



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

**EFFECT OF OIL PALM TRUNK (OPT) AND OIL PALM FROND
(OPF) FIBER TO PHYSICAL AND MECHANICAL
PROPERTIES OF POLYURETHANE (PU)**

This report submitted in accordance with requirement of the Universiti Teknikal
Malaysia Melaka (UTeM) for the Bachelor Degree of Engineering Technology
(Maintenance Technology)(Hons.)

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

by

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I hereby, declared this report entitled “Effect of Oil Palm Trunk (OPT) and Oil Palm Frond (OPF) Fiber to Physical and Mechanical Properties of Polyurethane (PU)” is the results of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours. The member of the supervisory is as follow:



Dr Abdul Munir H.S. Lubis
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ABSTRAK

Pada masa kini, industri kelapa sawit menjana sejumlah besar sisa pertanian di Malaysia seperti batang kelapa sawit (OPT), pelepah kelapa sawit (OPF) dan tandan buah kelapa sawit (EFB). Baki terdiri daripada biomass boleh dibangunkan komposit bahan baru, di mana (OPT) dan (OPF) digunakan sebagai tetulang dan Poliuretana Termoplastik (TPU) yang digunakan sebagai matriks. Kajian ini menyiasat kesan batang kelapa sawit (OPT) dan serat pelepah kelapa sawit (OPF) sifat-sifat fizikal dan mekanikal Poliuretana Termoplastik (TPU). Sebelum fabrikasi, gentian telah dirawat dengan 2% natrium hidroksida (NaOH) rawatan dan dikeringkan di bawah matahari. Spesimen sampel komposit dengan empat pecahan jumlah berbeza serat kelapa sawit telah direka, (0% berat, 10 berat %, 20% berat dan 30% berat). Sampel telah disediakan oleh kaedah pengacuan mampatan. Sifat-sifat mekanik komposit telah disifatkan oleh ujian tegangan, ujian lenturan dan ujian hentaman. Interaksi antara gentian dan matriks diperhatikan dari mikrogram elektron imbasan mikroskop (SEM). Ujian tegangan dan ujian lenturan bagi komposit telah dijalankan menggunakan Instron 5960 ruangan dual dan ujian hentaman akan dijalankan oleh impak pendulum. Ketumpatan komposisi menunjukkan penurunan dengan jumlah 1.322 g/m³ pada 0% sehingga 1.186 g/m³ pada 30%. Jumlah tertinggi bagi ujian tegangan adalah 8.389 MPa pada 30% manakala jumlah terendah adalah 7.073 MPa pada 0%. Untuk kekuatan lenturan didapati menurun dengan jumlah 3.587 MPa pada 20% serat di dalam matrik. Ujian hentaman menunjukkan trend yang semakin meningkat dari 4.23 J/m pada 0% sehingga 6.0 J/m pada 30% serat di dalam matrik. Tegangan tegangan, tegangan lenturan dan ujian hentaman meningkat dengan ketara dengan peningkatan serat di dalam matrik.

ABSTRACT

Nowadays, an oil palm industry generates a huge amount of agricultural waste in Malaysia such as oil palm trunk (OPT), oil palm frond (OPF) and oil palm fruit bunch (EFB). The remaining consist of biomass can be developed new material composite, where the (OPT) and (OPF) used as a reinforcement and Thermoplastic Polyurethane (TPU) used as a matrix. This research investigates the effect of oil palm trunk (OPT) and oil palm frond (OPF) fiber to physical and mechanical properties of Thermoplastic Polyurethanes (TPU). Prior to fabrication, the fiber was treated with 2% sodium hydroxide (NaOH) treatment and dried under the sun. Composite sample with four different volume fractions of oil palm fiber were fabricated, (0 wt %, 10 wt %, 20 wt % and 30 wt %). The samples were prepared by compressive molding method. The mechanical properties of composites were characterized by tensile test, flexural test and impact test. Interaction between fiber and matrix was observed by the scanning electron microscope (*SEM*) micrograph. Tensile test and flexural test of the composites were carried out using Instron 5960 dual column tester and the impact tests were conducted by Pendulum Impact Testing Machine. The density composition shows decreasing trend from 1.322 g/m³ at 0% to 1.186 g/m³ at 30%. Tensile strength significantly increases with an increase in fiber loading. The highest value of tensile stress 8.389 MPa at 30% fiber loading and the lowest tensile stress 7.073 MPa at 0% fiber loading. For flexural strength was found decreased 3.587 MPa at 20% fiber loading. Impact energy shows the increasing trend from 4.23 J/m at 0% to 6.0 J/m at 30% fiber loading. Tensile strength, flexural strength and impact energy significantly increased with an increasing of fiber loading.

DEDICATION

Specially dedicated to my beloved father Ab. Razak Bin Ab. Rahim and beloved mother Nik Bte Ali, brothers and sisters, to all family members, lecturers and friends.



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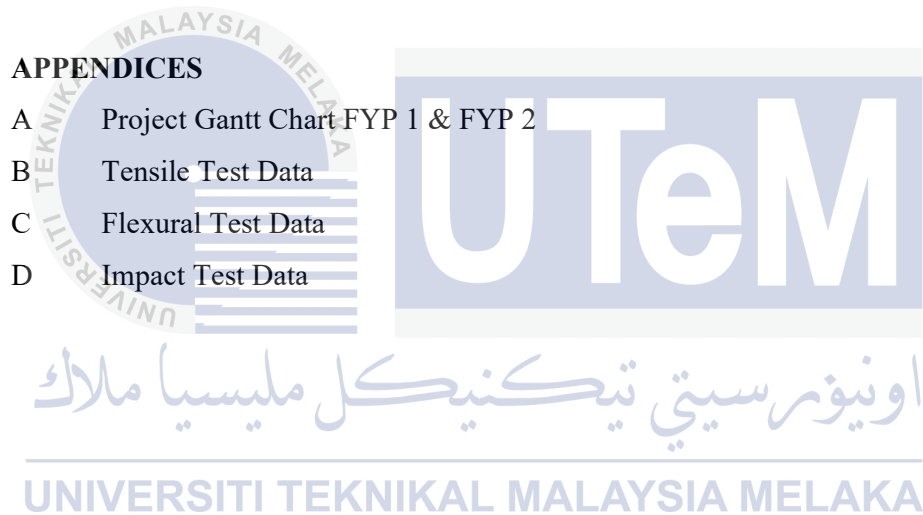
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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

OPT	-	Oil Palm Trunk
OPF	-	Oil Palm Frond
PU	-	Polyurethane
EFB	-	Empty Fruit Bunch
MMCs	-	Metal Matrix Composites
PMCs	-	Polymer Matrix Composites
CMCs	-	Ceramic Matrix Composites
nm	-	nano meter
FRP	-	Fiber Reinforced Plastic
wt%	-	Weight Percentage
MDI	-	Methylene Diphenyl Diisocyanate
MEKP	-	Methyl Ethyl Ketone Peroxide
CO ₂	-	Carbon Oxide
FYP1	-	Final Year Project 1
FYP2	-	Final Year Project 2
UTM	-	Universal Testing Machine
ASTM	-	American Standard Testing Machine
MPa	-	Mega Pascal
J/m	-	Joule per Meter
g/m ²	-	Gram per Meter Square

CHAPTER 1

INTRODUCTION

1.0 Background of Study

Nowadays, oil palm industry grows up with quickly, almost very little room remains for any significant increase in oil palm plantations in Peninsular Malaysia. As such, all future growth is expected to be in Sabah and Sarawak. Nowadays, is the one biggest oil palm produce and presently creates around 6.5 million metric huge amounts of world palm oil generation, (Law and Jiang, 2001). Currently, a total of 3.5 million hectares of oil palm plantations, while the statistic of oil palms production for the year 2001 was 11.8 million tons (Hussin et al. 2002). Usually the lifespan of a palm tree has about 25 years; it can contribute high amount of agricultural waste in Malaysia. According to Khalid et al. (2008) the oil palm that dispersed all areas they had turned into an essential part in economy of the south east asia. However, oil palm industries produce a large amount of solid waste called biomass. Malaysia has produced about 70 million tons of oil palm biomass, including trunks, fronds and empty fruit bunches in 2006, (Yacob, 2007) and within a year millions of tons of oil palm biomass was produced by Malaysian palm oil industry. (Rozman et al. 2005).

An oil palm industry generates a huge amount to agricultural waste in Malaysia such as oil palm trunk (OPT), oil palm frond (OPF) and oil palm empty fruit bunch (EFB). In Malaysia oil palm trunk (OPT) and oil palm frond (OPF) biomass has many uses, because oil palm fiber are very multifunction and versatile, they can be processed into various dimensional grades to suit specific applications and can be used by manufactures to make various fiber composites such as furniture, infrastructures, mattress and many more. Other than that, Thakur et al. (2012) and

Bhowmick et al. (2012) stated that oil palm trunk (OPT) and oil palm frond (OPF) fibre is kind of natural fibres that very lightweight, can absorb a lot of water without congealing, renewable in nature, high modulus and specific strength properties. It also can withstand extremes temperature and moisture condition.

1.1 Problem Statement

Malaysia is the largest producer of palm oil in the world and through this activity, it produces huge production of biomass such as trunk, frond and empty fruit bunches. Therefore, huge quantities of these residues are generated and largely unutilized and cause problem to the environment. Thus, in order to manage the waste involved demand special attention from various segments of society. Currently, in Malaysia, we have about 7 million tons of oil palm trunks per year for replanting and burned, creating massive pollutions and economic problems. Sreekala et al. (1997) stated that when left on the plantation floor, these materials create great environmental problem. For this reason, economic utilization of these fibers will be beneficial. Therefore, with minimize and reuses the waste are important thing to recover the environmental problem. This project uses thermoplastic polyurethane (TPU) as the matrix for the composite. Polyurethanes are a standout amongst the most flexible plastic and adaptable materials, which demonstrate diverse practices by changing the proportion of their segments. Thermoplastic polyurethanes (TPU) are a subcategory of copolymers called thermoplastic elastomers (TPE). They were one of the first segmented copolymers to be made commercially available. To overcome this, the effect of oil palm trunk (OPT) and oil palm frond (OPF) fiber with addition of thermoplastic polyurethane (TPU) is still not much known. Not so many people nowadays discuss about the oil palm fibers and thermoplastic polyurethane (TPU). In several research had found with addition of composite to the natural fibres has given the highest tensile strength and flexural strength (Yusof et al. 2010). Other word, chance to find the use of palm fiber in the composite fiber will open a new market in the world for what would normally be considered waste or low value products.

1.2 Objective

Based on the introduction and problem statement above, the objective of this study are as follows:-

- i. To investigate effect of different ratio of OPT/OPF fiber to tensile test properties of Thermoplastic Polyurethane (TPU)
- ii. To investigate effect of different ratio of OPT/OPF fiber to flexural test properties of Thermoplastic Polyurethane (TPU).
- iii. To investigate effect of different ratio of OPT/OPF fiber to impact test properties of Thermoplastic Polyurethane (TPU).

1.3 Scope

These scopes are determined in order to achieve the objective:-

- i. Prepare the sample of oil palm trunk (OPT) and oil palm frond (OPF) fibres reinforced with thermoplastic polyurethane (TPU).
- ii. Test the sample by performing the mechanical properties test such as: -
 - Test using tensile testing machine ASTM D638
 - Test using standard flexural testing machine ASTM D790
 - Test using notched bar impact testing machine ASTM D256

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction of Composite

Nowadays, composite materials have changed the world of materials uncovering materials which are unique in relation to basic heterogeneous materials. The composite material can be classified as a combination of two or more materials. Example of composite material to reinforcing phase is in the form of fibers, flakes, and particles. Besides that, another word for composite material embedded in other materials are known as matrix phase. According Jartiz A. E (1965) composites are multifunctional material frameworks that give qualities not possible from any discrete material. They are strong structures made by physically joining two or more good materials, distinctive in organization and qualities and once in a while in structure. In several study, the composites are compound materials which vary from combinations by the way that the individual parts hold their qualities yet are so joined into the composite as to take advantage just of their traits and not of their deficiencies, in order to obtain improved materials, (Nucleus et al. 1966). Van Suchetclan et al. (1977) explained clarifies composite materials as heterogeneous materials comprising of two or more strong stages, which are in intimate contact with each other on a minute scale. They can be likewise considered as homogeneous materials on an infinitesimal scale as in any bit of it will have the same physical property. Kelly A (1967) stated very clearly that the composites ought not to be viewed straightforward as a blend of two materials. In other word, the blend has its own specials properties. The reinforcing material and the matrix material can be metal, ceramic, or polymer. Composites typically have a fibers or particle phase that

is stiffer and stronger than the continuous matrix phase and serve as the principal load carrying members.

Composites, the wonder materials are becoming an essential part of today's materials due to the advantages such as low weight, corrosion resistance, high fatigue strength, and faster assembly. They are extensively used as materials in making aircraft structures, transportation, aerospace, automotive industry, sport equipment, electronic packaging to medical equipment, and space vehicle to home building (M.K. Chryssanthopoulou, 2010). This is because the composite material has their own special properties. According F.C Cambell (2010) the main advantages of composite materials are many, including lighter weight, the ability to tailor the layup for optimum strength and stiffness, improved fatigue life, allowing for a weight reduction in the finished part, corrosion resistance, and with good design practice, reduced assembly costs due to fewer detail parts and fasteners. In terms of strength to resistance to heat or some other desirable quality, it is better than either of the components alone or radically different from either of them. According Callister W. D. (2007) stated that, most composites have been created to improve combinations of mechanical characteristics such as stiffness, toughness, and ambient and high-temperature strength.

