INVESTIGATION ON TENSILE AND HARDNESS PROPERTIES 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 Tensile And Hardness Properties 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 fibre composites (NFC) is currently being applied as substitute material for synthetic composites especially in automotive application. Oil palm empty fruit bunch (OPEFB) fibre is one of the potential source of reinforcement material for NFC, which offers low raw material cost for automotive application due to its abundance as major waste materials in Malaysia oil palm industry. However, OPEFB application is still limited due to the low structural performance of the fibres as compared to other type of natural fibre. Hybridization of OPEFB with other natural fibres is one of the alternative to compensate the drawback of OPEFB structural performance, while retaining balance to the overall material cost. In this research, a novel hybrid OPEFB and kenaf reinforced high density polyethylene (HDPE) composites was develop for automotive application. The aim of this research was to investigate the effect of tensile and hardness properties of novel hybrid OPEFB/kenaf reinforced HDPE composite at varying OPEFB fibre loadings. All samples were prepared at fix fibre to matrix ratio of 40:60 wt%. Meanwhile, the OPEFB/kenaf fibre loadings ratio were varied 40/0, 10/30, 20/20, 10/30 and 0/40 wt%. The fibres were first crushed and sieved to size between 1 t0 5 mm. Hybrid short fibers were later mixed with HDPE using compounding and formed into thin plates using hot compression moulding process. Finally, the samples were cut to size and tested in accordance to the ASTM D2240 for the hardness test. The Shore-D hardness values of the samples were later converted into tensile modulus using theoretical method. Based on the result of hardness and approximate tensile modulus, the hybrid composite samples of 30 wt% Kenaf + 10wt% OPEFB fibre loadings showed the highest hardness property at 73.77 HD or 32.79 N, with approximate tensile modulus of 335.24 MPa. The 30/10 hybrid formulation was able to increase approximately 1.65 times tensile modulus as compared to pure OPEFB reinforced HDPE composites. The findings revealed potential success of hybridizing OPEFB with kenaf to improve the structural performance of OPEFB thermoplastic composites, especially for automotive structural application.

ABSTRAK

Dalam zaman sekarang, komposit yang diperbuat daripada gentian semula jadi (NFC) telah dijadikan bahan penggantian kepada sintetik komposit. Gentian tandan kosong kelapa sawit (OPEFB) merupakan salah satu sumber yang berpontesi untuk memperkukuhkan NFC. OPEFB dapat dijadikan bahan mentah dalam aplikasi automotif dan diperoleh dengan harga yang rendah kerana ia merupakan produk sisa utama daripada industri kelapa sawit dan kuantitinya banyak dihasilkan. Walaupun begitu, aplikasi OPEFB masih terhad kerana prestasi strukturnya yang rendah berbanding dengan gentian semula jadi yang lain. Hibridisasi OPEFB dengan gentian semula jadi yang lain merupakan salah satu cara alternatif untuk mengimbangi kelemahan OPEFB dalam prestasi strukturnya, dengan cara ini keseimbangan kos bahan mentah dapat dikekalkan. Dalam kajian ini, NFC yang diperbuat daripada hibrid OPEFB dan Kenaf diperkukuh dengan polipropena ketumpatan tinggi (HDPE) telah dikaji untuk aplikasi automotif. Tujuan kaji ini adalah untuk mengaji kesan sifat kekenyalan dan kekerasan NFC yang diperbuat daripada hibrid OPEFB dan Kenaf diperkukuh dengan HDPE dengan penukaran pemuatan gentian OPEFB. Semua sampel telah disediakan dengan mengikut nisbah gentian dan matriks yang ditetapkan iaitu 40:60 wt%. Sementara itu, nisbah pemuatan gentian OPEFB/Kenaf diperubahkan dengan 40/0, 10/30, 20/20, 10/30 and 0/40 wt%. Pertama, gentian telah dihancurkan dan dilapis untuk medapatkan saiz gentian yang di antara 1mm dan 5mm. Hibrid gentian pendek akan dicampurkan dengan HDPE dan campuran ini menggunakan cara pengkompaunan. Selepas itu, ia dijadikan plat nipis dengan proses acuan mampatan panas. Akhirnya, sampel itu telah dipotong kepada saiz dan diuji megikut ASTM 2240 yang merupakan standard untuk uji kekerasan. Nilai kekerasan sampel yang didapatkan dengan penggunaan Shore-D hardness telah ditukarkan kepada modulus tegangan dengan menggunakan cara teori. Berdasarkan keputusan kekerasan dan anggaran modulus kekenyalan, sampel komposit hibrid yang mengandungi 30 wt% Kenaf + 10wt% OPEFB pemuatan gentian menunjukkan sifat kekerasan tertinggi iaitu 73.77 HD atau 32.79 N dan anggaran modulus kekenyalan ialah 335.24 MPa. Komposit yang diperbuatkan daripada formlasi 30/10 dapat meningkatkan prestasi modulus kekenyalan kira-kira 1.65 kali ganda berbanding dengan komposit OPEFB tulen diperkukuh dengan HDPE. Penemuan ini mendedahkan potensi kejayaan hibridasi OPEFB dan Kenaf dapat meningkatkan prestasi stuktur OPEFB dalam komposit termoplastik, terutamanya dalam aplikasi automotif struktur.

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LIST OF ABBREVIATIONS

HDPE	High density polyethylene
OPEFB	Oil palm fruit bunch
ASTM	American Society for Testing and Materials
std dev	Standard deviation

LIST OF SYMBOLS

wt%	=	Weight percentage
S_D	=	Hardness reading of Shore D durometer
E	=	Tensile modulus

CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, the number of vehicle in the whole world is growing dramatically. On the other hand, the current trend has shown that life span of the vehicle is shortening and it results that the number of the End-of-life vehicle (ELV) is also increasing. ELV stands for the discarded vehicles or the vehicles that is going to be discarded. The vehicle sector has contributed about 5% of the world's industrial waste and the discarded vehicles give a big impact to the environment as they contain of mercury, cadmium, hexavalent chromium, anti-freeze, brake fluid and oils which may pollute the environment if they are not handled well. Currently, the recyclable part for a vehicle is the metal part such as steel and aluminum. Life cycle assessment (LCA) is a method that is used to evaluate the environmental sustainability of a product. Alves and his team had used the LCA to show the possibility and advantages for applying the natural fibres in the automotive sectors [1].

Oil palm industry is one of the main agroindustry in Malaysia which is also the main income of the country. In 2000, Malaysia was once the largest producer and exporter of oil palm in this world, which Malaysia produced 10.8 million tonnes of oil palm annually and this amount was around 50% of the world palm oil production. In 2008, Malaysia's production had grown up to 17.7 million tonnes and 4,500,000 hectares of land had been used for planting the oil palm tree. It is expected that in between 2016 and 2020, the production of oil palm will be 15.4 million tonnes annually. The industry has grown big and the impact on the environment is also growing. Hence, the Roundtable for Sustainable Palm Oil (RSPO) which is a NGO has been formed, and it is supported by the government and Malaysia Palm Oil Council (MPOC). This organization's aim is developing a sustainable oil palm industry. In processing the oil palm, it will produce large amount of solid waste and liquid waste such as empty fruit bunches (EFB), mesocarp fruit fibers (MF), palm kernel shells (PKS) and palm oil mill effluent (POME). The waste disposal of the oil palm has become a critical issue and developing a sustainable method is necessary and encouraged [2].

There are two categories of fibres which are the synthetic fibres and the natural fibres. Natural fibres are widely used in this world since thousand years ago such as cotton. Natural fibres can be obtained from the plant, animal and minerals each of them has different properties. For the fibres from plant, the fibres can be obtained from the leaf, seed, bast, core and others. The natural fibres is environmental friendly as it is biodegradable and renewable. Comparing to the synthetic fibres, the natural fibres possess the advantages such as recyclable, nonabrasive, acceptable specific strength and modulus, low density, good acoustic property, low cost, and easily available. There are also weaknesses on the natural fibres. They are facing the problem of the high tendency to absorb the moisture, poor wettability, low adhesion with the synthetic matrix and poor thermal stability during processing [3].

Oil palm empty fruit bunch (OPEFB) fibres is the natural fibre that is obtained from the waste product of the oil palm industry. The source of this fibre is abundance and it is recyclable and low cost. Same as other natural fibres' limitation, the OPEFB has low thermal stability during process and it processing temperature is limited at about 200°c as it may degrade or have volatile emission during process and affect the properties of the composite. From the investigation of Rozman and his team, they mixed the OPEFB and the high density polyethylene (HDPE) and the result showed that increase of the percentage of OPEFB in the composite polymer will decrease the flexural, tensile, and impact strengths [4].

Kenaf fibre is a natural fibre which can be easily found in Malaysia. The species of Hibiscus cannabinus is the species of Kenaf. Kenaf is a plant with fibrous stalk hence it is resistant to damage of insect, only few or no pesticide are needed to be used on it [5]. It is economically cheaper if compared with other natural fibres that can be found in Malaysia. It is widely used in making the composite polymer as the reinforce fibre. Generally, a composite polymer that contains of Kenaf fibre will show a good result in tensile and flexural testing [6].

