MECHANICAL PROPERTIES OF COCONUT SHELL IN REINFORCED POLYMER COMPOSITE

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This report is submitted

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DECLARATION

I declare that this thesis entitled “The Mechanical Properties of Coconut Shell in Reinforced Polymer Composite” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree

Signature :.....

Name :.....

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor in Mechanical Engineering (Hons)

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Signature :…….

Supervisor Name :…….

Date :…….

DEDICATION

I would like to dedicate my Bachelor Degree to my late father, Tar Singh Tiwana A/L Gurdial Singh, the person that encourages me to pursue mechanical engineering field. My father, who taught me that the best knowledge in life which is to look at the positive side in every negative things. Next, it also dedicates to my beloved mother, Sarzi Kaur who worked hard to give me moral and financial support to finish my studies.

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ABSTRACT

Nowadays, the utilization of natural fibers in composites has been increasing and developed to save the environment by using biodegradable materials. The aim of this project is to study the mechanical properties of polymer composite reinforced with coconut shell. Previous studies show that synthetic fiber has more disadvantages than natural fiber such as lower mechanical properties, high cost and higher environmental risk. Powders are produced from coconut shell by using crusher machine, will be the reinforcing material of composite meanwhile unsaturated polyester resin will be the matrix of composite. The optimum ratio of filler content must be obtained to analyze the performance and effects of increasing filler content to tensile properties of composite. In this project, powder particle size 500 µm and below which is randomly distributed, and filler concentration varies by 10%, 15%, 20%, 25% and 30% into polyester matrix. The composites will be produced by using open-mould method and by mixing the powder with resin using stirrer machine. The characterization of particles will be determined by collecting data from the tensile, hardness test, density test and microstructure analysis. ASTM standards were obliged for every specimens that will be fabricated for each test. Polyester Resin and hardener will be mixed to form a solid. Methyl Ethyl Ketone Peroxide (MEKP) are hardeners that referred to as catalyst. MEKP used in this project is Butanox-M60. The main finding of this project is sample with 15% filler content shows maximum tensile properties while hardness increases gradually as filler content increase from 10% to 30%. The Tensile Stress and extension at break increased 15.91% and 6.11% respectively and filler content increased from 10% to 15% then reduce as filler content further increased. Meanwhile, the hardness and Young's Modulus shows increase 21.5% and 33.26% respectively for sample from 10% to 30% filler content. The density decreases by 0.58% as filler content increase from 10% to 30%.

ABSTRAK

Dewasa ini, penggunaan gentian semulajadi dalam komposit telah meningkat dan dibangunkan untuk menyelamatkan alam sekitar dengan menggunakan bahan biodegradable. Tujuan projek ini adalah untuk mengkaji sifat mekanik komposit polimer yang diperkuat dengan kulit kelapa. Kajian terdahulu menunjukkan bahawa gentian sintetik mempunyai lebih banyak kelemahan berbanding gentian semulajadi seperti sifat mekanikal yang rendah, kos yang tinggi dan risiko alam sekitar yang lebih tinggi. Serbuk yang dihasilkan daripada kelapa dengan menggunakan mesin penghancur, akan menjadi bahan pengukuhan komposit manakala resin poliester tidak tepu akan menjadi matriks komposit. Nisbah optimum kandungan pengisi mesti diperolehi untuk menganalisis prestasi dan kesan peningkatan kandungan pengisi terhadap sifat mekanikal komposit tersebut. Dalam projek ini, saiz partikel serbuk 500 μm dan ke bawah yang diedarkan secara rawak, dan kepekatan pengisi berbeza sebanyak 10%, 15%, 20%, 25% dan 30% ke dalam matriks poliester. Komposit akan dihasilkan dengan menggunakan kaedah acuan terbuka dan dengan mencampurkan serbuk dengan resin menggunakan mesin pengaduk. Pencirian zarah akan ditentukan dengan mengumpul data dari tegangan, ujian kekerasan, ujian ketumpatan dan analisis mikro. Piawaian ASTM adalah wajib bagi setiap spesimen yang akan direka untuk setiap ujian. Resin poliester dan pengeras akan dicampur untuk membentuk pepejal. Metil Etil Ketone Peroksida (MEKP) adalah pengental yang disebut sebagai pemangkin. MEKP yang digunakan dalam projek ini ialah Butanox-M60. Temuan utama projek ini adalah sampel dengan kandungan pengisi 15% menunjukkan sifat tegangan maksimum manakala kekerasan meningkat secara beransur-ansur sebagai kandungan pengisi meningkat dari 10% hingga 30%. Tekanan tegangan dan sambungan pada rehat meningkat masing-masing 15.91% dan 6.11% dan kandungan pengisi meningkat daripada 10% kepada 15% kemudian menurun jika kandungan pengisi yang semakin meningkat. Sementara itu, kekerasan dan Modulus Young menunjukkan peningkatan sebanyak 21.5% dan 33.26% untuk sampel dari 10% hingga 30% kandungan pengisi. Ketumpatan berkurangan sebanyak 0.58% apabila kandungan pengisi meningkat dari 10% hingga 30%.