2.2 Classification of Composite Materials by Matrix

According M. Neitzel (1998) based on its matrix; composite material can be classified into metal matrix composites (MMCs), ceramic matrix composites (CMCs), and polymer matrix composites (PMCs) as shown in the Figure 2.1. The classifications according to types of reinforcement are particulate composites (composed of particles), fibrous composites (composed of fibers), and laminate composites (composed of laminates). Fibrous composites can be further subdivided on the basis of natural/biofiber or synthetic fiber. Biofiber encompassing composites are referred to as biofiber composites. They can be again divided on the basis of matrix, that is, non biodegradable matrix and biodegradable matrix (Nicoleta, I. and Hickel, H. 2009). Bio-based composites made from natural/biofiber and biodegradable polymers are referred to as green composites. These can be further

subdivided as hybrid composites and textile composites. Hybrid composites comprise of a combination of two or more types of fibers. Many different combinations of reinforcement and matrix materials are used to produce composite materials. Most composites comprise of a bulk material (matrix) and reinforcement or something to that affect, added basically to expand the quality and increase the strength and stiffness of the matrix. Depending on type of matrix used, the composite may be classified as: -

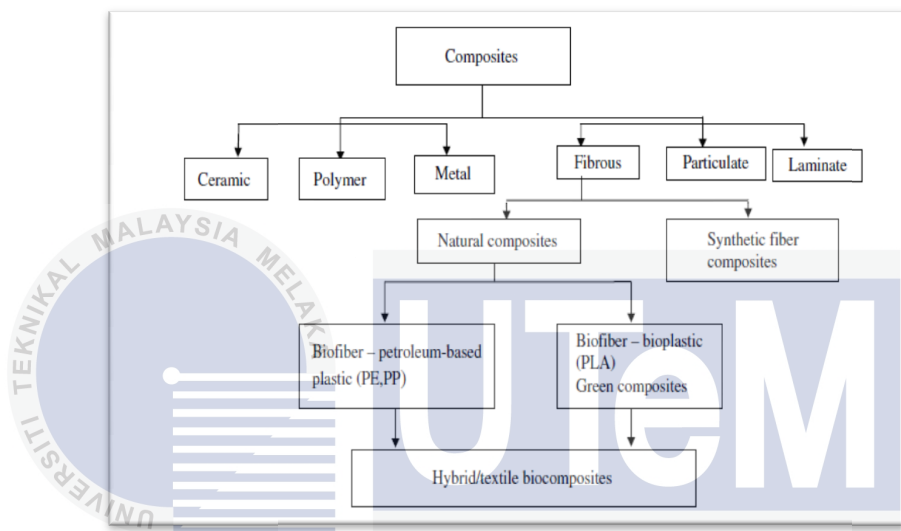


Figure 2.1: Classification of Composites (Bunsell, A.R. and Harris, B. 1974)

2.2.1 Metal Matrix Composite

Metal matrix composite materials have been so intensely researched over the past years that much new high strength to weight materials have been produced. Most of these materials have been developed for the aerospace industries, but some are being used in other applications such as automobile engines. Pradeep R et al. stated that metal matrix material has their own properties like hardness strength, fracture toughness and stiffness. Metal matrix can withstand elevated temperature in corrosive environment than polymer composites. Titanium, aluminium and magnesium are the popular matrix metals currently in vogue, which are particularly

useful for aircraft applications. Because of these attributes metal matrix composites are under consideration for wide range of applications viz. combustion chamber nozzle (in rocket, space shuttle), housings, tubing, cables, heat exchangers, structural members etc. According D. Verma et al. (2012) metal matrix composites possess some attractive properties, when compared with organic matrices. Example attractive properties are great quality and good strength at higher temperature, higher transverse strength, excellent electrical and superior thermal conductivity, and higher erosion resistance. However, the major disadvantage of metal matrix composites is their higher densities and consequently lower specific mechanical properties compared to polymer matrix composites.

2.2.2 Ceramic Matrix Composite

Ceramic matrix composites have been developed recently with improved mechanical properties such as strength and toughness over the unreinforced ceramic matrix. Naturally it is hoped and indeed often found that there is a concomitant improvement in strength and stiffness of ceramic matrix composites. Ceramic materials are inorganic, non-metallic materials made from compounds of a metal and a non-metal. Ceramic materials may be crystalline or partly crystalline. They are formed by the action of heat and subsequent cooling. Clay was one of the earliest materials used to produce ceramics, but many different ceramic materials are now used in domestic, industrial and building products. According Callister W. D. (2007) ceramic materials tend to be strong, stiff, brittle, chemically inert and non-conductors of heat and electricity, but their properties vary widely. For example, porcelain is widely used to make electrical insulators, but some ceramic compounds are superconductors. Ceramic fibres, such as alumina and SiC (Silicon Carbide) are advantageous in very high temperature applications and also where environment attack is an issue. Since ceramics have poor properties in tension and shear, most applications as reinforcement are in the particulate form (e.g. zinc and calcium phosphate). Ceramic Matrix Composites (CMCs) used in very high temperature environments, these materials use a ceramic as the matrix and reinforce it with short fibres, or whiskers such as those made from silicon carbide and boron nitride.

2.2.3 Polymer Matrix Composite

A fibre reinforced polymer is a composite material consisting of a polymer matrix imbedded with high strength fibers, such as glass, aramid, and carbon. Generally, polymers can be classified into two classes, which is thermoplastic and thermosetting. . A very large number of polymeric materials, both thermosetting and thermoplastic, are used as matrix materials for the composites. Most commercially produced composites use a polymer matrix material often called a resin solution. There are many different polymers available depending upon the starting raw ingredients.

Polymer matrix composite PMC is the materials that consist of a polymer (resin) matrix combined with a fibrous reinforcing dispersed phase. Polymer matrix composites are very popular due to their low cost and simple fabrication method. Polymer matrix composites are very popular due to their low cost and simple fabrications methods. Using the non-reinforced polymer as structure materials is limited due to the low level of their mechanical properties: tensile strength of one of the strongest. Most commonly used matrix materials are polymeric. In general, the mechanical properties of polymers are inadequate for many structural purposes. In particular, their strength and stiffness are low compared to metals and ceramics. These difficulties are overcome by reinforcing other materials with polymers. Secondly the processing of polymer matrix composites need not involve high pressure and doesn't require high temperature. Today glass also equipment's required for manufacturing polymer matrix composites are simpler. For this reason, polymer matrix composites developed rapidly and soon became popular for structural applications. Today glass reinforced polymers are still by far the most popular composite materials in terms of volume advantages with the exception of concrete (F. L. Matthews, and R. D. Rawlings, 2002). There are also have disadvantage of PMCs. The main disadvantages are their low maximum working temperature, high coefficient of thermal expansion, dimensional instability, and sensitivity to radiation of moisture. Absorption of water from the environment may cause harmful effect which degrades the mechanical performance, including swelling, formation of internal stress and lowering of the glass transitions temperature (F. L. Matthews, and R. D. Rawlings, 2002).

2.3 Component of Polymer Matrix Composite

There are four major components in polymer composites; which are the matrix, filler, reinforcement and solid lubricant:-

2.3.1 Matrix

Most composites consist of a bulk material (matrix) and a reinforcement of some kind, added primarily to increase the strength and stiffness of the matrix (Verma et al. 2012). The matrix is the substance that available in the composite which the reinforcement embedded or two-phase microstructure in which a second phase is dispersed. In other words, that there is a path through the matrix to any point in the material, unlike two materials sandwiched together. The matrix phase of composite can may be a metal, polymer or ceramic.

In general, metals and polymer are used as a matrix when some ductility is desirable (F.L. Matthews, and R.D. Rawlings, 2002). The matrix isolates the fibres from one another in order to prevent abrasion and formation of new surface flaws and acts as a bridge to hold the fibres in place. A good matrix should possess ability to deform easily under applied load, transfer the load onto the fibres and evenly distributive stress concentration. According N K Gupta and R Velmurugan (2002) a good matrix for a composite material is thermally compatible, means both of fibers and matrix should have same co-efficient of thermal expansion. Others is chemically compatible (matrix shouldn't react with fibers) and physical compatible with both. The matrix gives compression strength to composite. The matrix material can be introduced to the reinforcement before or after the reinforcement material is placed into the mould cavity or onto the mould surface. The composite is designed so that the mechanical loads to which the structure is subjected in service are supported by the reinforcement. The function of the relatively weak matrix is to bond the fibers together and to transfer loads between them.

2.3.2 Filler

Fillers are particles added to material (plastics, composite material, concrete) to lower the consumption of more expensive binder material or to better some properties of the mixture material. Filler also materials are most often added to polymers to improve tensile and compressive strengths, abrasion resistance, toughness, dimensional and thermal stability, and other properties. Materials used as particulate fillers include wood flour (finely powdered sawdust), silica flour and sand, glass, clay, talc, limestone, and even some synthetic polymers. Particle sizes range from 10 nm to macroscopic dimensions.

Polymers that contain fillers may also be classified as composite materials. Often the fillers are inexpensive materials that replace some volume of the more expensive polymer, reducing the cost of the final product. In some cases, fillers also enhance properties of the products, e.g. in composites. In such cases, a beneficial chemical interaction develops between the host material and the filler. As a result, a number of optimized types of fillers, nano-fillers or surface treated goods have been developed.

2.3.3 Reinforcement

Reinforcement is the material contained in the composite is intended to improve the mechanical properties mechanical properties such as hardness, tensile, flexural and so on. This is because all of the different fibres used in composites have different properties and so affect the properties of the composite in different ways (Verma et al. 2012). According Alvrez V.A et al. (2003) stated reinforcement is intended to strengthen the power of the matrix becomes stronger and harder and able to change the mechanism to fail in the composite. This is because the number of elongation should not occur and no composite must behave as brittle as possible. The mechanical properties of composites include the functions of shape, dimensions and orientations of fiber reinforcement and also the quality interactions among them. Reinforcement can be both natural and man-made. Many materials are capable of

reinforcing polymer. Some materials, such as the cellulose in wood are naturally occurring product (F.L. Matthews, and R.D. Rawlings, 2002).

Reinforcement for the composite can be in many types, example like fiber, fabric, particle of whiskers. For the type of fibers can forms, from continuous fibers to discontinuous fibers, long fibers to short fibers and organic fibers to inorganic fibers. Fibers reinforced plastic (FRP) is a composite material made of a polymer matrix reinforced fibers whereas the fibers are usually glass, carbon, aramid and boron. Besides that, continuous fibers or long fibers are widely used for applications of pultrusion, braiding, weaving and filament winding. In addition, most thermoset and thermoplastic resin system are being used together with continuous fibers. The effectiveness of reinforcement essentially depends on the adhesion between the matrix and fiber, so this is a key factor in determining the final properties of the composite material, particularly its mechanical properties (Etcheverry and Barbosa, 2012). Figure 2.2 shows the type of reinforcement in composites can be classified as:-

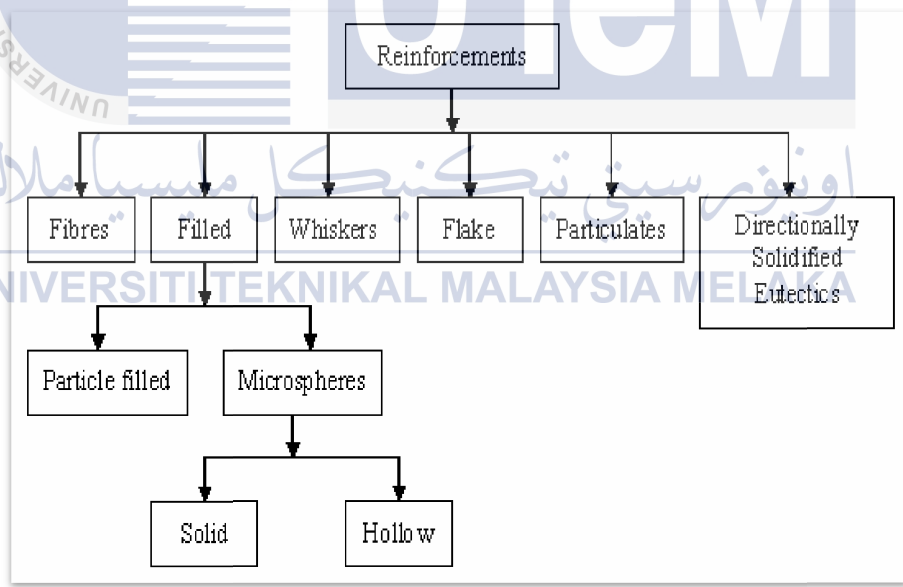


Figure 2.2: Classification of Reinforcement (Verma et al. 2012)

2.3.4 Solid Lubricant

For modern equipment today, solid lubricant is the appropriate substance to be used in manages the heavy services and heavy applications of the equipment. For the heavy application condition, solid lubricant can be used to reduce wear and friction (Erdimer, 2011). Different to the other type of lubricant, solid lubricant are preferred to be used when the operating condition of lubricating film cannot be secured by use of lubricating oils or grease. In applying difficulty application such as sealing problem, weight or other factors like environmental condition, oil and grease is inappropriate substance to been used (Miyoshi. K. 2007). Graphite and molybdenum disulfide (MoS_2) are ordinary substances that have been used as a solid lubricant. Graphite and molybdenum disulfide (MoS_2) are in the dry powder form. It also can be operate in high temperature and high load. They are used either in the dry powder form or with binders to make them stick firmly to the metal surfaces while in use. They are available as dispersions in unstable carriers like soaps, fats, waxes, etc and as soft metal films. In claim of (Cizaire, L. 2002 and Tannous, J. 2010) inorganic fullerenes-like (IF) have received great attention to the tribology application due to generate a new friction modifier and anti-wear additives in lubricating oil.

Solid lubricants are basically composed of inorganic or organic solid compounds such as graphite, molybdenum disulfide, talcum, etc. According to Menezes et al., (2013), a solid lubricant does not evaporate at high temperatures and can also withstand harsh operating and environmental conditions. Solid lubrication is often referred to as the substance that provides lubrication between two contacting surfaces in relative motion under dry conditions. Bhushan (2013) stated that, solid lubricants are materials which show the characteristics of low friction and low wear under sliding with the absence of external supply of lubricants. Graphite and molybdenum disulfide are the most used as solid lubricants due to their low friction qualities and slippery nature. The application of solid lubricants are under the condition which fluid lubricants are considered ineffective usually in applications involving high vacuum, very high temperature, cryogenic temperature, excessive dust or in corrosive environments.

2.4 Type of Polymer Matrix Materials

Properties of different polymers will determine the application to which it is appropriate. The chief advantages of polymers as matrix are low cost, easy process ability, good chemical resistance, and low specific gravity. On the other hand, low strength, low modulus, and low operating temperatures limit their use (Huang, H. and Talreja, R. 2006). The response of a polymer to mechanical forces at elevated temperatures is related to its dominant molecular structure. In fact, one classification scheme for these materials is according to behaviour with rising temperature. Varieties of polymers for composites are thermoplastic polymers, thermosetting polymers, are the two subdivisions.