There are two types of matrixes that are used to form composite polymer which are thermoplastic and thermoset. Thermoplastic matrixes that are commonly used are polyethylene (PE), polypropylene (PP), polystyrene (PS), and PVC (polyvinyl chloride), and thermoset matrixes that are commonly used are epoxy resin, polyester, phenol formaldehyde, and vinyl esters. Both matrixes are not fully biodegradable. Strength and stiffness of the composite polymer can be varied by controlling the composition of the fibre in the polymer. By increasing the volume of fibre in the polymer, the thermal conductivity and thermal diffusivity will decrease but it doesn't show significant effect in the temperature range of 170°c to 200°c [7]. Polyethylene is always chosen as the matrix in forming bio composite polymer as it has high availability, low melting point, low cost and recyclable [4].

1.2 Problem Statement

The automotive market is growing larger and the number of waste material that is caused by automotive is also increasing. The metal parts of the automotive can be recycled but most the plastic used in it cannot be recycled. The use of recyclable or biodegradable plastic can help to increase the recyclability end-of-life performance of vehicles. In another scenario, Malaysia is one of the biggest producers of oil palm in the world. Large oil palm industry produces large amount of waste, such as empty fruit bunch. The oil palm empty fruit bunch (OPEFB) can be processed into natural fibre, which can later be utilized to produce natural fiber composites (NFC). NFC is among the growing source of materials applied in the automotive sector. The feasibility of applying NFC for automotive application depends on many factors, such as type of fibre, processing method, reinforced matrix, weight percentage of fibre and others. Hybridization is one of the technique used to produce NFC, which able to offer a balance between cost and performance between the mix fibers. 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. In this research, the study on mechanical properties, namely hardness and tensile modulus of novel hybrid OPEFB/kenaf reinforced HDPE composites for automotive application were conducted. Varying OPEFB to kenaf fiber ratio was used to formulate the samples. All fibers were crushed and sieved to short fiber form, with size ranging between 1 mm to 5 mm. Thermoplastic compounding process and hot compression moulding process were also utilized to prepare the samples. The hardness testing based on ASTM D2240 was used to determine the Shore hardness value of the samples, while theoretical method was applied to convert the hardness value to equivalent tensile modulus properties.

1.3 Objectives

The objectives of this project are as follows:

i. To find the hardness of hybrid oil palm empty fruit bunch/kenaf reinforced HDPE with varying weight ratio of oil palm empty fruit bunch, kenaf and HDPE.

ii. To find the approximate tensile modulus of hybrid oil palm empty fruit bunch/kenaf reinforced HDPE with varying weight ratio of oil palm empty fruit bunch, kenaf and HDPE.

1.4 Scope of Project

The scopes of this project are:

1. To find the hardness of hybrid oil palm empty fruit bunch/kenaf reinforced HDPE
2. To find the approximate tensile modulus of hybrid oil palm empty fruit bunch/kenaf reinforced HDPE
3. The formulation of bio composite formula is determined by weight percentage. The weight ratio of natural fibre to HDPE will remain at 4:6.
4. Report writing.

CHAPTER 2

LITERATURE REVIEW

2.1 Natural Fibre

Fibre is a material that has continuity of filament which is looked like a thread. Natural fibre is an environment friendly item, basically it can be divided into three categories which are animal, plant and mineral. Animal fibre is the fibre that is obtained from animal such as silk, sheep's wool and feather. The mineral fibre is the fibre that is formed from the mineral naturally or the fibre obtained from mineral but has been slightly modified such as ceramic and metal fibre. Plant fibre is the fibre that obtained from parts of plant, basically it is made up from cellulose. For this fibre, it can be re-categorised into five groups which are seed fibre, skin fibre, leaf fibre, fruit fibre and stalk fibre [8].

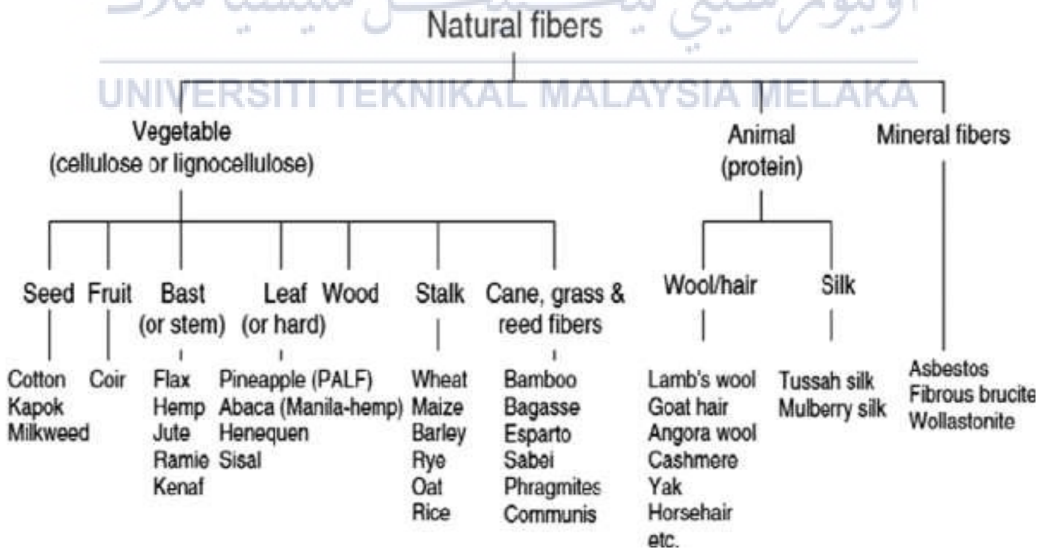


Figure 2-1: Categories of natural fibre [8]

The natural fibres is biodegradable and renewable hence it will not harm the environment and the source will not deplete. Besides, the natural fibres has also reasonable specific strength and modulus and low cost which can provide a product with good strength and low weight. Lastly, they are inexpensive and easily be obtained. However, the natural fibres tend to absorb moisture and provide a low adhesion force while processing with synthetic matrix. During processing, the natural fibres also show a poor thermal stability [3].

The natural fibres' properties depend on the chemical composition and the architecture. However, the natural fibres that contain of more cellulose and is aligned with the cellulose microfibrils will show a better performance. Previously, the asbestos group, which is a mineral natural fibre, was used extensively in making composite but due to the health issues such as carcinogenic, it is prohibited by many countries [9].

2.1.1 Oil Palm Empty Fruit Bunch

OPEFB is the waste product that is produced after the fresh oil palm fruit bunch is extracted for palm oil. Malaysia is one of the main exporter for palm oil in this world. The oil palm industry has produced huge amount of biomass residues every year. OPEFB is one of the main biomass residues, it is around 15.8 Million ton each year [10]. The composition of holocellulose in a OPEFB is 65 percent and the lignin content is 25 percent. The utilization of OPEFB will reduce the environmental issue caused by by-product of the oil palm industry [11]. With the amount of OPEFB generated each year, the source for producing the product with OPEFB base will be sustained [10].

2.1.2 Kenaf

Kenaf is a plant that under genus Hibiscus family and it is a dicotyledons plant. It is originated from ancient Africa. The growth rate of the Kenaf plant is fast and the yield in each year is 600-10000 kg of dry fibre from one acre of field. The survival rate of the Kenaf plant is high as it can adapt to across the broad of the climate condition. Low amount of water and fertilizers are needed to sustain the Kenaf plant. It is also a tough plant which can withstand the insect harm and it can grow well in various type of soil. Kenaf's bast can produce long fibre and the core can extract the short fibre [12]. In Malaysia, Kenaf fibre is relatively accessible and the cost will be lower if compared with other natural fibres. It is highly used in the bio-composite sector [6].

Figure 2-2: The dense kenaf plantation in Malaysia [6]

Raw Kenaf fibre is lignocellulosic fibre when it is extracted from the outer bark. The cellulose content of the Kenaf fibre is roughly 0.7 percent and the lignin and pectin consist of 21.6 percent. At bottom of the stalk, the length of fibre is commonly short but it grows longer at the top. The chemical properties and physical properties are different for fibre that is extracted from different parts of plant as the chemical composition and the fibre properties are different. Generally, the tensile strength and tensile modulus of Kenaf sigle fibre is 11.91 Gpa and 60 Gpa [13].

2.2 Matrix

The matrix is playing role to decide the strength of the polymer matrix composite to resist the degradative process such as impact damage, attack from chemical substance and others. Generally, the link of matrix in the polymer matrix composite is low. The polymer matrix can be classified into two categories which are thermoset and thermoplastic. The general characteristic of both matrix is as show in Figure 2.3 [14]. The environmental tolerance of the polymer matrix biocomposite is also depended on the type of matrix. In the market, 80 percent of the polymer products is based on the non-renewable petroleum resources. The matrix can also be categorized with the different in environmental tolerance, it is shown in the Figure 2.4 [7].