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Firstly, I would like to express my gratitude to Almighty God for His love, guidance and strength until I finally manage to complete my final year project. “Faith in God”, has been the has been the slogan that I planted in my mind, to develop moral values as way to succeed in life.

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LIST OF ABBREVIATIONS

PMC	Polymer Matrix Composite
CCS	Crushed coconut shell
CS	Coconut Shell
PR	Polyester Resin
MMC	Metal Matrix Composites
CMC	Ceramic Matrix Composites
ACM	Advanced Composite Materials
FRP	Fiber Reinforced Polymer
PRP	Particle Reinforced Polymer\
USP	Unsaturated Polyester
AC	Activated Carbon
ER	Epoxy Resin
UTeM	Universiti Teknikal Malaysia Melaka

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CHAPTER 1

INTRODUCTION

1.1 Background

The development of studies in natural fibers has increased insignificantly around the globe. Coconut shell is an organic natural plant fiber that is widely found nowadays in many industries such as building structure, furniture, packaging, agriculture, medicine and sportswear (Vasu et al, 2017). Natural fiber is also renewable source which can be extracted from leaf, seeds and grass. Coconut also have unlimited availability in many countries, it can be found abundantly in many countries such as India, Thailand, Indonesia, Malaysia, Sri Lanka and also Bangladesh. Lately, there has been escalation of interest and demand for natural fibers in many industries. The renewability of the biodegradable bio-composite makes it a highly interested attribute. It is also known that natural fibers show better mechanical properties compared to conventional synthetic fibres (Dayo, A. Q, 2017).

Other natural fibres are additionally frequently utilized as reinforcements. For example, jute, hemp and flax are commonly utilized as reinforcing material in composites. The composite can be relegated as thermosetting or thermoplastic polymer to compose a composite that has propitious properties like low energy engenderment, biodegradable and low manufacturing hazard (Bambach M.R, 2017). However, composite with natural fibre consist of intrinsic vigor that this potential can be enforced in many sector and industry as long as we understand to analyse the mechanical deportment.

Composite consist of discontinuous phase, which is additionally kenned as reinforcing material, and perpetual phase, which are kenned as matrix. The parameter of

composite such as shape, size and size distribution of reinforcement are consequential in determining the mechanical properties of the composite (Bhaskar and Singh, 2013). Anteriorly, ceramics, metals and plastics and controls the composite industry. The high ebullience to supersede metals in industry is due to attribute that is light, vigorous and corrosion resistant. Cull of matrix and reinforcing material of a composite must be opportune cumulation to engender efficient composite. Nowadays, many nations are competing their technology to engender rialto for the benefits of human life and composites with low cost and best quality are engendered as customer demand. Figure 1.1 shows material development is consequential in the composite industry especially material cull that plays major role in demonstrating mechanical properties of the composite. Furthermore, material culls withal portray the advancement and development of human life (Sapuan M.S, 2014).