2.4.1 Thermosetting Polymer

Thermosets have cross-linked or network structures with covalent bonds with all molecules. They do not soften but decompose on heating. Thermosetting resins are usually low-viscosity liquids or low molecular weight solids that are formulated with suitable additives known as cross-linking agents to induce curing and with fillers or fibrous reinforcements to enhance both properties and thermal and dimensional stability (Marino Xanthos, 2010). Once solidified by cross-linking process they cannot be reshaped. Common examples are epoxies, polyesters, phenolics, ureas, melamine, silicone, and polyimides. Thermosetting polymers are network polymers. They become permanently hard during their formation and do not soften upon heating. Network polymers have covalent cross links between adjacent molecular chains. During heat treatments, these bonds anchor the chains together to resist the vibrational and rotational chain motions at high temperatures. Thus, the materials do not soften when heated. Cross linking is usually extensive, in that 10% to 50% of the chain repeats units are cross linked. Only heating to excessive temperatures will cause severance of these crosslink bonds and polymer degradation. Thermoset polymers are generally harder and stronger than thermoplastics and have better dimensional stability. Most of the cross linked and network polymers, which

include vulcanized rubbers, epoxies, phenolics, and some polyester resins, are thermosetting.

2.4.1.1 Epoxy Resin

Epoxy resins represent some of the highest performance resins of those available at this time. Epoxies generally out-perform most other resin types in terms of mechanical properties and resistance to environmental degradation, which leads to their almost exclusive use in aircraft components. As a laminating resin their increased adhesive properties and resistance to water degradation make these resins ideal for use in applications such as boat building. Here epoxies are widely used as a primary construction material for high-performance boats or as a secondary application to sheath a hull or replace water-degraded polyester resins and gel coats. With correct additives, epoxy resins can exhibit outstanding resistance to heat (some up to 290°C) and electrical insulation properties. They can be either liquid or solid form and can be formulated to cure either at room temperature or with the aid of heat. Heat curing is more common for situations where maximum performance is required. Epoxies generally cure more slowly than other thermoset resins.

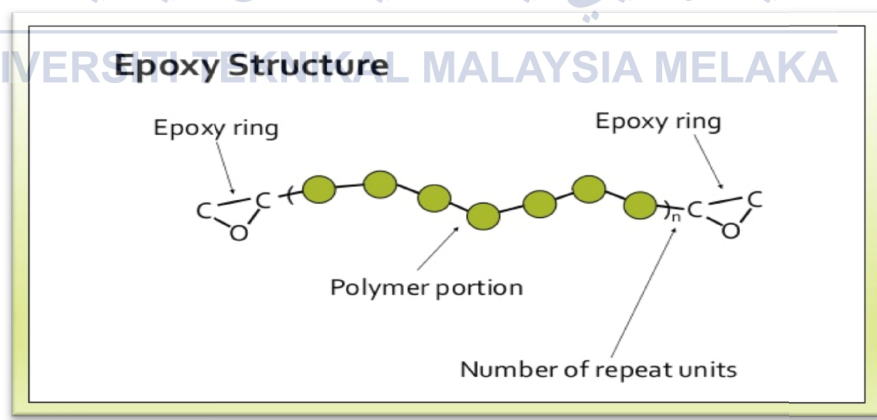


Figure 2.3: Epoxy Resin Chemical Structure (Biswajit Maity, 2012)

2.4.1.2 Polyurethane

Polyurethanes find plenty of applications in a wide range of engineering works including in the biomedical field. Polyurethane is a class of polymer containing organic segments joined to each other by urethane linkages. Polyurethanes are versatile materials, which show different behaviours by varying the ratio of their components. Their behaviour can vary from a soft (elastomeric) to a rigid (brittle) behaviour. They diversify widely in composition and can be designed to possess either soft or stiff mechanical characteristics according to the intended end-use with the proper control of their molecular structure. Besides their versatility, polyurethanes have moderate price. Some examples of market segments in which polyurethanes are found are construction, flexible packaging, footwear, synthetic leather and automotive industry (John Willey et al. 2010). Basically, polyurethanes are a broad group of polymers that contain a common urethane linkage, obtained by the reaction of polyol with isocyanate. Petroleum based polyols are usually applied on industrial applications, but many papers have presented the possibility of applying vegetal oils as polyol (M. He et al. 2011). Due to concerns over the depletion of petroleum resources, extensive research has been concentrating on developing bio-based polyols and PU products from renewable sources (C. Wan et al. 2012). Castor oil-based polyurethane is a useful, versatile material and widely used as an individual polymer possessing network structure because of its good flexibility and elasticity (A.R. Goncalves, 2011). It contains about 90% (wt/wt) of ricinoleic acid. This triglyceride contains hydroxyl groups in its chain which react with isocyanate groups to form urethane links (P.M. Fredericks et al. 2007). Different types of polyols are also available, allowing the development of many polyurethane polymers. The material studied on this research was composed by castor oil, as polyol, and MDI as diisocyanate. MDI is a molecule with two aromatic isocyanate groups of equal reactivity. It is used where high tensile strength, toughness and heat resistance is required and its lower volatility makes easier to handle (M. He et al. 2011).

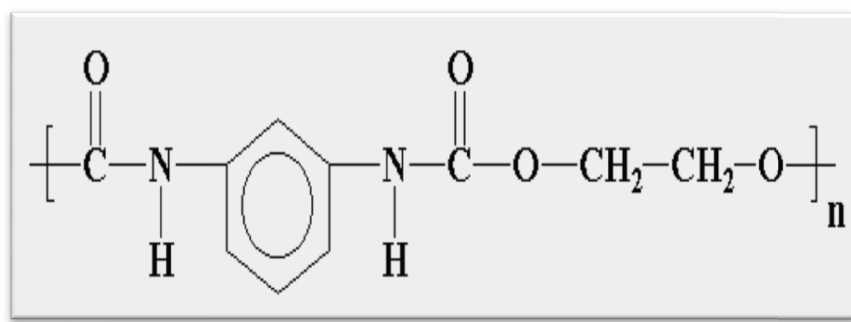


Figure 2.4: Polyurethane chemical structure
(Source: <http://www.pslc.ws/macrog/urethane.htm>)

2.4.2 Thermoplastic Polymer

A thermoplastic consists of linear or branched chain molecules having strong intermolecular bonds but weak intermolecular bonds. They can be reshaped by application of heat and pressure and are either semi crystalline or amorphous in structure. Examples include polyethylene, polypropylene, polystyrene, nylons, polycarbonate, polyacetals, polyamide-imides, polyether ether ketone, polysulfone, polyphenylene sulfide, polyether imide, and so on. Thermoplastics soften when heated (and eventually liquefy) and harden when cooled processes that are totally reversible and may be repeated. On a molecular level, as the temperature is raised, secondary bonding forces are diminished (by increased molecular motion) so that the relative movement of adjacent chains is facilitated when a stress is applied. Irreversible degradation results when a molten thermoplastic polymer is raised to too high a temperature. In addition, thermoplastics are relatively soft. Most linear polymers and those having some branched structures with flexible chains are thermoplastic. These materials are normally fabricated by the simultaneous application of heat and pressure. Examples of common thermoplastic polymers include polyethylene, polypropylene, polystyrene, poly (ethylene terephthalate), and poly (vinyl chloride).

2.4.2.1 Polypropylene (PP)

Polypropylene is a semi-crystalline polymer that is used widely due to its unique combination properties, the cost and due to it is easy fabrication. Polypropylene can be process by a variety of fabrication technique such as injection moulding and profile extrusion. Polypropylene is an economical material that offers a combination of outstanding physical, chemical, thermal and electrical properties. Polypropylene has excellent resistance to organic solvent and electrolytic attack. This polymer has lower impact strength but better working at temperature and tensile strength than polyethylene. Furthermore, this polymer has excellent resistance to acids and alkalises but poor aromatic, aliphatic and chlorinated solvent resistance.

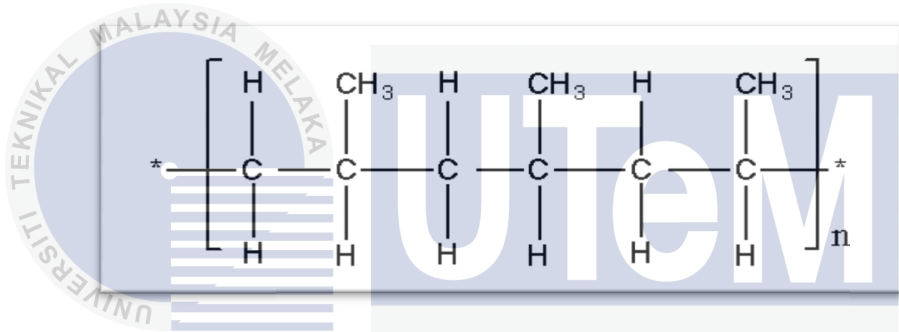


Figure 2.5: Polypropylene chemical structure

(Source: <https://prezi.com/wpzmd6rw1gca/polypropylene/>)

2.4.2.2 Thermoplastic Polyurethane

Amongst all the grades of polyurethanes, TPU is the most widely used material. This is because of its higher mechanical strength, excellent abrasion resistance, ease in processing and bio-compatibility. TPU is a block copolymer composed of hard segments and soft segments arranged in a (A-B-A) fashion. The soft segment is prepared by the reaction between the polyol and the diisocyanate, but hard segment is formed by the reaction between the diisocyanate and the chain extender. Phase separation (segregation) between the hard and soft segments occurs

due to the difference in secondary forces (van der Waals, dipole-dipole, H-bonding interactions, etc. (Hepburn, 1982). Thus, the degree of segregation between the hard and soft segments depends on the extent of interaction of the hard segments with each other and also with the soft segments (Senich and Macknight, 1980). The phase segregation is less pronounced in polyester polyurethane than in polyether polyurethane and is most pronounced in polybutadiene based polyurethane. Also a drastic development in phase segregation and domain organization can be encountered due to the incorporation of urea moiety in the hard segment (Bonart et al. 1974), which causes improved mechanical strength such as higher mechanical properties, lower hysteresis, greater toughness and slower rate of stress relaxation (Sung et al. 1980). Phase separation increases with increasing chain length of soft segment or with the increasing polarity leading to lesser hard-soft segment interactions.

Despite several advantages, TPU suffers from lower thermal stability and flame retardancy as compared to other engineering thermoplastics (polyether imides, polyether esters etc.) for similar applications (Holden et al. 2004).

2.5 Reinforcement Material Composite

Reinforcement can be in many types such as whisker, fiber, fabric and particle. For this research study, will be focuses on fibers, for the type of fibers can forms, from continuous fibers to discontinuous fibers, long fibers to short fibers and organic fibers to inorganic fibers. Hence, for the organic fibers will classify as:-

2.5.1 Natural Fiber

Natural fibers form an interesting alternative for the most widely applied fiber in the composite technology, which is glass. Recent researches have shown that these aspects can be improved considerably. Knowing that natural fibers are cheap and have a better stiffness per weight than glass which results in lighter components (P.D. Bhanawat et. al. 2012), the grown interest in natural fibers is clear. Secondly,

the environmental impact is smaller since the natural fiber can be thermally recycled and fibers come from a renewable resource. These fibers have special advantage in comparison to synthetic fibers in that they are abundantly available, from a renewable resource and are biodegradable. But all natural fibers are hydrophilic in nature and have high moisture content, which leads to poor interface between fiber and hydrophobic matrix. Several treatment methods are employed to improve the interface in natural fiber composite (Geethamma, V.G. et. al (1998). Their moderate mechanical properties restrain the fibers from being used in high-tech applications, but for many reasons they can compete with glass fibers. According to Schaffer et. al. (1999), composites are materials formed by uniting two or more basic materials in which one material, called the reinforcing phase is in form of fibres, sheets or particles, embedded in another material called the matrix.

The most common applications for fibre reinforces composites are as structural materials where rigidity, strength, and low density are important. Examples of some current applications of composites include the diesel piston, brake shoes and pad, tires, and the Beech craft aircraft in which 100% of the structural component are composites (Schaffer et al. 1999). Other form of composites that are very popular nowadays and easily available from the natural resources are natural composite (natural fibres). The examples of natural fibres are cotton, flax, jute, hemp, ramie, wood, straw, hair, wool, palm, coconut, banana and silk. In recent years, the use of natural fibres as reinforces in the fibre thermoplastic composites has been of great interest, particularly to automotive industry. These fibres have many advantages such as low density, high specific strength and modulus, relative non-abrasiveness, ease of fibre surface modification, wide availability and renewability (Krishnan, 1987).

2.5.2 Oil Palm Fiber (OPF)

Oil palm industries generates massive quantities of oil palm biomass such as oil palm trunk (OPT), oil palm frond (OPF) and oil palm empty fruit bunch (EFB) as shown in Figure 2.6. The OPF and OPT generated from oil palm plantation while the oil palm EFB from oil palm processing. Several studies showed that oil palm fibres have the potential to be an effective reinforcement in thermoplastics and

thermosetting materials (Khalil et al. 2008). In order to develop other applications for oil palm fibres they need to be extracted from the waste using a retting process. Oil palm frond (OPF) is one of the most abundant by-products of oil palm plantation in Malaysia. Oil palm fronds are available daily throughout the year when the palms are pruned during the harvesting of fresh fruit bunches for the production of oil. OPF contains carbohydrates as well as lignocellulose and it amounting to 24 million tons/year discharged from oil palm mills. Oil palm frond, consisting of leaflets and petioles, is a by-product of the oil palm industry in Malaysia and their abundance has resulted in major interest in their potential use for livestock feed (Dahlan, 2000). OPF are left rotting between the rows of palm trees, mainly for soil conservation, erosion control and ultimately the long-term benefit of nutrient recycling (Abu Hassan, 1994). The large quantity of fronds produced by a plantation each year makes these a very promising source of roughage feed for ruminants.