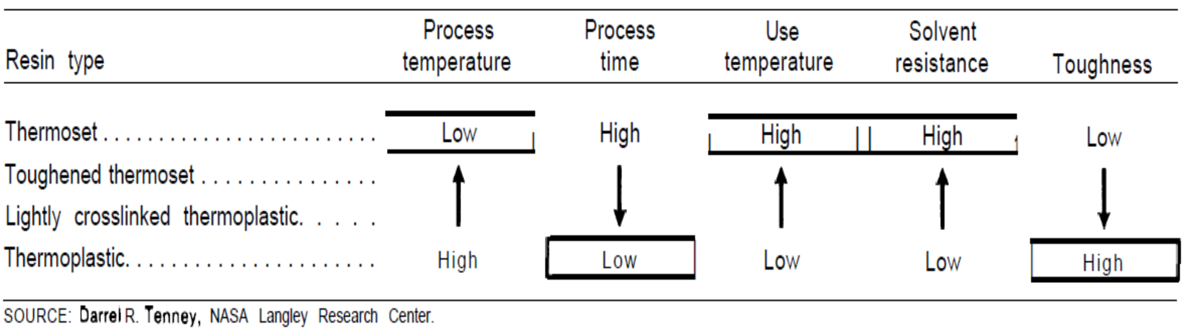


Figure 2-3: General characteristic of Thermoset and Thermoplastic [14]

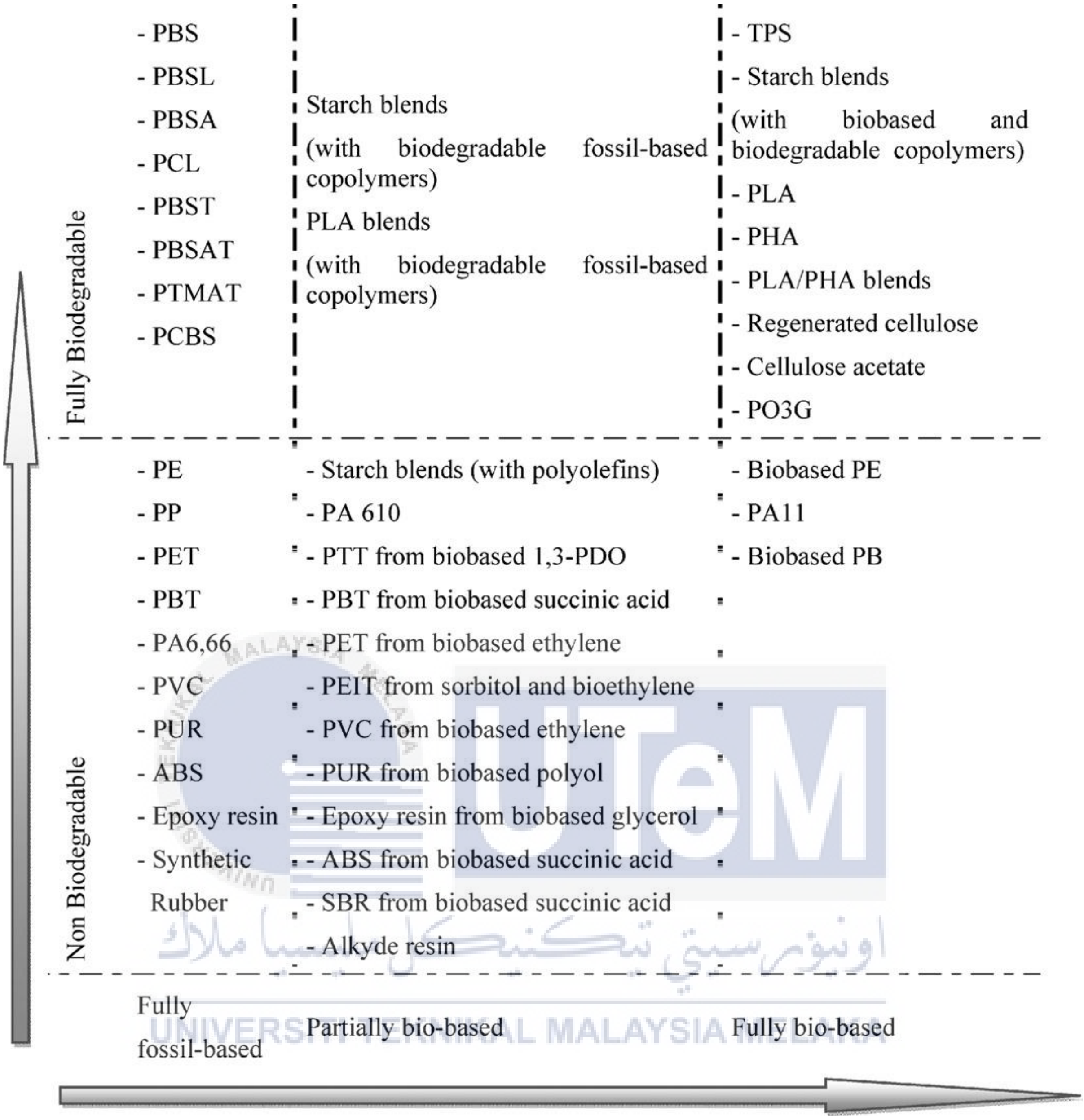


Figure 2-4: Current and emerging plastics and their biodegradability [7]

2.2.1 Thermoset

Thermoset matrix is a resin that has low viscosity at the start but after the curing process happened, the polymer chain will be crosslinked and a three-dimensional network is formed. Examples of thermosetting resins are polyester, epoxies and vinyl-esters. The most common resin that is used in the market is epoxies. The polymer matrix composite that use thermoset resin as matrix will tend to have stable dimension, good in resisting solvent and resist high temperature. The shape of thermoset polymer is irreversible [14].

2.2.2 Thermoplastic

Thermoplastic is also known as engineering plastics. Their molecules are long and discrete. Generally, their melting point or process temperature will be varied from 260ºC to 3710ºC. After cooling, the thermoplastic will form amorphous, crystalline, or semi-crystalline solid. The properties of the composite will be affect the degree of crystallinity. Generally, performance of thermoplastic in heat resistant and chemical resistant will be lower if it is compared with the thermoset. However, it has a higher resistant to impact and cracking. The shape of thermoplastic polymer is reversible, it can be reheated and form into the desired shape [14]. Polyethylene (PE) is one of the thermoplastic resin. For this resin, by controlling the composition of fibre and bonding in the composite polymer, the different toughness, strength and stiffness of the polymer can be obtained. When the content of fibre increases, the thermal conductivity and thermal diffusivity of the PE matrix composite will decrease but it doesn't show significant effect in the temperature range of 170°c to 200°c [10]. Due to the high availability, low melting point, low cost and recyclable, the high-density polyethylene (HDPE) is always chosen as the matrix in forming bio composite polymer [4].

2.3 Natural Fibre Composite

The globally environmental issues and the awareness about the sustainability life, the use of natural resource and waste has been focused [15]. In the recent year, people are finding the replacement substances for the fossil fuel and the petrochemical. Abundant of cellulose can be found on earth so it can act as a sustainable natural source. Natural resources are biodegradable, positive impact to the environment and generally low cost [16]. Natural fibre composite is a composite that use polymer as matrix and reinforced by using the natural fibre. The natural fibre can also be used in the form of filler. Natural fibre composite can be recycled and it is bio-degradable hence the natural fibre composite is more environmental friendly compared to the traditional glass/carbon polymer composites. Generally, the cost of natural fibre composite is low compare to the traditional composite. The density of natural composite is low but with the acceptable strength, hence it is suitable to make a product which need a light weight without extensively high strength. However, due to the limitation of low durability, high water absorption and the low bonding force between the matrix and natural fibre, the methods to improve the natural fibre composite are still needed [15].

2.3.1 Hybrid Natural Fibre Composite

Hybrid natural fibre composite is a composite that mix more than one type of natural fibre in the matrix. The fibres used in the composite can as complement to each other weakness. With a good material design, the performance of composite can be increased such as the hybrid composite made of coir and OPEFB, the performance in tensile strength and flexural has been improved compare to the composite form by coir fibre or OPEFB fibre alone [17].

2.4 Previous Research

There are researches that have been done with different materials and methods. The Table 2.1 below will show a short summary about the materials, researchers, methods been used and result of the previous researches.

