Conclusion

The literature study on investigation on flexural and morphological characteristics of novel hybrid oil palm empty fruit bunch/ kenaf reinforced high density polyethylene composite for automotive application has been presented in this report.

The experiment demonstrates that the 40wt% Kenaf + 60wt% HDPE has the highest flexural modulus and flexural strength at 1184.47MPa and 23.75MPa respectively. This is mainly due to the better adhesion of kenaf fibers with the polymer matrix, HDPE, compared to the OPEFB fibers with HDPE. Besides that, the orientation of the natural fibers plays an important role in the load carrying. If the orientation of the natural fibers is parallel to the fracture, the fibers plays no part in carrying the load, whereas natural fibers which are perpendicular to the fracture are responsible to carry the load. Besides that, in every composition of the natural fibers, the polymer matrix, HDPE demonstrates plastic deformation and ductility properties during the flexural test.

5.2 Recommendations for Future Research

For future research, acid/alkali treatment can be conducted on the natural fibers to improve its adhesion properties with the polymer matrix, HDPE. Besides that, the length of the fiber can be further decrease to obtain better mix and adhesion with the HDPE. In addition, different type of thermoplastic can be used as the polymer matrix.

Therefore, if the bio composite is to be used to in the automotive application, it can be used in the interior of the vehicle such as dashboard and door trim. This will significantly decrease the overall weight of the vehicle as bio composite is relatively lighter than metals and plastic.

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