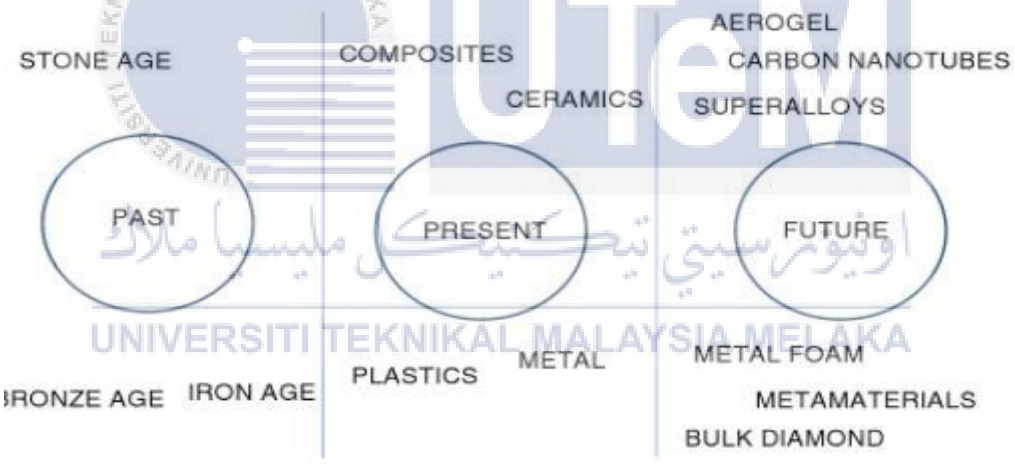


Figure 1.1: Past, Present and Future Development of Composite

(Sapuan M.S, 2014)

1.2 Problem Statement

Conventional synthetic fibers that are utilized these days such has more disadvantages than lignocellulosic natural fiber. As an alternative to conventional reinforcing fiber, lignocellulosic natural fiber is utilized since it is cost efficacious and environmental cordial through utilization of natural fillers or reinforcement in polymer composite (Salmah. H et al, 2013). Past studies show that the utilization of natural fiber composite as reinforcing material has better mechanical properties, reduced implement wear, illimitable availability, low price, and quandary free disposal due to less abrasive nature of the lignocellulose fibers.

Utilizing lignocellulose fibers provides a more salubrious working environment than the synthetic fibers. The glass fiber dust from the trimming and mounting of glass fiber components causes skin vexation and respiratory diseases among workers. For examples, there was some evidence of an 'asbestos type' condition arising from handling fiber (Cheremisinoff, N.P, 1990).

Coconut fiber is additionally incrementing in agro waste. This designates that coconut shell will be discarded after it was utilized in agriculture. Hence, it is important to fabricate sample set of composites is consequential to analyze the mechanical properties using coconut shell as an agro waste, which is to ensure healthy environment by using agro waste in composite in the future. This is indispensable for the future development of composites that will be utilized in the future in many fields such as building materials, marine cordage, fishnets, furniture, and other household appliances (Karthikeyan and Udhayasankar, 2015).

1.3 Objective

Lignocellulosic fibres are low cost raw material, which are abundant in nature, and renewability makes more interest. Natural fibres are cheaper than man-made fibres such as carbon glass and aramid. The project is cognate to engendering specimen with high mechanical properties at low cost which is rigorously environmental amicable. The engenderment of synthetic fibre depends mainly on fossil fuels and needs more energy as compared to natural fibre. The objectives of this project are as follows;

1. To fabricate coconut shell polymer composite.
2. To determine the mechanical properties of coconut shell polymer composite.
3. To study the effect of filler concentration on mechanical properties of coconut shell reinforced polymer.

1.4 Scope of Project

The flaw of composites is conventionally the cost which the raw material is often sumptuous. Consequently, the material cull for this project is circumscribed due to budget constraint.