Table 2-1: Summary of previous researches [18]-[29]

Materials	Authors	Methods	Type of test	Result	Year
Treated Kenaf + epoxy/ Untreated Kenaf + epoxy	Krishna et al.,	Resin casting	Tensile test by using ASTM D3039	-glutamic and lysine treated Kenaf fiber provide a better mechanical property.	2016
Bamboo fibre + Maleic anhydride polypropylene	Okubo et al.,	Steam explosion to extract fibre + Hot-press molding	Tensile test but does not fit ASTM completely	-Bamboo fibre has the potential to be reinforce material. -Tensile and Young's modulus of composite made by fibre that obtained by steam explosion show a better result	2004
Sawdust of softwood radiata pine + virgin/recycled HDPE.	Adhikary et al.,	Extrusion + Hot-press molding	Tensile test by using ASTM D638-99	-The mechanical properties of composite that made by recycled HDPE has similar properties as composite that made up from virgin HDPE, in some cases it is better.	2008
Banana fibre + Kenaf fibre + Polyester	Alavudeen et al.,	Hand-layup technique	Tensile test by using ASTM D638-10	-The woven hybrid composite of banana/kenaf fibres give better result in tensile strength compare to individual fibre is used.	2015
Kenaf fibre + Polypropylene	Asumani et al.,	Compression molding	Tensile test by using ISO 527	-Kenaf fibre that is treated with akali combine with three amino-propyltriethoxysilane will give a better result in tensile strength.	2012

Glass fibre + OPEFB + Polypropylene	Rozman et al.,	Compounding +Hot-pressing	Tensile test by using ASTM D618	-The tensile performance drops due to the incompatibility of OPEFB with glass fibre and polypropylene. -Tensile modulus increase when the overall fibre content in composite increase.	2001
Oil palm derived cellulose + OPEFB + Polypropylene	Khalid et al.,	Compounding +Hot-pressing	Tensile test by using ASTM 1882L	-The composite that consists of oil palm derived cellulose show a better result in tensile strength compare to the composite only consists of OPEFB fibre.	2008
Polypropylene + loose composite grade fibers + non-woven needlepunched mats of industrial hemp	Pervaiz et. al	Hot-pressing	Flexural test by using ASTM D790. Impact test by using ASTM D256	-The sample with 64 wt% fibre content shows the most comparable mechanical properties. -It is possible to use composite-grade random fibers.	2003
Natural rubber + banana stem fiber	Christian Ezema et. al	Layering + Hot-press moulding	Tensile test by using ASTM D638	-Composite reinforced by natural fiber get improvement in tensile strength and modulus. -Chemical treated fiber show slightly improve in tensile strength and modulus. -Orientation of fiber affect the tensile strength and modulus.	2014

Unsaturated polyester + alfa fibre	Rokbi et. al	Moulding + Hand lay-up	Flexural test by usingASTM D790	-Treatment time and concentration of chemical substance that are used on natural fiber affect its mechanical properties. -Treated Alfa fiber shows better flexural strength and modulus.	2011
Aluminium + Silicon carbide + Coconut fiber + Graphite + Aluminium oxide + Zirconia oxide + Phenolic resin	Maleque et. al	Powder metallurgy technique + Hot compaction die	-Density test -Porosity test by using Japanese Standard JIS D 4418: 1996 -Rockwell hardness test by using Malaysian Standard MS 474 PART 2: 2003	-Coconut fiber is well distributed in the composite. -Coconut fiber can act as the candidate as filler brake pad without harmful effect.	
Woven flax + Epoxy resin/ Woven jute + Epoxy resin/ Chopped strand hemp mat + Epoxy resin	Meredith et. al	Vacuum assisted resin transfer moulding	-Tensile test by using ASTM D3379-75. -Static testing by using Quasi-static testing -Dynamic testing	-Volume fraction is the main factor affecting the specific energy absorption. -Higher fiber volume fraction, higher the specific energy absorption.	2012

2.5 Application of Natural Fibre Composite in Automotive Industry

Natural fibre reinforce composite is believed to be the new substitution for the metal or ceramic based material in the industry such as automotive and aerospace. There are good specific properties possessed by the natural fibre composite and the weakness can be solved with the suitable development. The factors that affect the automotive industry to involve the natural fibre composite are the price, reduction in weight and market. Generally, the car manufacturers use the composite to make the interiors of car such as door panel, mirror casing and roof. Some composites are also used in structural application such as beam and water tank. There are also developments of hybrid natural fibre composite in automotive industry [30].

Aspects	Property	Natural fibers	Synthetic fibers
	Mechanical properties	Moderate	High
Technical	Moisture sensitivity	High	Low
	Thermal sensitivity	High	Low
	Resource	Infinite	Limited
Environmental	Production	Low	High
	Recyclability	Good	Moderate

Figure 2-5: Comparison between Natural Fibers and Synthetic Fibers [g]

Depletion of petroleum resource has made the natural fibre reinforced composite gains attention. The uses of natural have bring the society many advantages as they are biodegradable, environmentally friendly, lightweight, inexpensive and good mechanical properties. The automotive industry uses the natural fibre composite because its density is low hence the weight of vehicle can be reduced. However, the crashworthiness and energy absorption of the composite must be considered. The natural fibre possesses a lower density but higher tensile strength and stiffness compare to synthetic fibre. It makes the natural fibre is more favored in the automotive industry [31]. According to the Germany-based Nova-Institut, Europe industry has used 150000 tons of composite to produce cars and trucks and 80000 tons of wood and natural fibres have involved in the production of those composites. An estimation had stated that average of 1.9 kg of natural fibres and 1.9 kg of wood fibres can be found in each current European passenger car. In order to improve the market of bioplastic, more efforts are needed [32].

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter will explain the process that is used to obtain the best sample of hybrid composite that form by two types of fibre which are kenaf fibre and OPEFB fibre with HDPE as a matrix. Generally, the process can be divided into three parts which are material preparation, sample preparation and hardness testing. The standard that will be used for hardness testing is ASTM D2240.

3.2 General Process

The process is started with literature review to find the method to produce sample and the method to do hardness test. Then, it is followed by the material preparation. Next is sample preparation. Lastly, the sample is used for the hardness testing. For the hardness testing, the specimens will be prepared by following the standard ASTM D2240. The general process is shown in Figure 3.1.

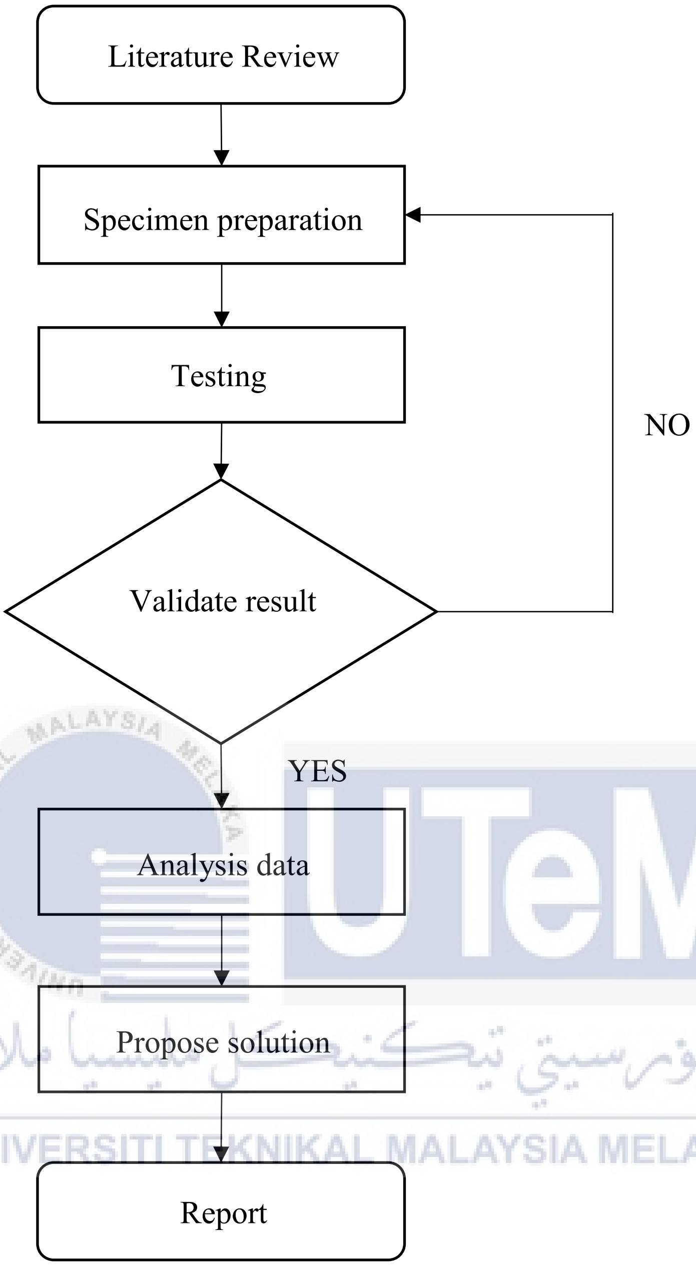


Figure 3-1: Flow chart of general process

3.3 Material Preparation

There are three raw materials which are Kenaf fibre, OPEFB and the HDPE. Kenaf is obtained from Lembaga Kenaf dan Tembakau Melaka, which extracted from the bast of the Kenaf plant. OPEFB is provided by Sime Darby Plantation Merlimau Melaka. The HDPE comes from industry Etilinas.

The Kenaf fibre and the OPEFB fibre is obtained in a long fibre type. Hence, a crusher is used to crush the fibre into the short fibre which is the length in the range between 1mm to 5mm.