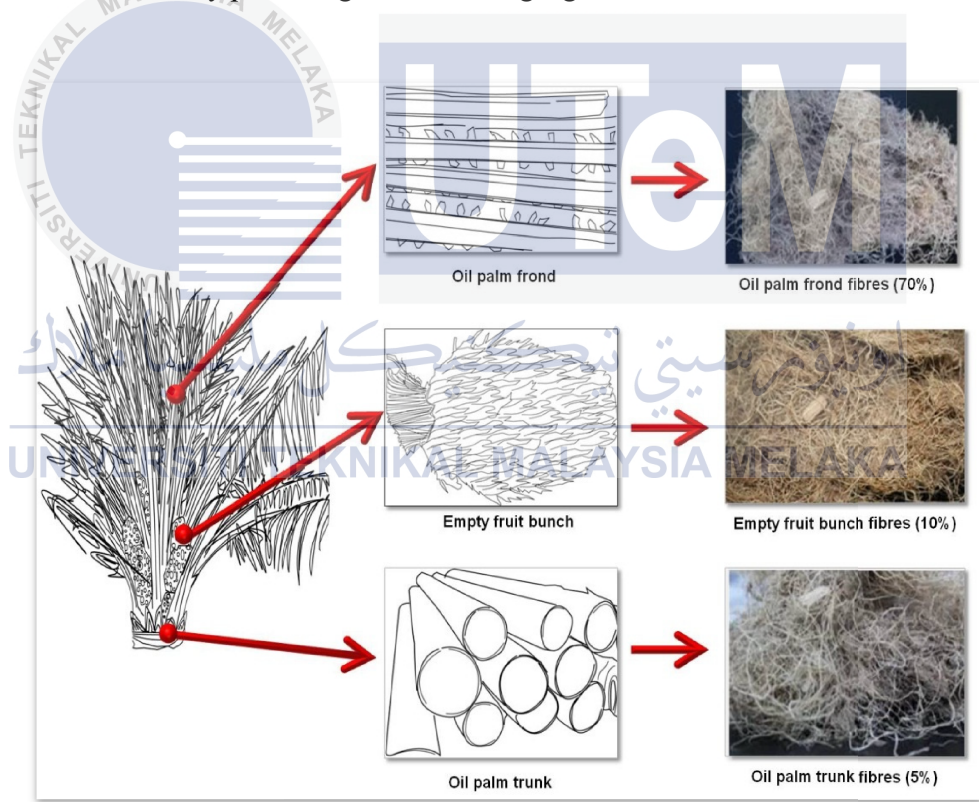


Figure 2.6: Oil Palm Biomass Fibers from Oil Palm tree (Khalil et al. 2012)

2.6 Polyurethane Matrix Composites

According Yildiz et al. (2009) defined that, Polyurethane (PU) matrix composite is very important in group of polymer which is has a wide range of applications such as automotive, construction and sport materials. Polyurethane (PU) are available in the form of bulk, films or foams. Their properties can be customized with different polyols and isocyanates (Callister W. D. 1994). Isocyanates are the hard rigid segments giving the strength and polyols are the delicate sections giving versatility and durability (Bonart R. J. 1968). According Callister W. D. (1994) these versatile properties and applications make the polyurethane (PU) a very valuable polymer. The properties of the polymers and polyurethane are further improved in the form of composite materials. Table 2.1 below show result another researcher investigate the polyurethane matrix composite.

Several researches on polyurethane has been conducted and the results on polyurethane are the tensile strength of OPT fiber incorporated PU bio-composite was found to be increased with the increase in the OPT fiber content up 20% in the composites (Yaacob et al., 2010). Other than that, the lightweight concrete achieved density of 1557 kg/m³ and compressive strength of 17.5 MPa. The compressive strength result exceeded the minimum compressive strength of 17.0 MPa. The inclusion of palm-based PU improved the thermal conductivity of the lightweight concrete (Aini et al., 2012). Lastly, these montmorillonite / polyurethane nanocomposites displayed enhanced mechanical, thermo-degradation and water absorption properties than that of the pure polyurethane (Tien and Wei 2000). All of this research shows that PU is can be used as a modifier in mechanical properties reinforced by OPT and OPF fiber.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the material and the methodology used in this research project. The first section describes the flow chart of the steps involve, follows with part describes the parameters that are required in learning and training. Subsequent sections explicate the conducted experiments and analysis to investigate the mechanical properties of the specimen was being conducted with the tensile test, flexural test and impact test. The instrument that was used for data collection is also described and the procedures that were followed to carry out this study are included.

3.2 Flowchart

The chart shown in Figure 3.1 below shows the process that performed for this research. So, to accomplish this project, the flowchart make the process of this project goes smoothly and knows the state of priority task that need to be done first. Roughly, this project was beginning with the specimen received from the manufacturer, and specimen preparation. Then, the mechanical properties test such as tensile test, flexural test and impact test was conducted.

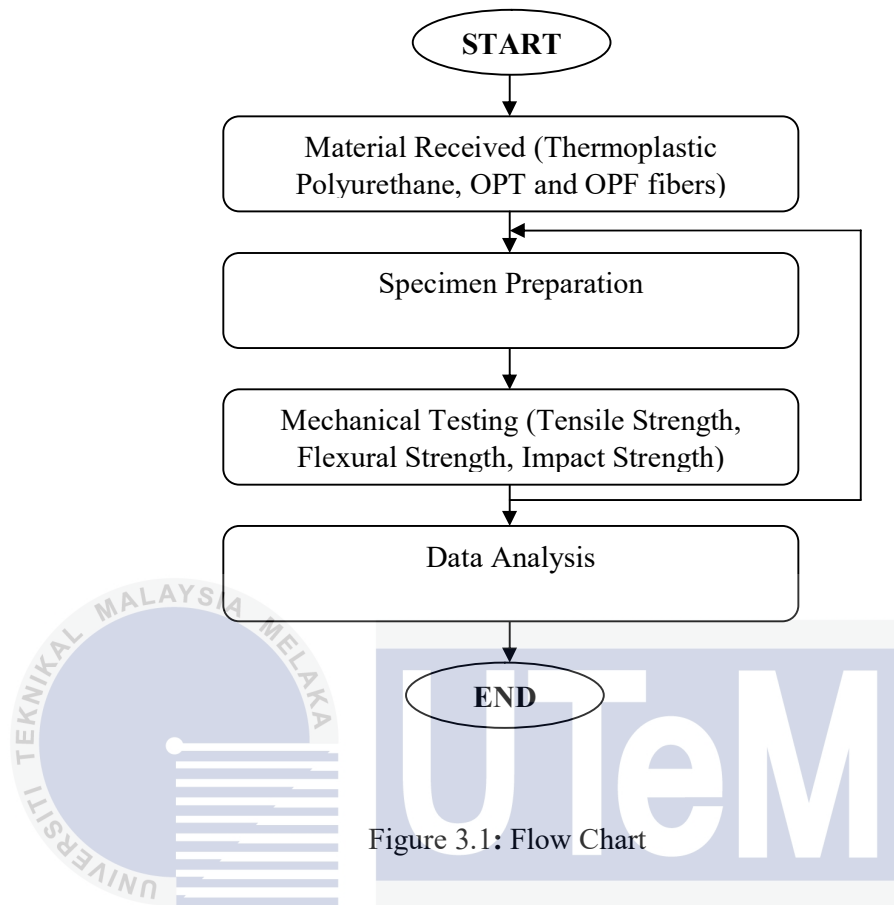


Figure 3.1: Flow Chart

3.3 Project Plan

Project plan is needed to make the project run smoothly and systematic. One year timeline were given to finish the project. A Gantt chart was help us to manage the progress of the project have been set up and show in appendices.

3.4 Material Selection

In this study, there are two types of the most important raw material was used in this project, that is, oil palm trunk (OPT) and oil palm frond fiber (OPF) as a reinforcement and thermoplastic polyurethane (TPU) as the matrix.

3.4.1 Reinforcement

Oil palm trunk (OPT) and oil palm frond (OPF) fiber was used as the reinforcement. The OPT and OPF fibers were obtained from the oil palm plantation and oil palm mill at Melaka. Figure 3.2 show the OPT and OPF fibers blend that was used as the reinforcement.



Figure 3.2: Oil Palm Frond (OPF) and Oil Palm Trunk (OPT) Fiber

3.4.2 Matrix

Thermoplastic polyurethane (TPU) was used as a matrix in this research. The matrix Elastollan B90A was obtained from BASF. It comes with pallet form. Figure 3.3 shows the thermoplastic polyurethane (TPU).



Figure 3.3: Thermoplastic Polyurethane (TPU)

3.5 Specimen Preparation

There were few steps for specimen preparation, which are fiber chopping, fiber treatment, mix fiber with composite, crushed into pallet size and compress (Hot and Cold Press). Lastly, was cutting the specimen into standard size and shape according ASTM. Figure 3.4 shows the flowchart for specimen preparation.

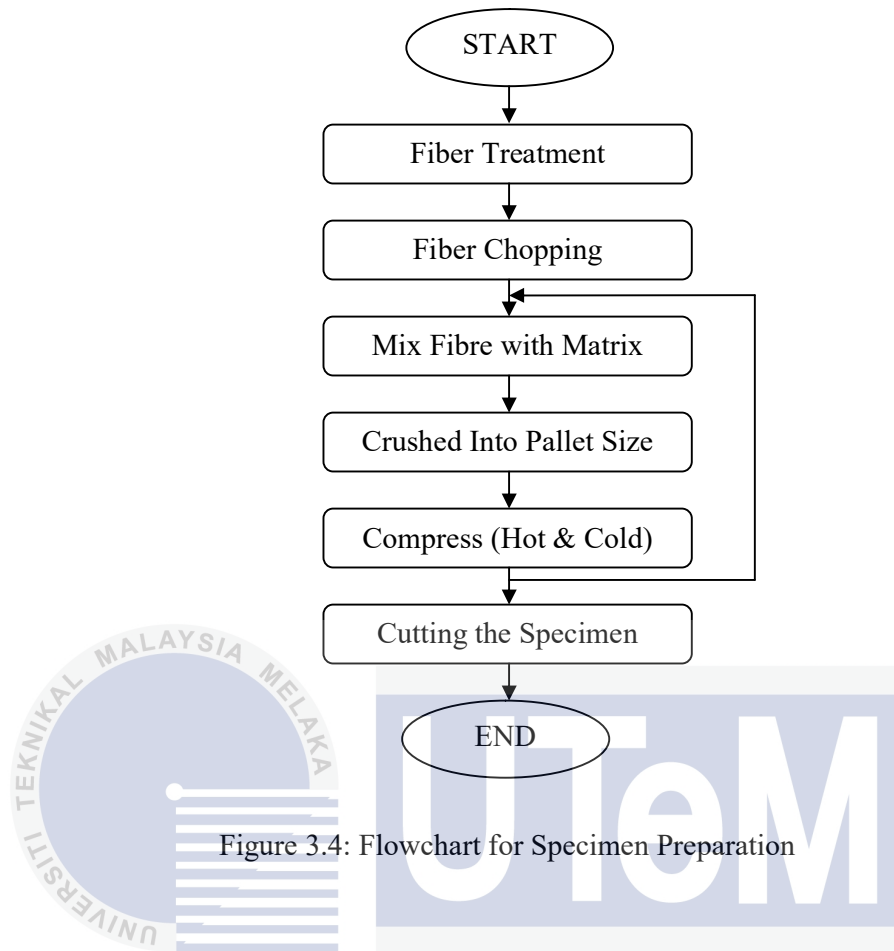


Figure 3.4: Flowchart for Specimen Preparation

3.5.1 Fiber Treatment

The treatment oil palm trunk (OPT) and oil palm frond (OPF) was conducted with, soaked in 2% sodium hydroxide (NaOH) solution at the room temperature. The OPT and OPF fibers was kept immersed in the alkali solution for 30 minutes. Then the OPT and OPF fibers treated are filtered out and washed several times with water until all the sodium hydroxide (NaOH) was eliminate. After that, the OPT and OPF fibers was dried under the sun to make sure the OPT and OPF fibers is properly dried. This process was to ensure no water moisture exist in OPT and OPF fibers.

3.5.2 Fiber Chopping

OPT and OPF fibers were crushed into small pieces (2-3mm) with by using the crusher machine. The Figure 3.5 shows the crusher machine.



Figure 3.5: Crusher Machine

3.5.3 Fiber – Matrix Mixing

After the fiber was crush into small pieces, the OPF and OPT fibers were mixes with thermoplastic polyurethane (TPU). The OPF and OPT fiber mix with matrix was conducted using the internal mixer with different compositions. Table 3.1 below shows the composition between OPF and OPT fibers and thermoplastic polyurethane (TPU).

Table 3.1: Composition Of OPT and OPF Fibers with Thermoplastic Polyurethane (TPU)

Sample No.	Composition (wt% of OPT & OPF Fiber)	(wt% Polyurethane)
Sample 1	0	100
Sample 2	10	90
Sample 3	20	80
Sample 4	30	70

The maximum capacity of the internal mixer is 50 gram. To produce the specimen with all compositions need in one mould. So, every composition was mix together approximately 3 times (150g/m^3) for one specimen.

The internal mixer was rotates at 60 rpm for 12 minutes at 190°C . Firstly, only the thermoplastic polyurethane (TPU) was put into the internal mixer. After 3 minutes, some of the chop of OPT and OPF fibers was added into the internal mixer and mix until 12 minutes. The reason why the OPT and OPF fibers was added in the internal mixer by stages is to make sure that all OPT and OPF fibers will be fully saturated with thermoplastic polyurethane (TPU). The Figure 3.6 shows the internal mixer that was used mix fiber with matrix.

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Figure 3.6: Haake Internal Mixture

3.5.4 Crushed Into Pallet Size

After that, the mixture of the OPT and OPF fiber was crushed by using the plastic crusher machine to get the pallet size (1-2mm). The purpose to get the mixture into pallet size was because it will be easier to place and fit in mould that was used to produce OPT and OPF fiber composite using hot and cold press machine. Figure 3.7 shows the plastic crushers machine.



Figure 3.7: Plastic Crusher Machine

3.5.5 Compress (Hot & Cold Press)

Finally, the crushed pallet were put inside the mold as shown in Figure 3.9 before proceed into hot and cold press machine as shown in Figure 3.8 to produce oil palm fiber composite sample. The pallet of mixture with matrix was put in 200 x 200 x 3mm mold and put into the hot press machine to be compressed. In order to produce the desired specimen, the mixture in the mold was pre heated at 190°C for 7 minutes and 3 minutes for hot press with pressure 95kgf/cm². After that, continue with cold press for 5 minutes.