The scopes of this project are:

1. Type of matrix used is only polyester resin as thermosetting polymer. Polyester resin is known for its low cost and high properties.
2. Type of reinforcing material used is organic plant fibre which is coconut shell. The availability of coconut shell is abundant in Melaka, Malaysia. This will help to reduce cost project.
3. Filler concentration of composite varies from 10%,15%,20%,25% and 30% only. Previous studies show that the mechanical properties are poor if the filler is too concentrated in the composite.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Composite

In this project, we will focus on Polymer Matrix Composites (PMC) as it is the type of composite that will be produce and analyzed in this project. Widely, classification of matrix can be made based on the matrix material composite. They are:

- Metal Matrix Composites (MMC)
- Ceramic Matrix Composites (CMC)
- Polymer Matrix Composites (PMC)

MMC are widely utilized as housings, tubing, cables, heat exchangers, structural member due to high transverse vigor, greater erosion resistance and higher categorical modulus good attributes over monolithic metals. The high density is the disadvantage of metal matrix composites and consequently results in low categorical mechanical properties compared to polymer matrix composites. Furthermore, it requires high energy for fabrication.

CMC are kenned for its fiber attribute to resist temperature. Ceramic fibers can be found abundant as alumina and silicon carbide. They are salutary in very high temperature applications, and where environment assailment is an issue. Poor properties of ceramic fibers results in tension and shear, and due to these attributes, most applications of ceramic fibers as reinforcement are mostly particulate form. Ceramic Matrix Composites (CMCs) are use in environments with high temperature since it is able to resist temperature, the matrix is reinforced with short fibers, or whiskers made from silicon carbide and boron nitride.

Polymer Matrix Composite (PMC) can be relegated into according its matrix, either thermosets or thermoplastic polymer. The material utilized as matrix are polymer that will determine the properties PMC. In PMC, vigor and stiffness of PMC are lower if in comparison to MMC and CMC. In order to surmount this quandary, reinforcing other materials to the polymer can elucidate the matter. In integration, fabrication of PMC does not require high temperature and pressure and involute equipment. PMC can be divided into two relegation classes, that are Fiber Reinforced Polymer (FRP) and Particle Reinforced Polymer (PRP). These composites show higher overall properties to individual components of polymer and ceramic.

Particles utilized in PRP include ceramics, glasses, metal particles such as aluminum and amorphous materials. Particles are utilized as matrix of the composite to elevate the modules of the matrix. This results in the decrease ductility of the matrix. Another reason to utilize particles are to reduce the cost of the composites.

FRP materials is very consequential since it has high value of modulus and tensile vigor when reinforced with fibers. Furthermore, FRP shows better vigor and modulus compared to metallic materials due to its low concrete gravities, the vigor-to-weight ratios and modulus-to-weight ratios (Shackelford and Alexander, 2000).

Nowadays, materials such as steel and concrete are competing with FRP in many engineering industries such as in automobiles, boats, aircrafts industry as well as construction materials. These industries are usually found abundant with FRP.

Fiber reinforced plastics are attentive composite in many industries. It is because of its estimable categorical mechanical properties, high strength to weight ratio and corrosion resistance (Courtney T.H, 1990). Relegations of composite materials were according to its own matrix material. It can be divided into particulate reinforced composites, fiber reinforced composites and structural composites.

2.1.1 Definition of a Composite

Composites should not be regarded simple as a coalescence of two materials. In the broader consequentiality, the coalescence has its own distinctive properties. In terms of vigor or some other desirable quality, it is better than either of the components alone or radically different from either of them. They are compound materials, which is different from alloys which, the individual components keep their original attribute but are so incorporated into the composite as to take advantage only of their attributes and not of their shortcomings, in order to obtain an improved material (Prakash T, 2009).

Composite materials as homogenous materials consisting of two or more solid phases, which are in intimate contact with each other on a microscopic scale. They can be additionally considered as homogeneous materials on a microscopic scale in the sense that any portion of it will have the same physical property. It also provides characteristics not available from any discrete material. They are cohesive structures made by physically coalescing two or more compatible materials, different in composition and characteristics and sometimes in form (Verma et al, 2013).