Figure 3-2: Kenaf fibre

Figure 3-3: OPEFB fibre

3.4 Sample Preparation

The sample is prepared by varying the weight percentage of natural fibre and the weight percentage of matrix remains constant. The weight percentage of natural will be remains at 40% and 60% for the HDPE. The sample will be prepared as table below.

Table 3-1: Weight percentage of each composition in hybrid composite

Natural fibre (%)		Matrix (%)
OPEFB	Kenaf	HDPE
0	40	60
10	30	60
20	20	60
30	10	60
40	0	60

The sample preparation will start with mixing the raw material according to the weight percentage by using the internal mixer. The internal mixer is set at 50RPM and 160ºC. The composite will be mixed for 8 minutes. Then, the mixed composite will be left to cool. After the composite is cooled, it will be crushed by using the crusher. Then, the crushed composite will be hot-pressed by using hydraulic hot molding machine. The crushed composites are spread out smoothly in the mold. Follow by letting the mold heated for 15 minutes at temperature of 160ºC, at this moment the mold is not pressed with pressure but just let both sides of mold touch on the surface. Then, it is hot-pressed with a temperature of 160ºC for 15 minutes under a pressure of 90 kgf/cm^2. After that, it is cooled under the pressure of 90kgf/cm^2 for 15 minutes. The process is shown in the Figure 3.10.

Figure 3-4: Internal mixer machine

Figure 3-5: Composite after mixing

Figure 3-6: Crusher

Figure 3-7: Composite after crushed

Figure 3-8: Hot compression molding machine

Figure 3-9: Sample after hot-pressed

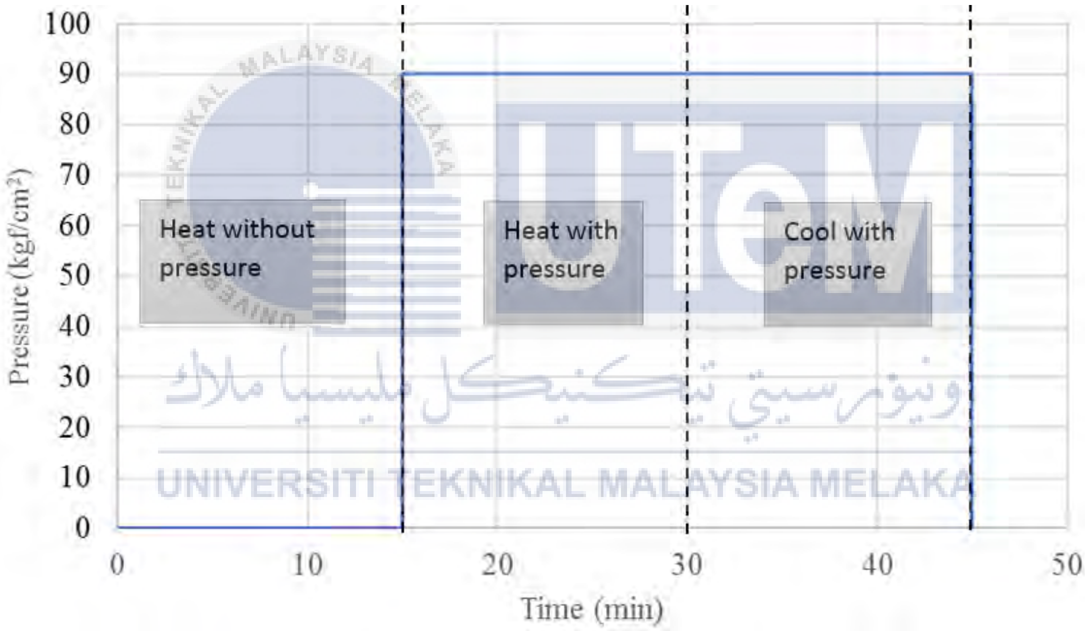


Figure 3-10: Process for Hot-press

3.5 Hardness Testing

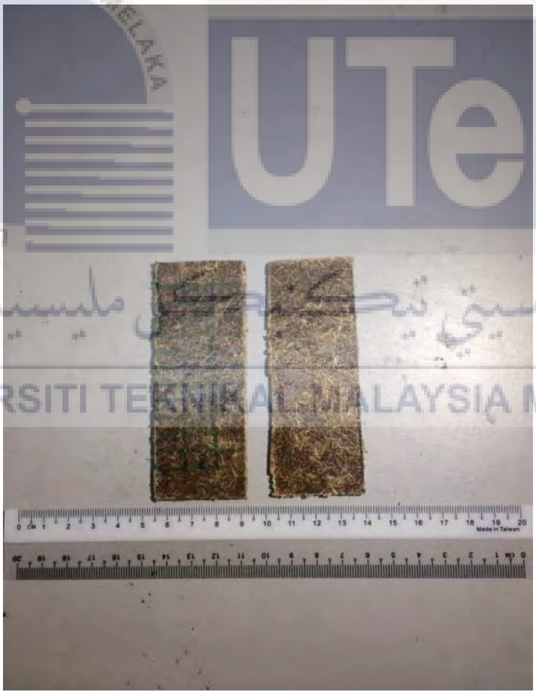
The hardness test will be conducted by following the ASTM D2240. The equipment that use to test the hardness of sample is Shore D Durometer. The size of sample is 100mm x 36mm. The thickness is 3.2mm. Each formulation is cut into the size and each formulation has two sample, they are piled together while testing is conducted. The sample will be divided into 5 regions. Each region has six point to do the hardness testing. Type-D indentor is used to conduct this testing. The indention point must be 12 mm from any edges of the sample. Each indention point is 6 mm apart from each other. The testing is conducted on the granite table as the specimen must be put on a flat, hard and horizontal surface. Then, the durometer is hold vertically and the indentor tip contacts with the testing point. Sufficient pressure is applied to the durometer to press the indentor tip into the sample and ensure the pressure foot contacts with the surface of sample. Once it is contacted, the reading is taken within 1 ± 0.1 s [33].

(a)

(b)

(c)

(d)



(e)

Figure 3-11: Sample of Hardness Testing. Kenaf wt% / OPEFB wt%: (a) 40/0, (b) 30/10, (c) 20/20, (d) 10/30, (e) 0/40

Figure 3-12: Shore D Durometer

3.6 Approximate Tensile Modulus

The approximate tensile modulus is converted by using the hardness results. By referring to the report that had been done by Qi and the team, there is a formula that can convert the hardness results, that are obtained by using Shore D durometer, to the tensile modulus. The formula has been used to convert the hardness is:

$$S_D = 100 - \frac{20(-78.188+\sqrt{6113.36+781.88E}}{E}\ .$$

It is a formula that used to convert hardness that is obtained by using type-D indentor [34].

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Hardness Result

4.1.1 Reult of HDPE 60% + Kenaf 40% + OPEFB 0%

The sample is divided into 5 regions to do the hardness test. The data are recorded in Table 4.1.

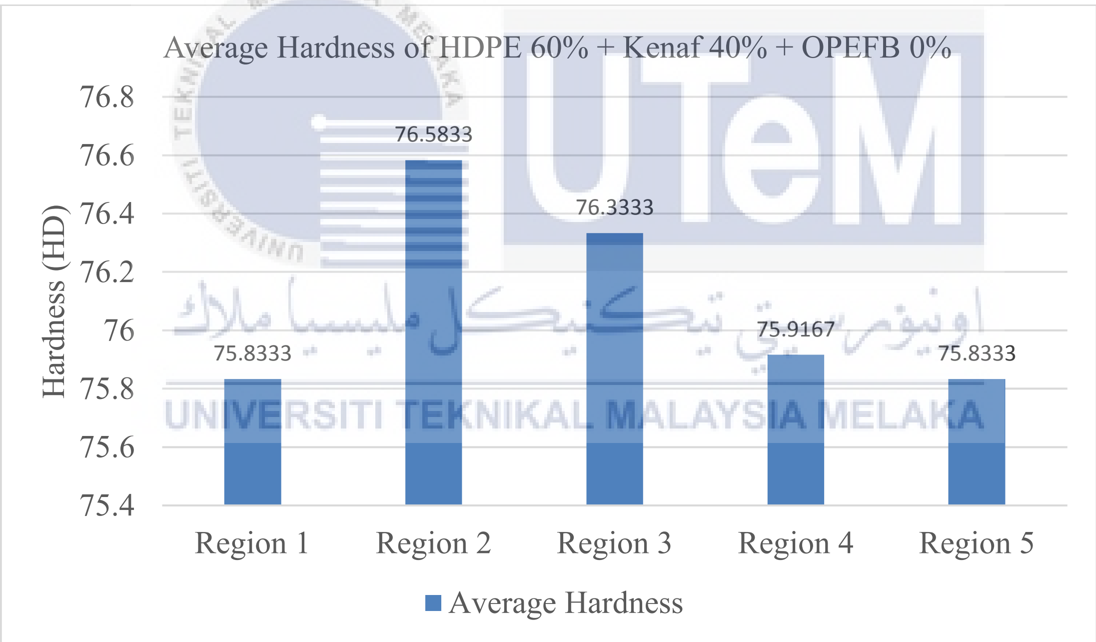


Figure 4-1: Average hardness of HDPE 60% + Kenaf 40% + OPEFB 0%

Table 4-1: Result of hardness for HDPE 60% + Kenaf 40% + OPEFB 0%

Point/Region	Region 1 (HD)	Region 2 (HD)	Region 3 (HD)	Region 4 (HD)	Region 5 (HD)
Point 1	75.0000	76.5000	76.5000	75.5000	75.0000
Point 2	76.5000	76.0000	75.5000	78.0000	76.0000
Point 3	76.5000	77.0000	77.0000	75.5000	75.5000
Point 4	75.5000	76.5000	77.5000	75.5000	77.0000
Point 5	76.5000	76.0000	74.0000	75.0000	76.0000
Point 6	75.0000	77.5000	77.5000	76.0000	75.5000
Average	75.8333	76.5833	76.3333	75.9167	75.8333

4.1.2 Result of HDPE 60% + Kenaf 30% + OPEFB 10%

The sample is divided into 5 regions to do the hardness test. The data are recorded in Table 4.2.