Figure 3.8: Hot and Cold Press
Machine

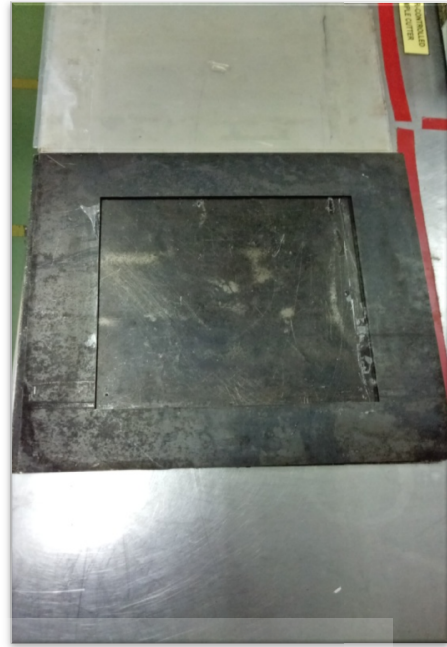


Figure 3.9: Mold for One Specimen

3.5.6 Cutting the Specimens

After the curing time was complete, the specimen taken out from the moulding as shown in the Figure 3.10. Next process was cut the specimen according ASTM D638 for tensile, ASTM D790 for flexural and ASTM D256 for impact. For the tensile test specimen was cut using level controlled cutter as shown in the Figure 3.11. Figure 3.12 show the sample of the specimen for tensile and flexural test.



Figure 3.10: Specimens

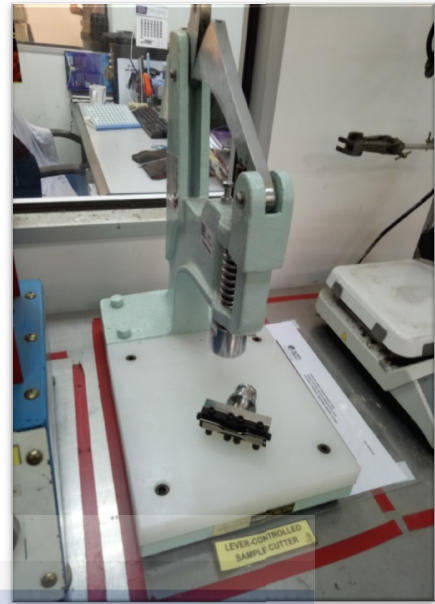


Figure 3.11: Level
Controlled Cutter



Figure 3.12: Specimen for Tensile and Flexural Test

3.6 Density of Fiber Mix with Matrix

Once the volume of the specimen is known the mass can be measured with balanced the specimen. The density (ρ) formula is in equation 2.

$$(\rho)=M/V \text{ (2)}$$

Where the (ρ) =Density, M =Mass of the specimen and V =Volume of the specimen. Within the mass was obtained as, the density is determined. Volume can calculate by using volume formula for all specimens. Table 4.2 show the average mass and density of all the specimens.

Table 3.2: Average Mass and Density of the All Specimens

Sample	Average (g)	Density (g/m ³)	Std. Deviation
100% TPU 0% OPT&OPF	4.134	1.322	0.123
90% TPU 10% OPT&OPF	3.946	1.267	0.098
80% TPU 20% OPT&OPE	3.722	1.189	0.038
70% TPU 30% OPT&OPF	3.692	1.185	0.090

3.7 Mechanical Properties Testing

These are three types of tests that were conducted in order to get the mechanical properties of these composites. The test is tensile test, flexural test and impact test.

3.7.1 Tensile Test

A tensile test, also known as tension test, was probably the most fundamental type of mechanical test can perform on material. In this project the tensile test was conducted with the machine Instron 5960 Dual Column Testing Systems for Tensile,

Compression and Flexure. Four specimen different compositions were test and the specimen for testing according ASTM D638 with dog bone shape. By conducting tensile test on the specimens, the tensile strength, tensile strain, and young modulus and other tensile properties of the specimens can be determined. Tensile strength determine from the relationship of the tensile and strain. Other than that, the method were used for this equipment is clamping the specimen between the fastener as shown in Figure 3.13 with a load cell 50kN and cross head speed two (5)mm/min. The result of the tensile strength was automatically calculated by the Bluehill software installed with the equipment. Figure 3.14 shows the equipment of tensile testing machine.



Figure 3.13: Tensile Testing



Figure 3.14: Instron 5960
Dual Column

3.7.2 Flexural Test

Flexural properties were used to determine the ductility or resistance to fracture of that material. The flexural tests were conducted according ASTM D790 and the size of the specimens is 130 x 13 x 3mm. The machine used for the three-point flexure test was the Instron 5960 Dual Column Testing Systems for Tensile, Compression and Flexure. A Figure 3.15 shows three-point fixture mounted on the Instron 5960 machine to hold the specimen at a certain ratio of support span to depth with load cell 50kN and cross head speed two (2) mm/min. The result of the flexural strength was automatically calculated by the Bluehill software installed with the equipment. Twelve specimens of different compositions were test, each specimens were test three times. The Figure 3.14 shows the equipment for Flexural Test.

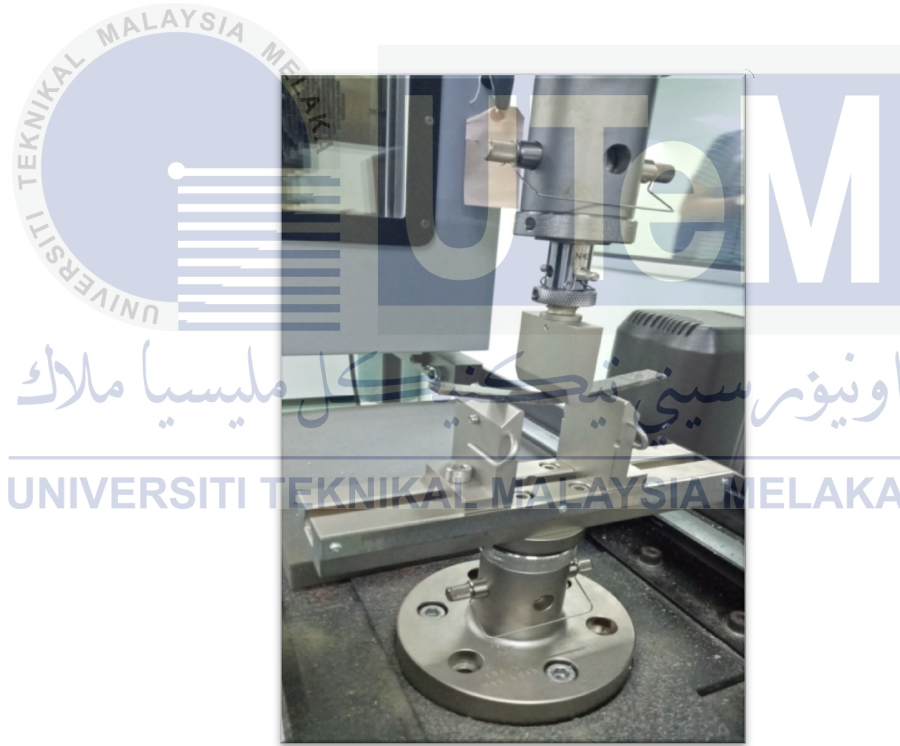


Figure 3.15: Flexural Specimen Testing

3.7.3 Impact Test

Impact test was conducted by pendulum impact tester. This equipment was designed for determining the durability of material to impact, in other word the strength of the material and, how hard is it to fracture or break. The test fulfils according the ASTM D256. The specimen sizes are 63 x 13 x 3 mm. The point of impact is ± 8.25 mm above the centre of the test sample. Besides that, the impact test was conducted with clamping or supporting a specimen on the bottom, the sample can be released to strike and break the specimen. The pendulum was continued to swing up after the break event to a height somewhat lower than that of a free swing. The gauge shows the result of abs energy, or impact energy in (J/m) velocity. The Figure 3.16 shows the equipment of the pendulum impact tester.

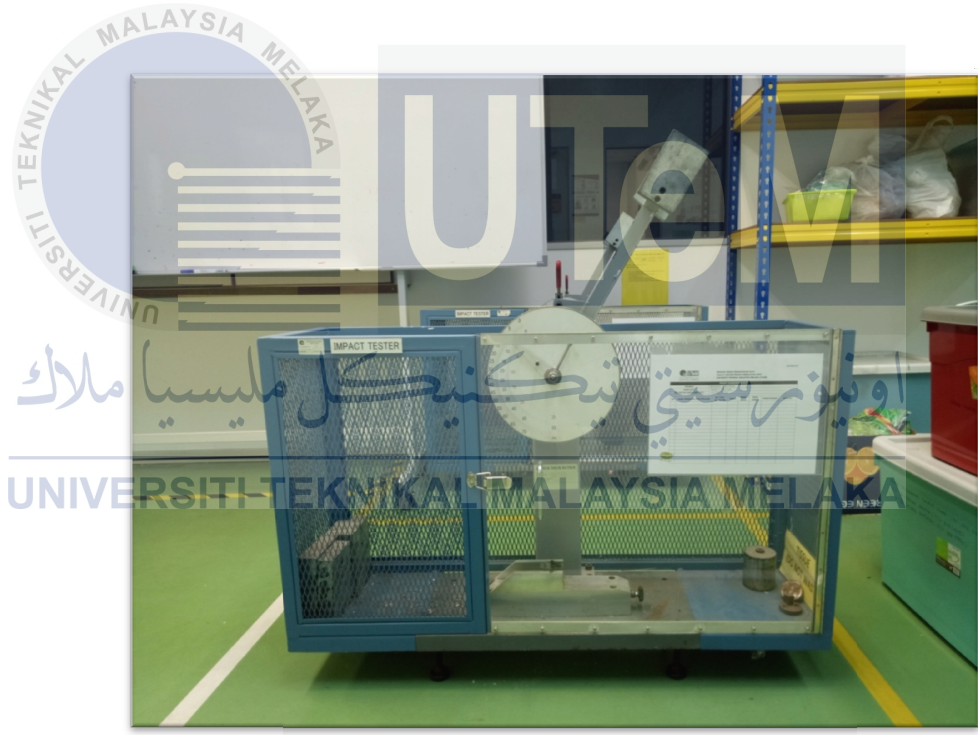


Figure 3.16: Pendulum Impact Tester

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

In this chapter, the observation and the result obtained from the experiment were explained. The result observation from the mechanical testing of the composite through tensile test, flexural test and impact test were reported in this chapter. In this chapter also discusses and analysis the observation and findings that was achieved during this research.

4.2 Effect of Density of OPT&OPF Fiber

From the Figure 4.1 illustrates the relationship between the density and the fiber content of all specimens, its shows that the graph is inversely proportional. The 0% fiber content give the highest density with 1.322 g/m³ and the lowest density was 30% fiber content with 1.186 g/m³. Factor that give influence to the composite was the mixing ratio between fiber and matrix. This is because give the biggest effect to the mechanical properties of tensile strength, flexural strength and impact strength.

The overall effect of composite density of OPT and OPF fiber reinforced thermoplastic polyurethane (TPU) on the sample fabricated show the effect to the tensile test, flexural test and impact test. As expected, as the density of the specimen is increased, the lowest test result was obtained. However, density values were attributed to the difference composition of fiber content.

According Doan et al. (2006) stated that density of the specimens is plays important role to strength the specimens. Besides that, Anyalebechi (2005) stated that crucial factor to determining the material that best suited for an application is classified the density of a material. The density also was used to determine the relative weight of the specimens. From the result obtained from tensile test, flexural test and impact test, it can show that the specific of the specimen's strength can be calculated. According, Anyalebechi (2005) the specific strength is simply the strength to weight of ratio of the composition each specimens.

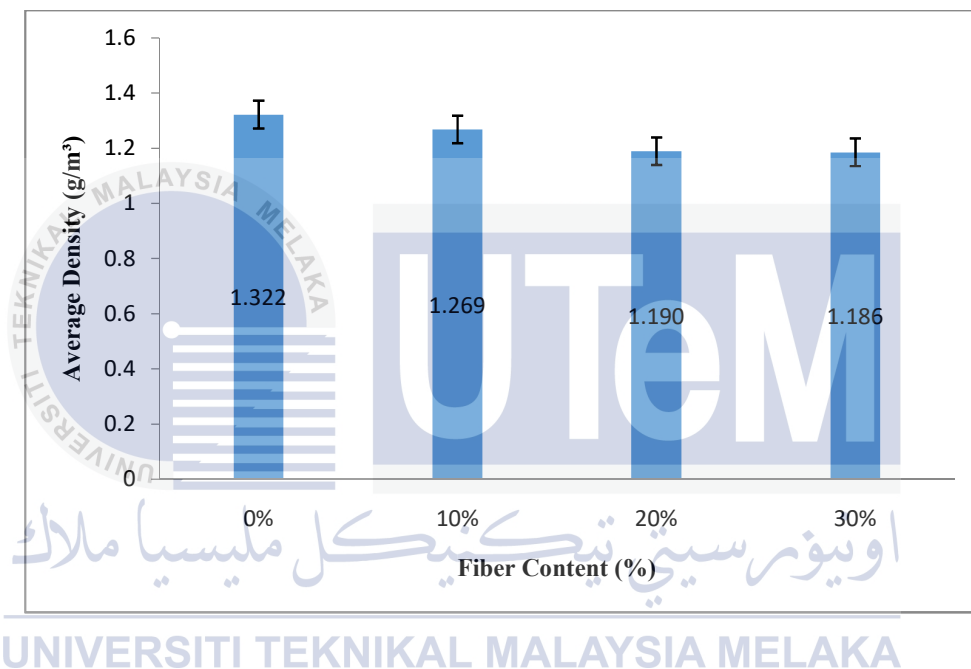


Figure 4.1: Average Density versus Fiber Content of All Specimens

4.3 Effect of OPT&OPF Fiber on the Tensile Strength

The most fundamental type of mechanical test that was performed on the material is tensile test or also known as tension test. The main function tensile test is performed to get the tensile strength of the specimen. Tensile strength were explained as to measure the ability of a material with stress that give to the material or expressed as how far the material can stand if give the greatest stress. The average

value and standard deviation of tensile strength was calculated from the results that are obtained after the entire specimen was tested and it is shown in the appendices.