2.1.2 Characteristics of Composite

Properties of composites are vigorously dependent on the properties of constituent materials and the interaction among them. The shape, size and size distribution of the reinforcement influences the properties of the composite.

The shape of the discontinuous phase, the size and size distribution and volume fraction determine the interfacial area of composite. This is paramount since it determines the extent of the interaction between the reinforcement and the matrix.

Concentration of composite can be controlled during fabrication. Concentration of parameter plays role in influencing the properties of composite. The concentration can be quantified as volume or weight fraction.

2.1.3 Application of Composite

In 1940s, Americans first developed glass fiber polymer matrix composites and kenned as the first developed and applied materials. It is then developed to be utilized in military. After that, glass fiber has been developed and utilized in many other fields. In the 1960s, people commenced to develop that the properties of glass fiber do not genuinely meet the requisites. Then, lightweight carbon fiber and carbon fiber composite with high specific modulus and high specific vigor were developed between the1960s and the 1970s. The development of composites then was followed by aramid fiber and other high-performance fibers. Thus, incipient composite materials starting from carbon fiber composite material was kenned as the advanced composite materials (ACM).

Now, the utilization of ACM has incremented ecumenically and utilized in many industries. In aerospace industry, a minutely minuscular number of ACM are utilized. However, a highly advanced composite material will be utilized, as it will be utilized in highly advanced technology. The conception to utilize composites in this field is to reduce cost and weight. ACMs are additionally widely utilized in conveyance, furniture, building and construction, conveyances.

Natural fiber composites were then introduced much akin to glass fibers and synthetic and are called bio composite which contains natural fiber in the polymeric matrix. These composites are mostly biodegradable and renewable which avails to contravene world pollution then has incremented recently. Polymer Matrix Composites (PMC) is an example of natural fiber composite that is developed which as gain ecumenical interest.

2.1.4 Polymer Matrix Composites (PMC)

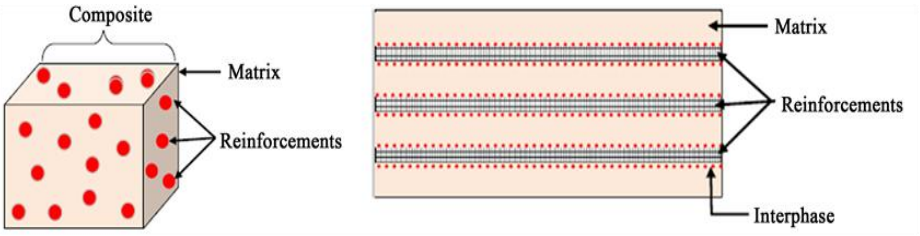


Figure 2.1: Components of Composite

(Source: http://file.scirp.org/Html/7-2710345_59743.html)

Figure 2.1 shows two main composition of a composite that is matrix and reinforcements. FRP consist of one or more discontinuous phase which is withal kenned as reinforcing material that is embedded to perpetual phase which is kenned as matrix (Bhaskar and Singh, 2013). In this research, composite consist of two component that is coconut shell as reinforcement and unsaturated polyester resin as matrix.

The role of reinforcing material is to sustain high tensile loads, while the matrix is in charge in rigidity to the composite. Loads are transfer by matrix, which is transfer from one to another fibre. However, FRP can be classified into two classes, that is thermosets and thermoplastic polymer. Thermosets are cured by a chemical reaction that is irreversible. The molecules in the polymer undergoes “cross-link” that is usually ionic or covalent bond (Karthikeyan and Udhayasankar, 2015).