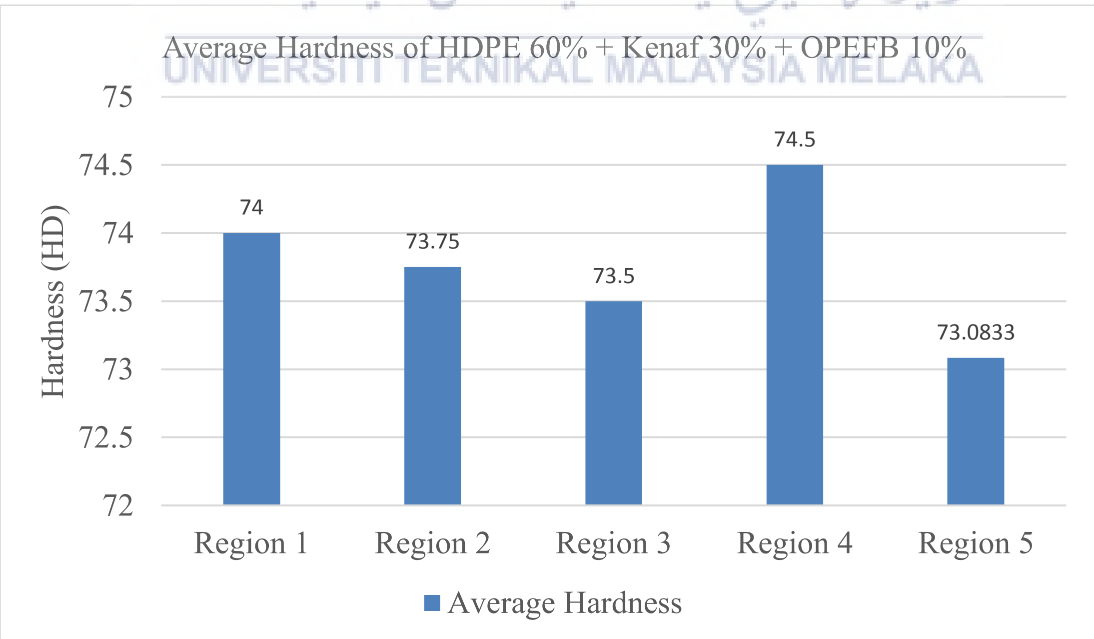


Figure 4-2: Average hardness of HDPE 60% + Kenaf 30% + OPEFB 10%

Table 4-2: Result of hardness for HDPE 60% + Kenaf 30% + OPEFB 10%

Point/Region	Region 1 (HD)	Region 2 (HD)	Region 3 (HD)	Region 4 (HD)	Region 5 (HD)
Point 1	77.0000	75.5000	69.0000	76.5000	72.0000
Point 2	74.5000	74.5000	74.0000	74.5000	72.0000
Point 3	73.0000	74.0000	75.0000	78.0000	73.5000
Point 4	74.0000	75.0000	74.5000	74.5000	74.0000
Point 5	72.0000	72.0000	74.0000	70.0000	74.0000
Point 6	73.5000	71.5000	74.5000	73.5000	73.0000
Average	74.0000	73.7500	73.5000	74.5000	73.0833

4.1.3 Result of HDPE 60% + Kenaf 20% + OPEFB 20%

The sample is divided into 5 regions to do the hardness test. The data are recorded in Table 4.3.

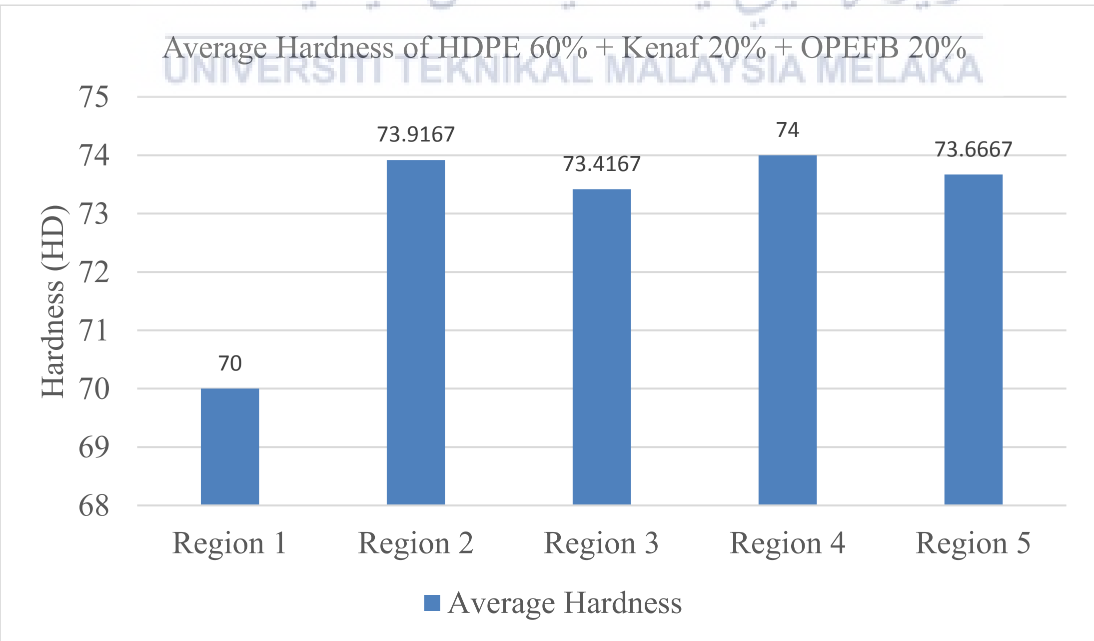


Figure 4-3: Average hardness of HDPE 60% + Kenaf 20% + OPEFB 20%

Table 4-3: Result of hardness for HDPE 60% + Kenaf 20% + OPEFB 20%

Point/Region	Region 1 (HD)	Region 2 (HD)	Region 3 (HD)	Region 4 (HD)	Region 5 (HD)
Point 1	67.5000	70.5000	74.5000	74.0000	75.0000
Point 2	70.5000	73.0000	74.5000	73.0000	73.5000
Point 3	71.0000	76.5000	73.5000	76.0000	71.5000
Point 4	71.0000	74.0000	71.5000	73.5000	74.5000
Point 5	69.0000	74.5000	72.0000	75.5000	72.5000
Point 6	71.0000	75.0000	74.5000	72.0000	75.0000
Average	70.0000	73.9167	73.4167	74.0000	73.6667

4.1.4 Result of HDPE 60% + Kenaf 10% + OPEFB 30%

The sample is divided into 5 regions to do the hardness test. The data are recorded in Table 4.4.