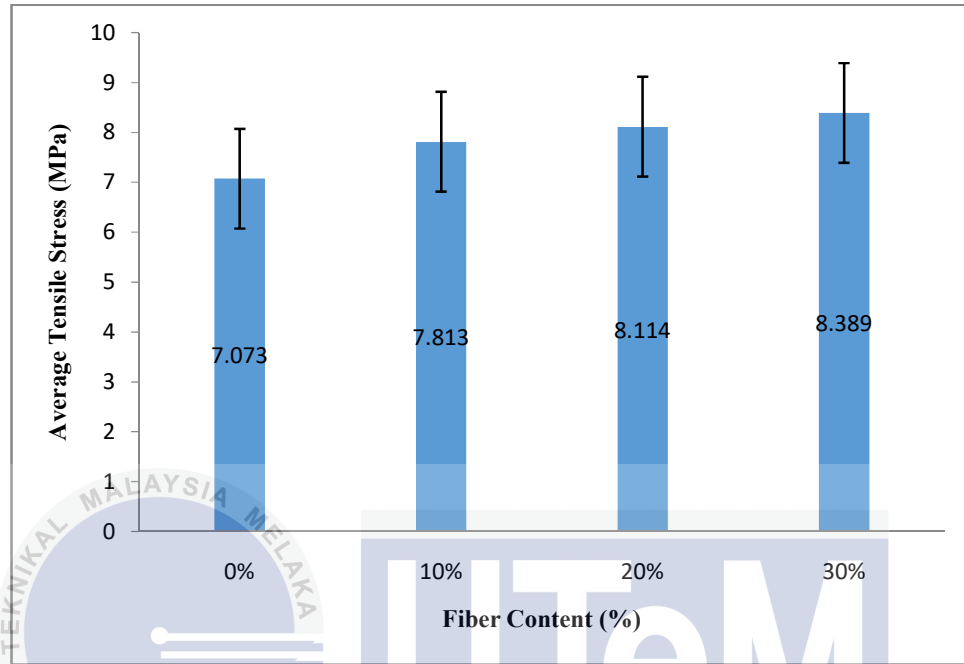


Figure 4.2: Average Tensile Stress versus Fiber Content Graph of All Composition

Figure 4.2 shows the average tensile stress versus fiber content graph of all composition composites. It is observed that the tensile stress increase steadily from 0% to 30% fiber mass content. Besides that, it shows that the increasing of fiber content gave increasing trend and directly proportional of the tensile stress. From the tensile test, pure thermoplastic polyurethane (TPU) was the lowest tensile stress with 7.073 MPa. From the Figure 4.2 shows that tensile stress increase at 10% fiber content with 7.813 MPa and following with 20% fiber content with 8.114 MPa. The tensile stress at 30% fiber content gave the highest tensile stress with 8.389 MPa. It can be seen from its average result that has the highest result than other specimens. This is because greater fibre loading will enhance the strength of the composites. According Matthews FL et al. (2000) the matrix function is to transfer the forces to the fibres; hence if the fiber loading has been increased, it can withstand higher forces compared to lower fiber contents. However, the result obtained in this

experiment shows the contrary, which is that the addition of fiber content improves the strain properties.

For this research, the fiber arrangement in thermoplastic polyurethane composite (TPU) is random orientation. It shows the fiber could not hold the load when matrix transfers. Doan et al. (2006) stated the most important role in the mechanical properties performance of fiber reinforced is the length of fiber. Compared with another research with El Shekeil et al. (2011) the experimental and theoretical tensile strengths for kenaf bast fiber reinforced thermoplastic polyurethane (TPU) composite and found that the way regulation of the mixture failed to give or provide a good fit. Besides that, also found if the number of fiber fraction increase, the discrepancy also increase. The presence of voids in the composite also can contribute factor of mechanical properties, if the fiber not aligned perfectly. The fibre is not perfectly aligned and the presence of voids in the composites may also be the factor contributing to the lower experimental value. On the other hand, the best tensile strength and modulus is the fiber size in the range of 125μ and 300μ .

4.4 Effect of OPT&OPF Fiber on Flexure Strength

A flexure test, also known as the tests only measure the bending behaviour of materials subjected to simple beam loading. The flexural strength can define as the maximum stress that give to the material until the material fracture. In this research, the flexural test is conducted using three point bending method with according ASTM D790. The average value and standard deviation of flexural stress was calculated from the results that are obtained after the entire specimen was tested and it is shown in appendices.

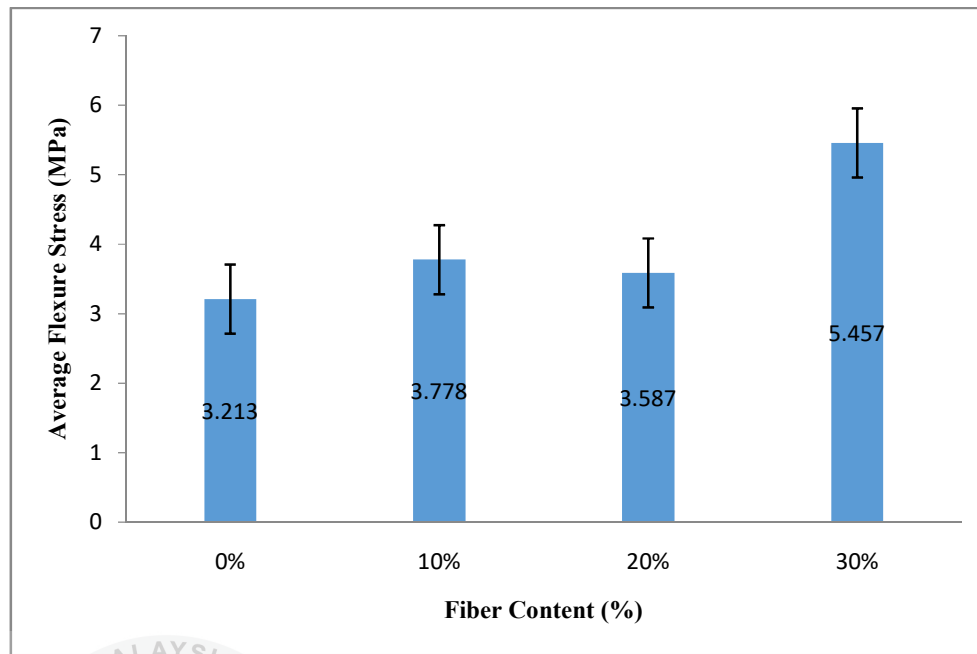


Figure 4.3: Average Flexural Stress versus Fiber Content Graph of All Composition

Figure 4.3 shows the average flexural stress has an increasing trend from 0% to 30% fiber content. In other word, flexural stress increases if the volume of fiber content increase. It can be found that at 30% of fiber has the highest average value of flexural stress which is 5.427MPa, while fiber with 0% has the lowest average value of flexural stress which is 3.213MPa. A similar observation was found by R.Ramli et al. (2011), where 30% fiber content was found to having the highest flexural stress. This is because with increasing flexure stress, can be explained that the fiber-matrix interactions give great pressure during bending, developed in the transverse section of the flexural specimens for whether the surface condition of the fibers.

Mohemed et al. (2010) have found the flexural strength of OPF and OPT fiber reinforced with epoxy with random fiber orientation gave the highest flexural stress was 0% fiber content and the lowest flexural stress was 5% fiber content. It also found decreasing trend when the increasing fiber content. Compared with result obtained from this research, at the 20% fiber content slightly decrease of the flexure stress with 3.587 MPa. This is because difficulties during the processing due to the dispersion of fiber in the matrix, leading to weak stress transfer from the matrix to fiber when load applied.

4.5 Effect of OPT&OPF Fiber on Impact Strength

Impact test was measure the amounts of the energy absorbed of a material during fracture or also known as measure the strength material if the pendulums give the impact. In this research, the impact test was using charpy impact test also known as charpy V-notch test. The average value of charpy impact energy is calculated from the results that are obtained after the entire specimen was tested and it is shown in appendices.

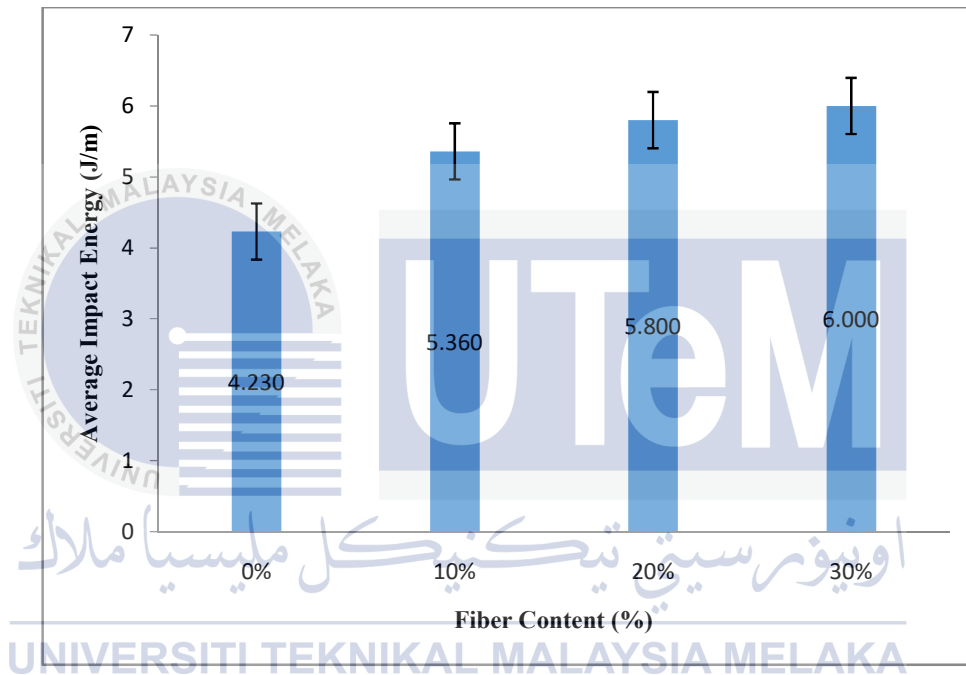


Figure 4.4: Average Charpy Impact Energy versus Fiber Content Graph of All Composition

Figure 4.4 shows the charpy impact energy versus fiber content graph of all compositions composites. It can be observed that the impact energy increase steadily from 0% to 30% of fiber content or other word with increasing of fiber content give increasing trend to the impact strength. This is because of the increase of density and decreasing on the free volume polymer chains with increase in the fiber content. There was a significant increase from 4.23 J/m at the 0% fiber content to 5.36 J/m at the 10% fiber content followed by a slightly increase to 5.80 J/m at the 20% fiber

content and lastly the highest impact energy is 6.00 J/m at the 30% fiber content. This means that the highest fiber content contributed more to the absorption of energy. The result obtained from the impact test was compared with El Shekeil et al (2011) kenaf bast fiber reinforced thermoplastic polyurethane (TPU) composite was found that, the increasing fiber size gave the highest value of impact strength. This is because the effect of fiber size contributed more impact strength.



CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

By the end of my research project of the effect of OPT and OPF fiber reinforced with thermoplastic (TPU) was successfully characterized by determined the physical properties and mechanical properties have been measured such as tensile strength, flexural strength and impact strength. Based on the result from the tensile had been obtained. The composition of 30% fiber content gave the highest tensile stress with 8.389 Mpa. This result revealed that the specimen exhibits better properties than other fiber content. On the other hand, the pure thermoplastic polyurethane (TPU) gave the lowest tensile stress with 7.073 MPa. Based on the result obtained, it can conclude that increment the OPT and OPF fiber content tensile stress also increase.

According from the flexural test, the highest was flexural stress obtained is 30% fiber content with 5.427 Mpa and the lowest flexural strength at 0% fiber content with 3.213 MPa. 30% OPF and OPT fiber content give a better properties of specimens compared with another composition of fiber. On the other hand, the fiber length also give the extremely impact to the mechanical properties of the composite.

The result obtained from the impact test shows the increasing trending from 0% to 30% fiber content. The highest value of impact energy that obtained from the impact test is 30% fiber content with 6.00 J/m. For the lowest impact energy is 0% fiber content with 4.23 J/m. It was found also, the decreasing of the density of

composite shows the increasing of the impact energy and the increment of the fiber content give more to the absorption of energy.

5.3 Recommendation

In future research, do more test on the composite with water absorption and moisture conditioning. On the other hand, study more the physical properties to get various mechanical properties of the composite such as size of fiber and the arrangement of fiber. Can pursue future work with microstructure study to check the interaction between the composite and also to determine the homogeneity of the element in the composite at the same time the element can be analysed. For the future application, thermoplastic polyurethane (TPU) can be used for application in automotive industry such as manage the vibration, noise and shock that can cause mechanical systems to fail and preferred to manufacture car dash boards. Besides that, TPU also can be use to improvement the footwear industry.

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APPENDICES

APPENDIX A	-	GANTT CHART FYP1 AND FYP2
APPENDIX B	-	TENSILE TEST DATA
APPENDIX C	-	FLEXURAL TEST DATA
APPENDIX D	-	IMPACT TEST DATA