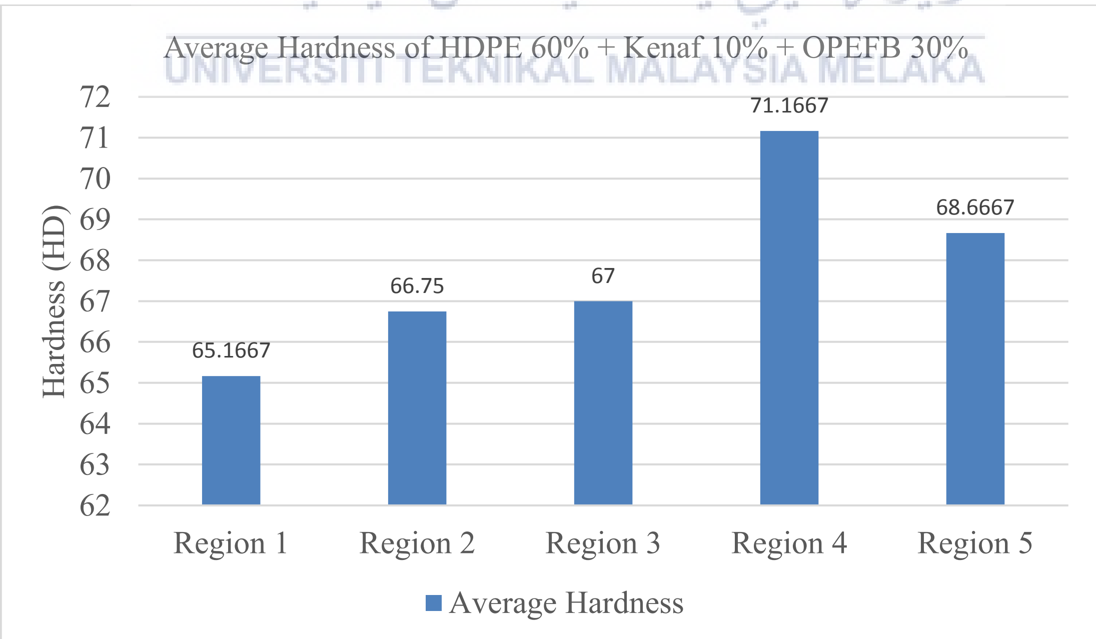


Figure 4-4: Average hardness of HDPE 60% + Kenaf 10% + OPEFB 30%

Table 4-4: Result of hardness for HDPE 60% + Kenaf 10% + OPEFB 30%

Point/Region	Region 1 (HD)	Region 2 (HD)	Region 3 (HD)	Region 4 (HD)	Region 5 (HD)
Point 1	64.0000	62.5000	68.0000	70.5000	66.5000
Point 2	66.5000	68.0000	71.0000	70.0000	67.5000
Point 3	68.0000	71.0000	63.5000	69.5000	69.0000
Point 4	62.5000	66.0000	68.0000	68.0000	70.0000
Point 5	65.0000	68.5000	64.5000	76.0000	73.0000
Point 6	65.0000	64.5000	67.0000	73.0000	66.0000
Average	65.1667	66.7500	67.0000	71.1667	68.6667

4.1.5 Result of HDPE 60% + Kenaf 0% + OPEFB 40%

The sample is divided into 5 regions to do the hardness test. The data are recorded in Table 4.5.

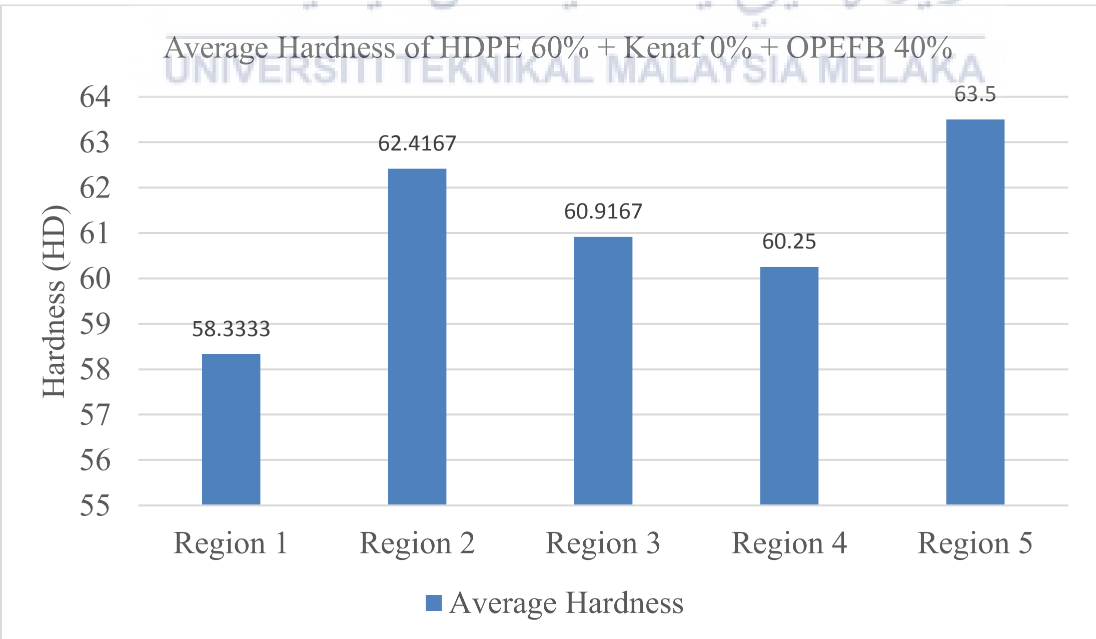


Figure 4-5: Average hardness of HDPE 60% + Kenaf 0% + OPEFB 40%

Table 4-5: Result of hardness for HDPE 60% + Kenaf 0% + OPEFB 40%

Point/Region	Region 1 (HD)	Region 2 (HD)	Region 3 (HD)	Region 4 (HD)	Region 5 (HD)
Point 1	58.0000	64.0000	64.0000	61.0000	63.5000
Point 2	57.0000	64.0000	63.5000	62.0000	60.0000
Point 3	57.0000	62.5000	59.5000	58.5000	66.0000
Point 4	56.5000	62.0000	61.5000	60.5000	63.5000
Point 5	60.5000	61.0000	58.0000	61.0000	61.0000
Point 6	61.0000	61.0000	59.0000	58.5000	67.0000
Average	58.3333	62.4167	60.9167	60.2500	63.5000

4.2 Comparison of Hardness Result for All Formulation

Every sample consists of 5 regions and each region has 6 points to be tested. Each region average has been considered to obtain the average hardness of the sample. The average hardness of each sample and its standard deviation are obtained and tabulated in Table 4.6.

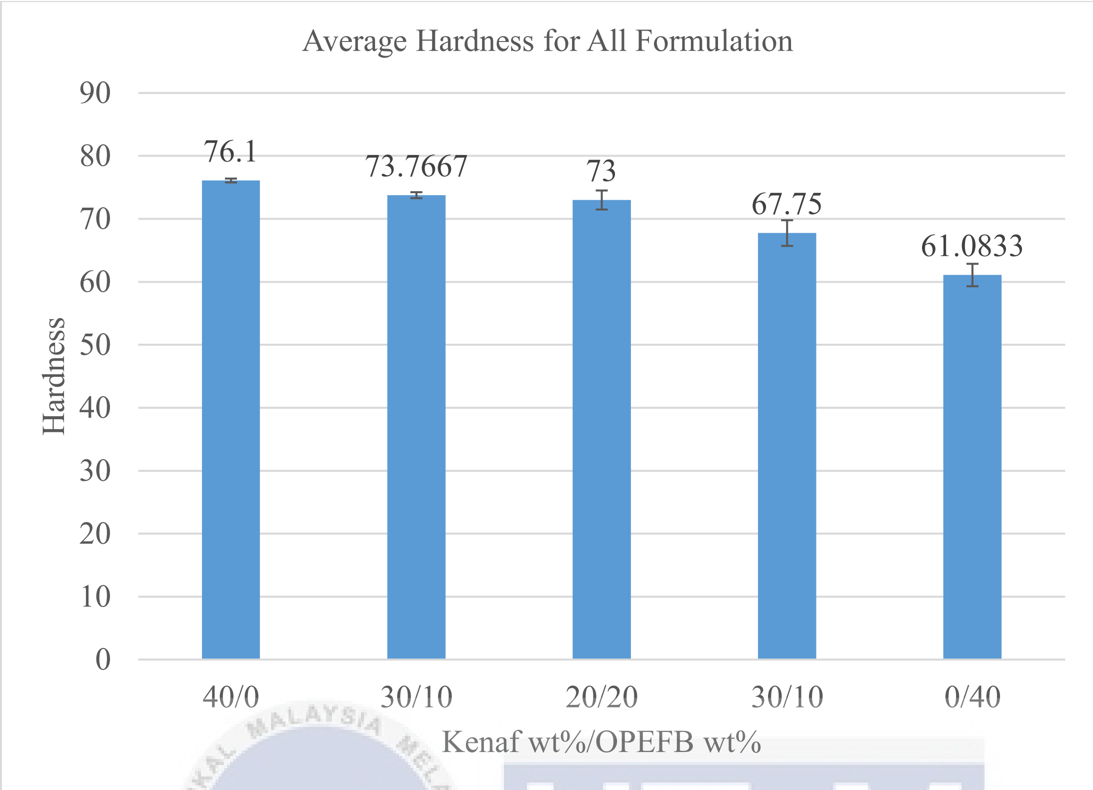


Figure 4-6: Result of average hardness for all formulation

Table 4-6: Result of average hardness for all formulation

Kenaf wt% / OPEFB wt%	Average Hardness (HD)	Standard deviation (HD)
40/0	76.1000	0.3064
30/10	73.7667	0.4755
20/20	73.0000	1.5138
10/30	67.7500	2.0372
0/40	61.0833	1.7834

4.3 Approximate Tensile Modulus

Average hardness of each formulation is converted by using the formula. The result is tabulated in Table 4.7.

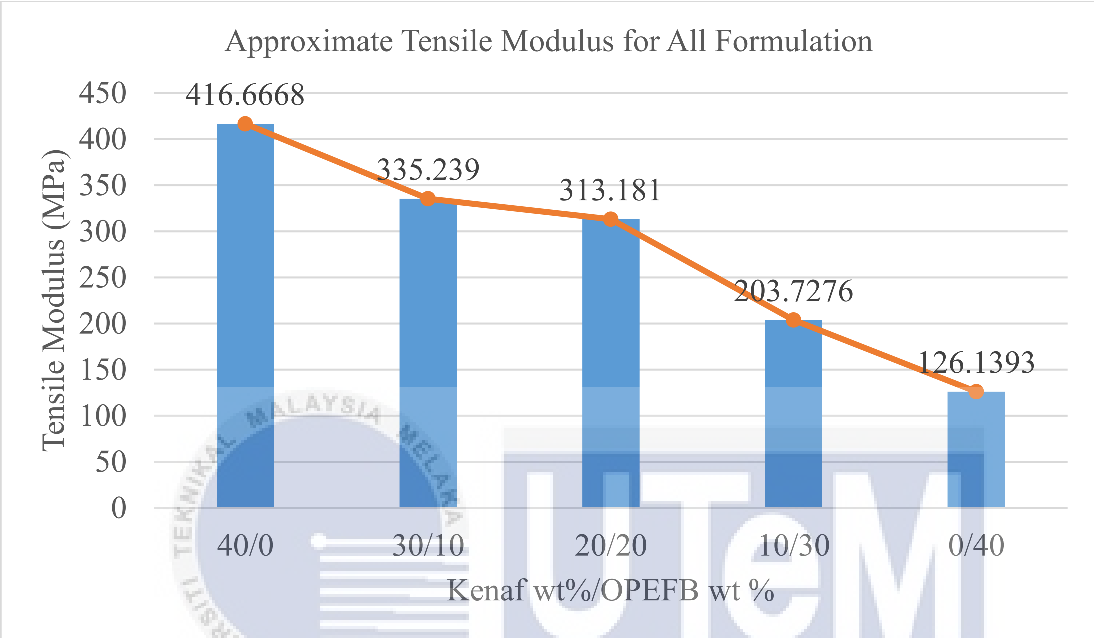


Figure 4-7: Approximate tensile modulus for all formulation

Table 4-7: Approximate tensile modulus for all formulation

Kenaf wt% / OPEFB wt%	Average Hardness (HD)	Approximate Tensile Modulus (MPa)
40/0	76.1000	416.6668
30/10	73.7667	335.2390
20/20	73.0000	313.1810
10/30	67.7500	203.7276
0/40	61.0833	126.1393

4.4 Analysis

For hardness testing, as the wt% of OPEFB increases, the result of hardness testing decreases. From the graph shows that, the sample, which has only Kenaf without OPEFB, owns the highest hardness value that equal to 76.1 HD. Apart from that, the samples which has only OPEFB without Kenaf shows lowest hardness value that equal to 61.0833 HD. The value of the lowest is 19.73% lower from the highest. The samples which have 30 wt% Kenaf + 10wt% OPEFB and 20 wt% Kenaf + 20 wt% OPEFB show the similar values which are 73.7667 HD and 73 HD. The sample of 20wt% Kenaf + 20% OPEFB is 1.04% lower from sample of 30 wt% Kenaf + 10wt% OPEFB. The trendline tally with the trendline that shows by Hamma and the team, which used starch-grafted-polypropylene and Kenaf fibre to make the composite. It shows that increase in Kenaf wt% will increase the hardness of composite [35]. From report of Ewulonu and the team, it shows that the size of fibre OPEFB will affect the hardness of composite. As the size increases, the hardness of composite will decrease. To increase the result a compatibilizer can be used [4]. This may be the reason of the sample which only contains OPEFB show a lower result. From report of Sreekala and the team, when the volume of OPEFB fibre increases, the hardness value will be reduced. There is interrelationship between density and hardness. Generally, the higher the density, the higher the value of hardness. The poor adhesion force of OPEFB with matrix may form cavities that will affect the hardness result [36].

For the approximate tensile modulus result, it shows that the increase in Kenaf wt% will result the increase in tensile modulus. The sample which only has Kenaf without OPEFB give the highest tensile modulus which is 416.6668 MPa. On the other hands, the sample only consists of OPEFB show the lowest result which is 126.1393 MPa. The lowest tensile modulus value is 69.7266% is lower than the highest value. The samples which have 30 wt%

Kenaf + 10wt% OPEFB and 20wt% Kenaf + 20% OPEFB show the similar values which are 335.2390 MPa and 313.1810 MPa. The sample of 20wt% Kenaf + 20wt% OPEFB is 6.5798% lower from sample of 30 wt% Kenaf + 10wt% OPEFB. According to the report Hamma and the team, the increase in fibre loading of Kenaf will increase the value of tensile modulus. From the result can observe that as the hardness increase, the tensile modulus increases [35]. In the result, it shows that the as the Kenaf fibre loading increases, the tensile modulus will increase. This is because the Kenaf fibre has a good adhesion force form with the matrix [37]. Base on the result that provided by Azmi and the team, the hardness and tensile modulus is interrelated. As the hardness increases, the tensile modulus increases [38]. There are different equations that can be used to convert the hardness to the tensile modulus. It is just an approximation. There are factors or limitation that will affect the conversion as the sample hardness can be affect by temperature which may cause degradation in mechanism and material fatigue over time. Not only that, the lower the value of hardness, the more scatter data occur [39].

In term of hybrid natural fibre composite, the samples of 30 wt% Kenaf + 10wt% OPEFB and 20 wt% Kenaf + 20wt% OPEFB show the similar good result. Their value is similar however the standard deviation of sample of 20wt% Kenaf + 20% OPEFB is higher, which equal to 1.5138 HD, compare to other one which standard deviation is 0.4755 HD. The samples of 30 wt% Kenaf + 10wt% OPEFB' s standard deviation is 0.64% from its hardness value. The higher the standard deviation stands for the consistency of result is lower. This may due to the dispersion of natural fibre. From the research of K.L. Pickering and the team, the fibre dispersion bring the significant effect on the properties of natural fibre composite, especially the composite made of short fibre. The length of fibre will affect the tendency of fibre to agglomerate, which will affect the bonding effect of fibre and matrix

[40]. The adhesion force will affect the existence of cavities in the composite which will affect hardness. It can be said that the sample of 30 wt% Kenaf + 10wt% OPEFB can give the best performance among other samples.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This research's aim is to investigate the tensile and hardness properties of novel hybrid oil palm empty fruit bunch/ kenaf reinforced high density polyethylene composite. The wt% of HDPE is fixed at 60 and vary the wt% of Kenaf and OPEFB. There are 5 sets wt% of Kenaf and OPEFB used in this research which are 40/0, 10/30, 20/20, 10/30 and 0/40.

Sample preparation is started with crushing the raw material to obtain the short fibre. Then, the materials are mixed by using the internal mixer according to the desired weight percentage. Then, the mixed composite will be crushed then only spread smoothly and evenly in the mold. Follow up, the mold will be hot-pressed. Initially, the mold is heated for 15 minutes at temperature of 160ºC without pressure. Then, it is hot-pressed with a temperature of 160ºC for 15 minutes under a pressure of 90 kgf/cm^2. After that, it is cooled under the pressure of 90kgf/cm^2 for 15 minutes. After that, the sample is tested by following standard of ASTM D2240 to conduct the hardness test.

Base on the result of hardness and approximate tensile modulus, the sample only consist of the Kenaf fibre show the highest value which is 76.1 HD or 33.8265 N for hardness and 416.6668 MPa for approximate tensile modulus. However, in term of hybrid natural composite, the samples of 30 wt% Kenaf + 10wt% OPEFB show the best result and lowest standard deviation. Its hardness result is 73.7667 HD or 32.7893 N and approximate tensile modulus is 335.2390MPa. Its standard deviation in hardness is 0.4755 HD or 0.2114 N which is 0.64% from its value. It shows that the samples of 30 wt% Kenaf + 10wt% OPEFB is the best sample of hybrid fibre composite in this research. A higher result and lower standard deviation.

The main limitations in this research is the interfacial adhesion of natural fibre and the matrix. A better adhesion can prevent the occurrence of cavities which will result a lower hardness. The other limitation is fibre dispersion which will result an inconsistent result.

5.2 Recommendation for Future Work

Several recommendations for future works on this project are listed as below:

1. Treated fibre should be used
2. Adding of stabilizer or compatibilizer
3. Different fibre length should be tested

Chemical substance can be used to treat the surface of fibre which will enhance interfacial adhesion force of fibre with matrix. Adding the stabilizer or compatibilizer will also improve interfacial adhesion force. In the other researches show that the fibre length will affect the result of mechanical properties. Generally, the smaller fibre length can give better mechanical properties as the it forms a better adhesion force with matrix. It can be concluded that a better interfacial adhesion force of matrix and natural fibre will result better mechanical properties.

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