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APPENDIX A

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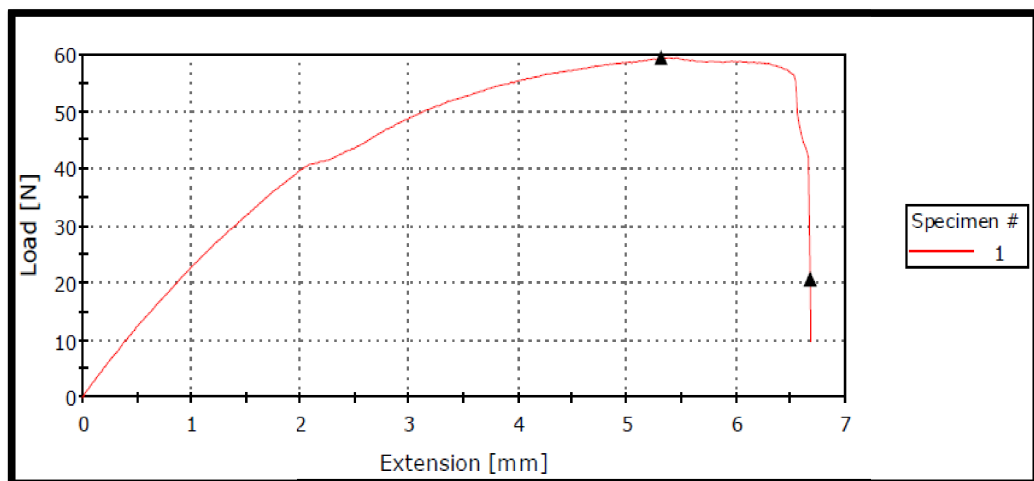
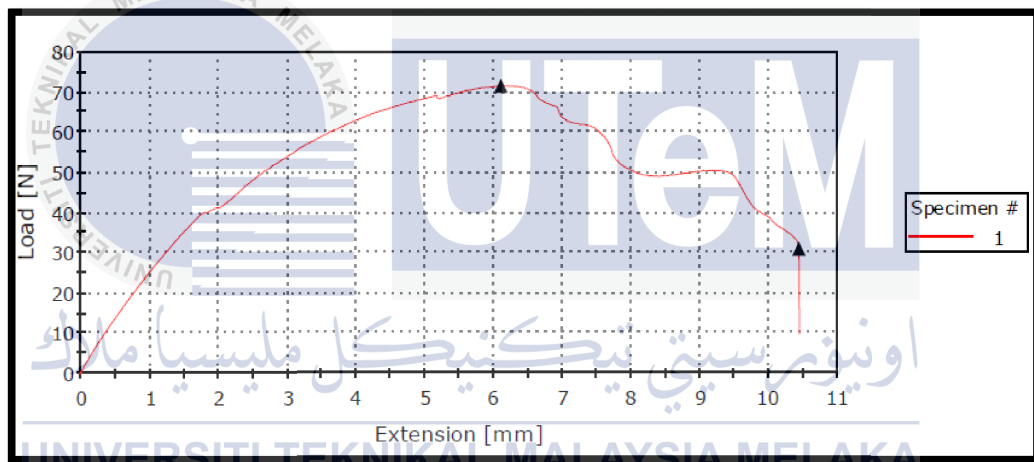
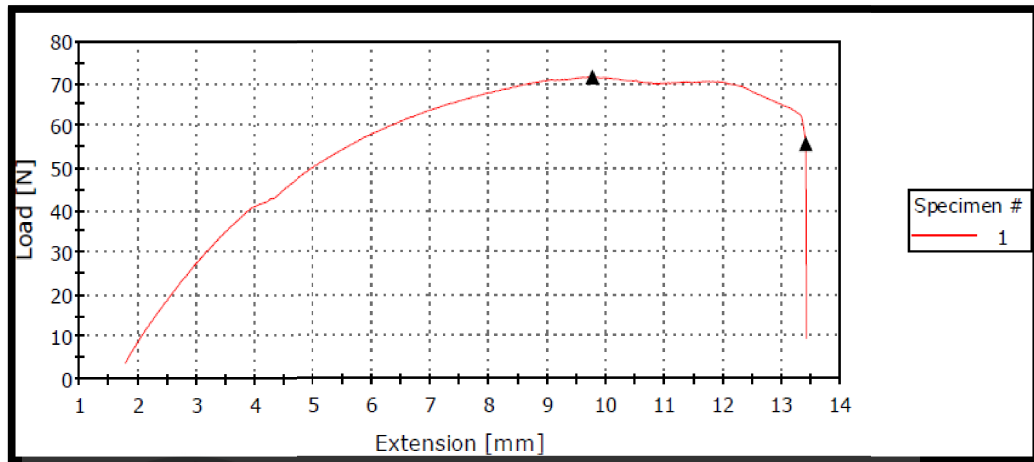
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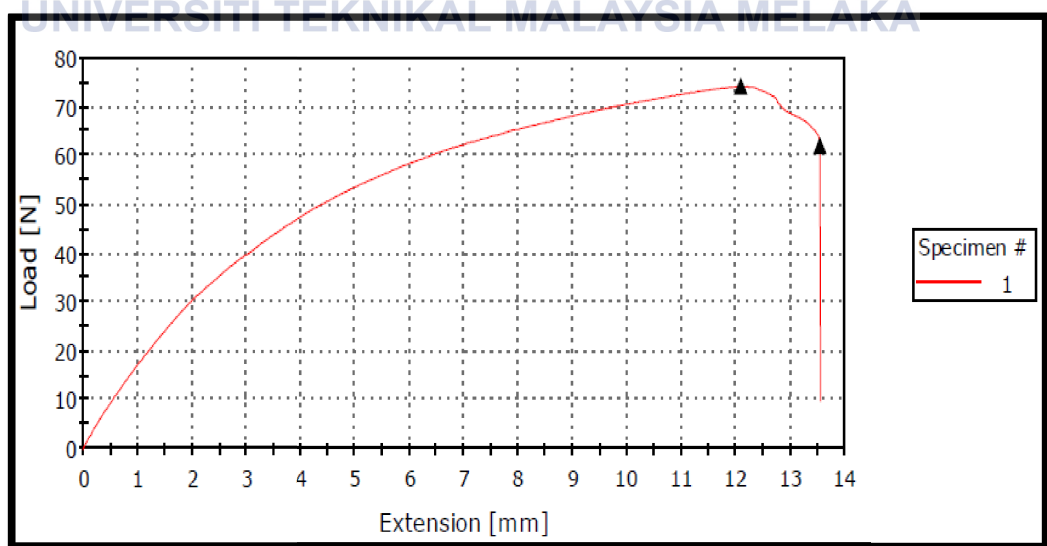
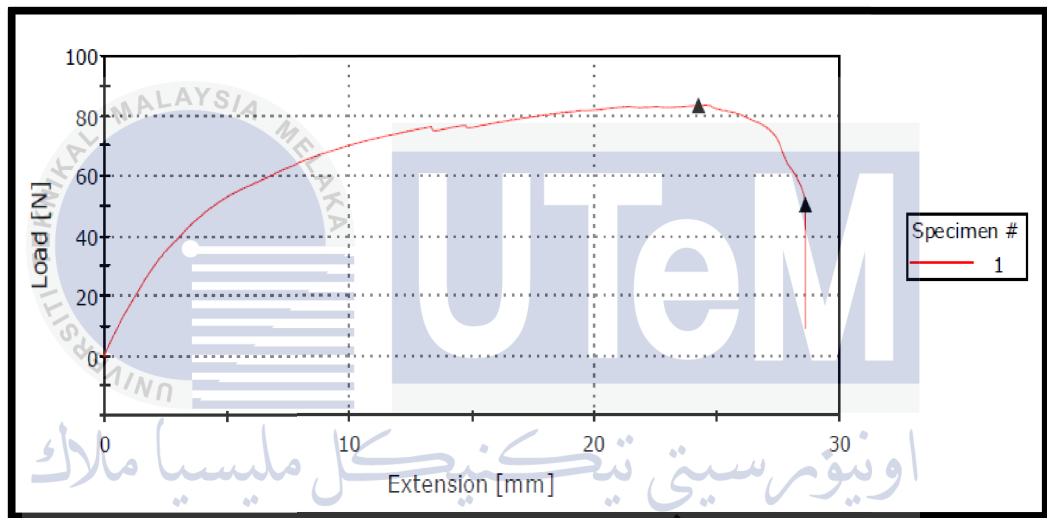
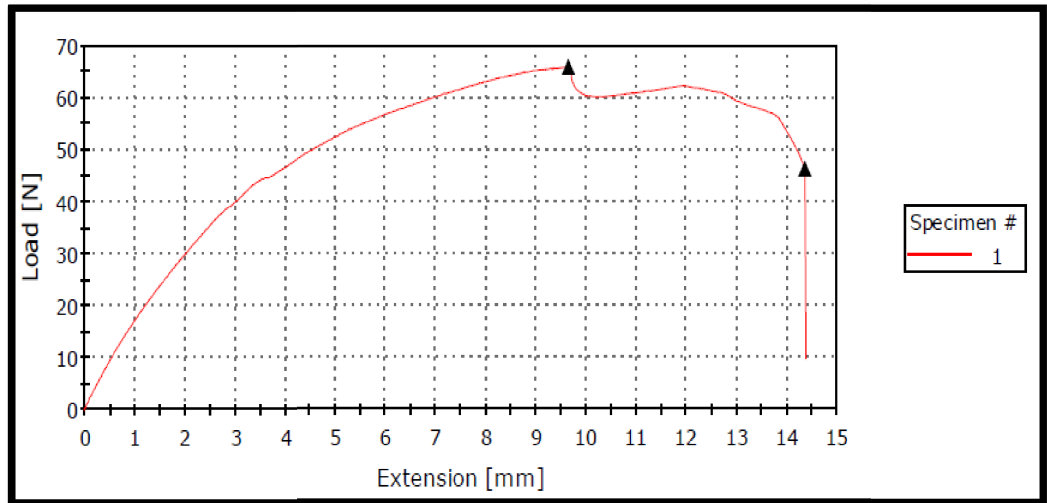
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APPENDIX B



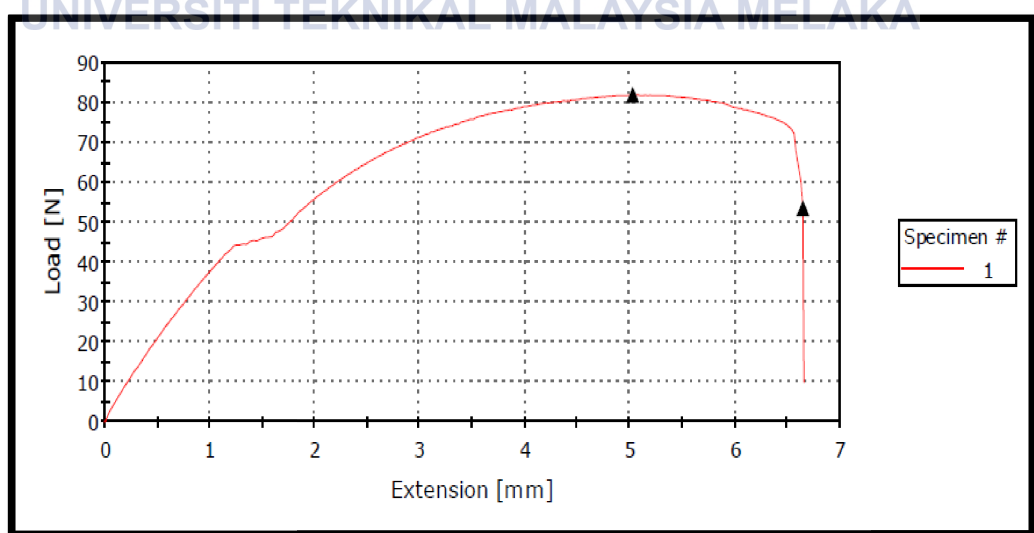
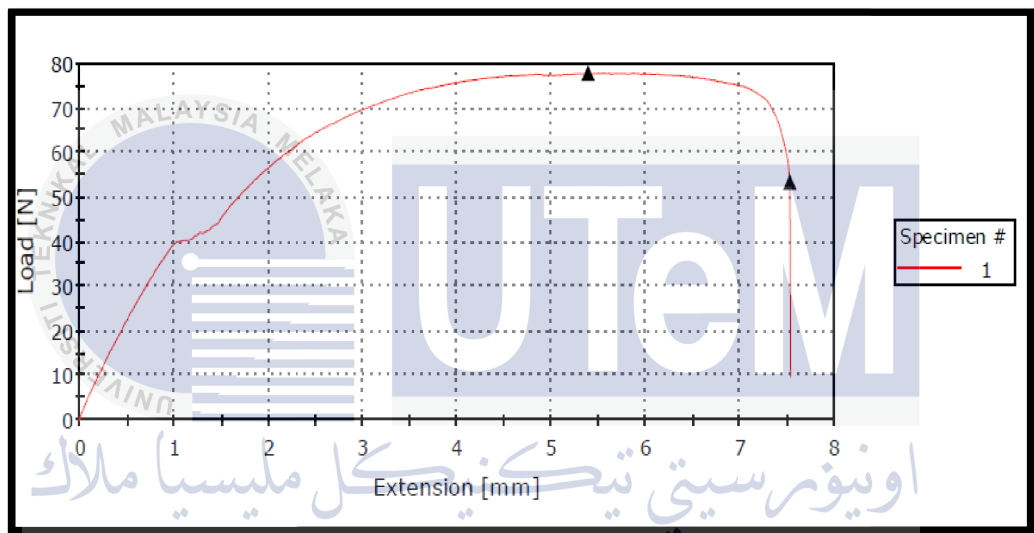
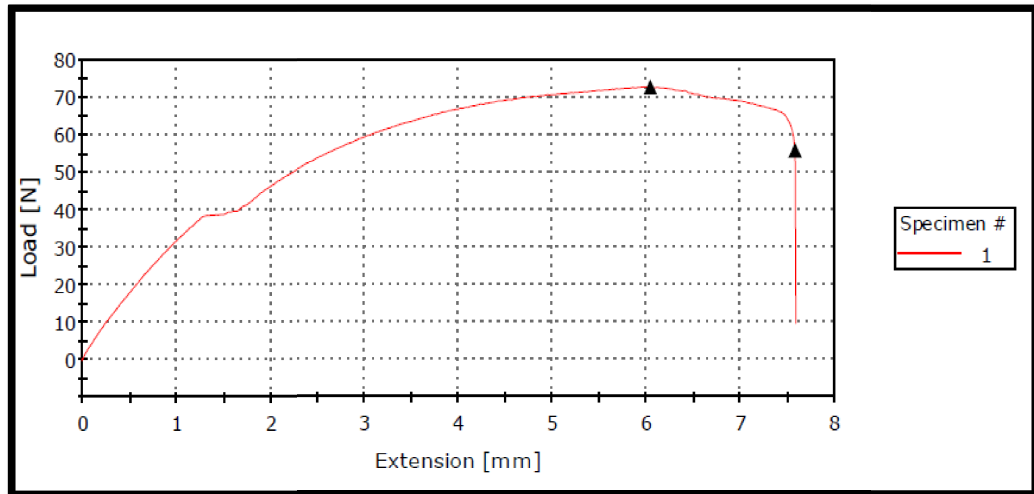
Sample	Tensile Stress (MPa)	Tensile Strain (%)	Ultimate Tensile load (N)
100% TPU 0% Fiber - 1	7.501	13	71.56
100% TPU 0% Fiber - 2	7.493	9	71.49
100% TPU 0% Fiber - 3	6.225	8	59.39





Sample	Tensile Stress (MPa)	Tensile Strain (%)	Ultimate Tensile load (N)
90% TPU 10% Fiber - 1	6.908	15	65.91
90% TPU 10% Fiber - 2	8.755	37	83.52
90% TPU 10% Fiber - 3	7.777	19	74.19

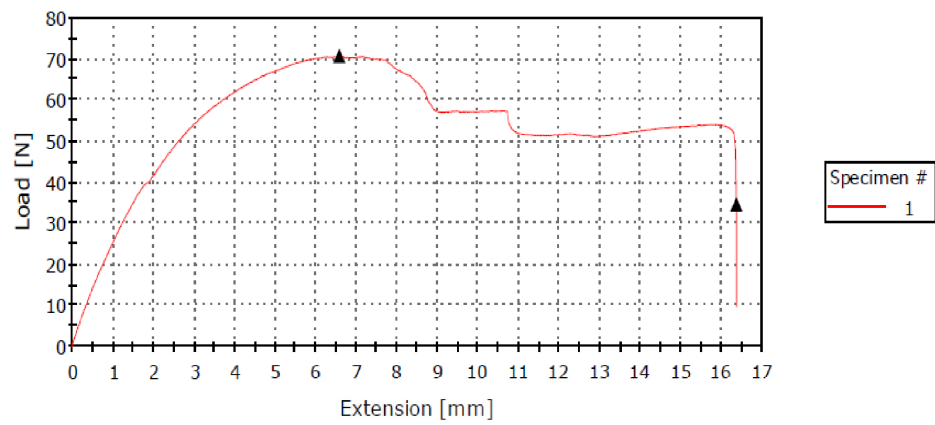




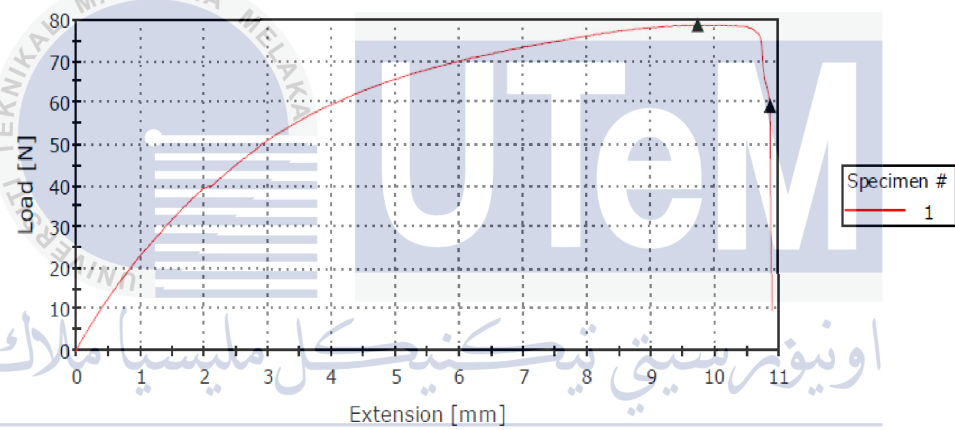
Sample	Tensile Stress (MPa)	Tensile Strain (%)	Ultimate Tensile load (N)
80% TPU 20% Fiber - 1	7.613	9	72.63
80% TPU 20% Fiber - 2	8.153	8	77.78
80% TPU 20% Fiber - 3	8.575	8	81.85



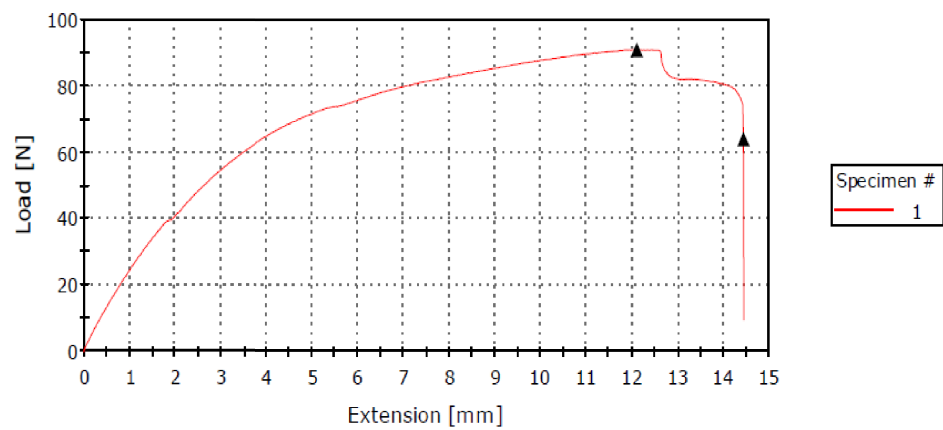
Specimen 1 to 1



Specimen 1 to 1



Specimen 1 to 1



Sample	Tensile Stress (MPa)	Tensile Strain (%)	Ultimate Tensile load (N)
70% TPU 30% Fiber - 1	7.409	10	70.68
70% TPU 30% Fiber - 2	8.237	15	78.58
70% TPU 30% Fiber - 3	9.522	19	90.84



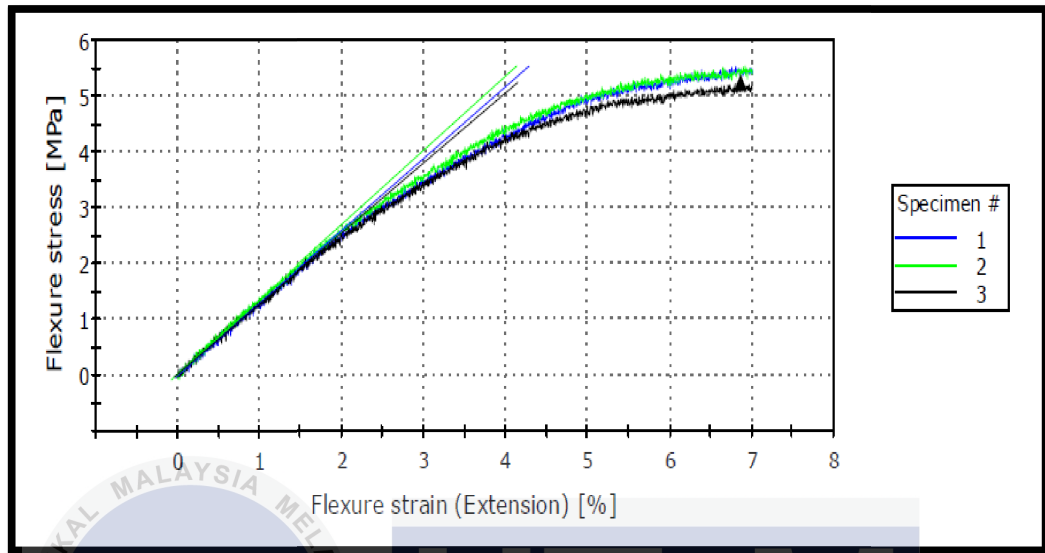
Specimen	Tensile Stress (MPa)			Average	Std. Deviation
	1 st test	2 nd Test	3 rd Test		
100% TPU 0% OPT&OPF	7.501	7.493	6.225	7.073	0.599
90% TPU 10% OPT&OPF	6.908	8.755	7.777	7.813	0.754
80% TPU 20% OPT&OPF	7.613	8.153	8.575	8.114	0.394
70% TPU 30% OPT&OPF	7.409	8.237	9.522	8.389	0.869



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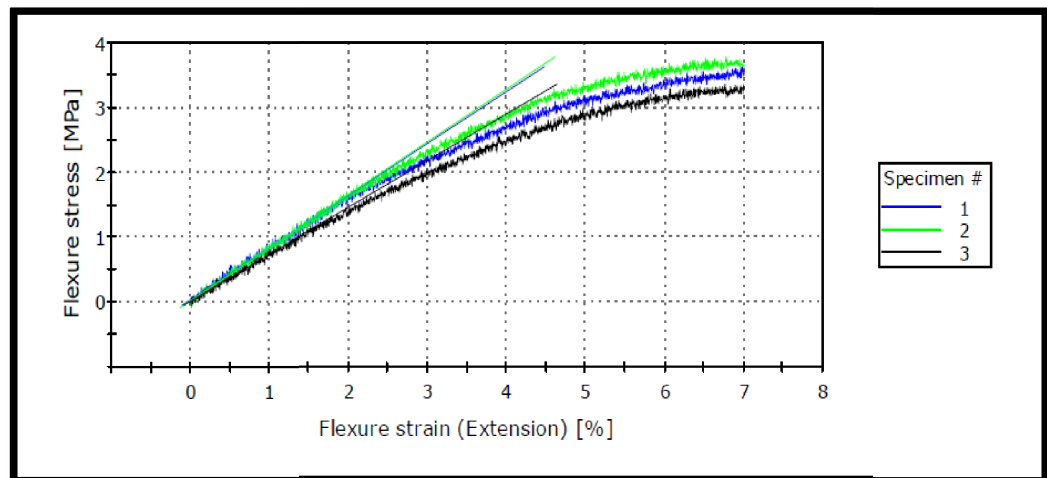
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APPENDIX C



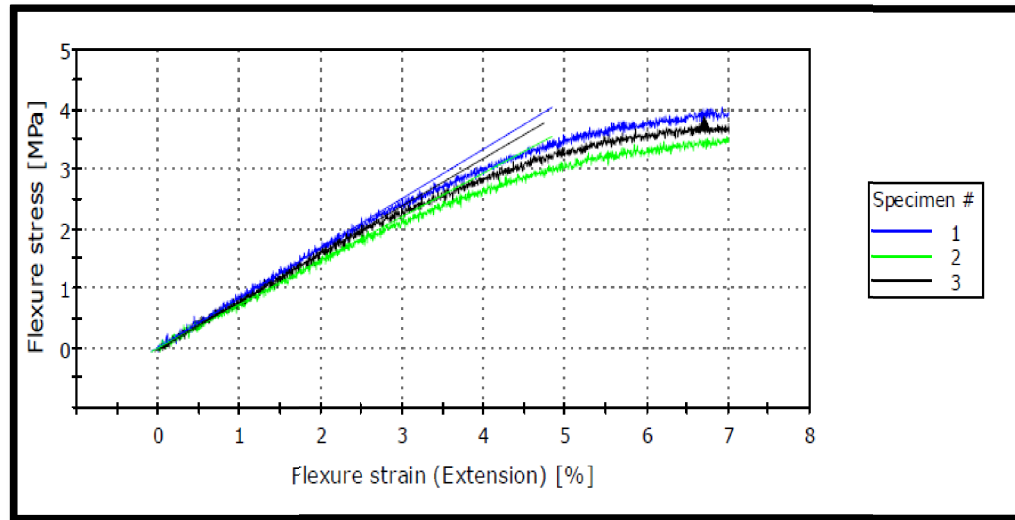
Specimen	Ultimate Flexural Stress (Mpa)
100% TPU 0% Fiber - 1	3.268
100% TPU 0% Fiber - 2	3.260
100% TPU 0% Fiber - 3	3.112





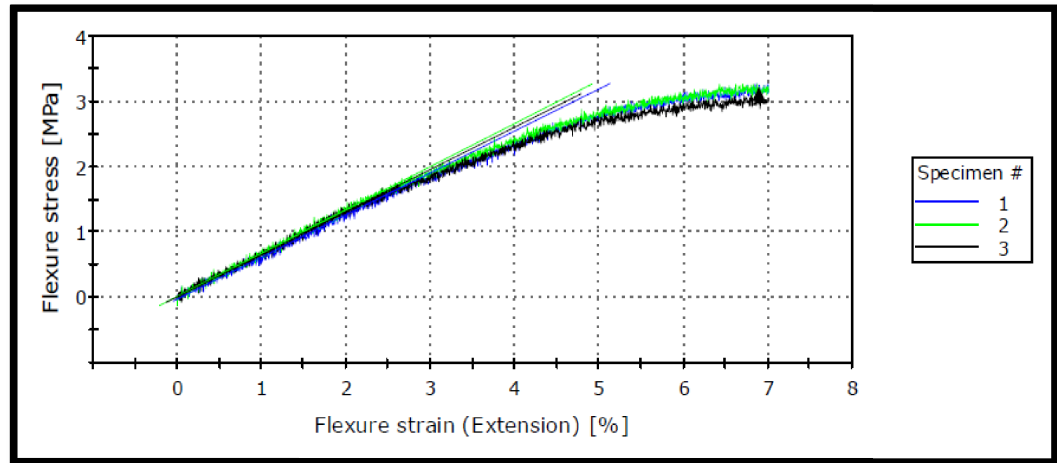
Specimen	Ultimate Flexural Stress (Mpa)
90% TPU 10% Fiber - 1	4.028
90% TPU 10% Fiber - 2	3.542
90% TPU 10% Fiber - 3	3.766





Specimen	Ultimate Flexural Stress (Mpa)
80% TPU 20% Fiber - 1	3.625
80% TPU 20% Fiber - 2	3.778
80% TPU 20% Fiber - 3	3.359





Specimen	Ultimate Flexural Stress (Mpa)
70% TPU 30% Fiber - 1	5.522
70% TPU 30% Fiber - 2	5.530
70% TPU 30% Fiber - 3	5.231



Specimen	Ultimate Flexural Stress (MPa)			Average	Std. Deviation
	1 st Test	2 nd Test	3 rd Test		
100% TPU 0% OPT&OPF	3.268	3.260	3.112	3.213	0.072
90% TPU 10% OPT&OPF	4.028	3.542	3.766	3.778	0.198
80% TPU 20% OPT&OPF	3.625	3.778	3.359	3.587	0.173
70% TPU 30% OPT&OPF	5.522	5.530	5.231	5.427	0.139



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APPENDIX D

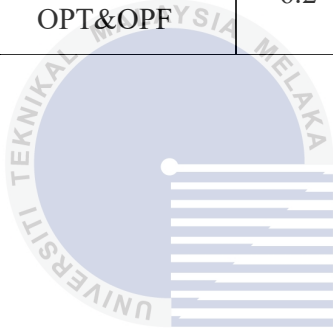
Specimen	Charpy Impact Energy (J/m)
100% TPU 0% OPT&OPF - 1	4.5
100% TPU 0% OPT&OPF - 2	4.0
100% TPU 0% OPT&OPF - 3	4.2

Specimen	Charpy Impact Energy (J/m)
90% TPU 10% OPT&OPF - 1	5.5
90% TPU 10% OPT&OPF - 2	5.2
90% TPU 10% OPT&OPF - 3	5.4

Specimen	Charpy Impact Energy (J/m)
80% TPU 20% OPT&OPF - 1	5.8
80% TPU 20% OPT&OPF - 2	6.0
80% TPU 20% OPT&OPF - 3	5.6

Specimen	Charpy Impact Energy (J/m)
70% TPU 30% OPT&OPF - 1	6.2
70% TPU 30% OPT&OPF - 2	5.8
70% TPU 30% OPT&OPF - 3	6.0

Specimen	Charpy Impact Energy (J/m)			Average impact energy (J/m)	Std. Deviation
	1 st Test	2 nd Test	3 rd Test		
100% TPU 0% OPT&OPF	4.5	4.0	4.2	4.23	0.205
90% TPU 10% OPT&OPF	5.5	5.2	5.4	5.36	0.125
80% TPU 20% OPT&OPF	5.8	6.0	5.6	5.80	0.163
70% TPU 30% OPT&OPF	6.2	5.8	6.0	6.00	0.163



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