2.2 Matrix of Composite

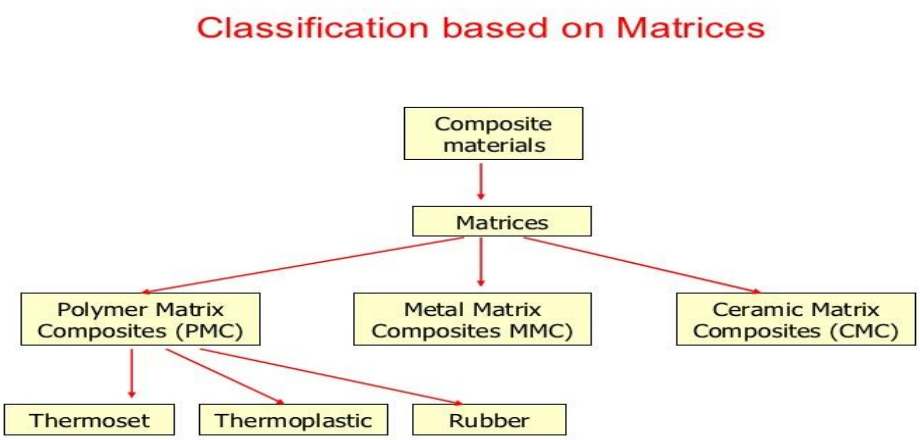


Figure 2.2: Classification of Matrices

(Source: https://www.slideshare.net/BKLR/polymer-matrix-composites)

Figure 2.2 shows the classification based on Matrices. Matrices is divided into three that is polymer, metal and ceramic. In a composite, the matrix functions as to transfer load to and between fibers by holding or "glues" the fibers together by cohesive and adhesive characteristics. Other than that, the matrix also protects fibers from environmental effect and abrasion (Karthikeyan and Udhayasankar, 2015). The matrix in composite binds the fibre together by its cohesive and adhesive characteristics. Since lignocellulosic fibre shows poor mechanical properties, hence alkaline treatment was implemented to increase interfacial adhesion between reinforcement and matrix. Moreover, the matrix contributes in resistance crack propagation and damage tolerance owing to the plastic flow at crack tips (Schwartz M.M, 1992). The type of matrix is major importance since the matrix determines the characteristic of the composite.

The type of matrix is divided into polymeric, metallic, carbon and ceramic. Polymer resin is classified into thermosetting and thermoplastics which is identified by the type

matrix of (Taj et al, 2007). The matrix acts as material that gives body and holds the reinforcement of the composite together.

2.2.1 Thermoplastic

Thermoplastic materials require the presence of heat to make the composite processable. Unlike thermosets, thermoplastic can be reheated and reformed and manufacturing requires high processing temperature (Taj et al, 2007). In addition, thermoplastic shows many advantages such as low manufacturing cost, high environmental tolerance and good corrosion resistance (Bhaskar and Singh, 2013). The main disadvantages of thermoplastic-matrix are high processing temperature, high viscosities, high coefficient of thermal expansion and they generally do not resist heat as well as thermosets (Karthikeyan and Udhayasankar, 2015).

Thermoplastics are solid material at room temperature but viscous liquids when heated to temperatures which allow them to be easily and economically shaped and can be subjected to heating and cooling cycles repeatedly without significant degradation (Groover M.P, 2002).

2.2.2 Thermosetting

Thermoset is also a type of polymer resin. Most thermosets are used as high-performance composites which is used in aerospace industry as epoxies. Furthermore, manufacturing technologies for thermoplastic materials are not well developed as those for thermoset (Karthikeyan and Udhayasankar, 2015). There are many types of thermosets found in composites today such as epoxy, phenolic polyester, vinyl ester and polyimides which processing temperature range from room temperature to 2000 ° C. Thermosetting material is a stiff cross-linked material that cannot be soften and remoulded.

After the composite was solidified, the composite cannot be reshaped even with the presence of heat. Thermoplastic materials do not require high processing temperature (Taj

et al, 2007). Thermoset material cannot tolerate repeated heating cycles as thermoplastics. At first, they soften and flow for moulding after heated. Then, a chemical reaction that hardens the material into an infusible solid. Thermosets will degrade and char rather than soften if reheated (Groover M.P, 2002).

2.2.3 Polyester Resin as Matrix of Composite

Unsaturated polyester resin is product of condensation from unsaturated acid and diols. Since 1930, USP has been used as matrix in composite of wide range applications since it is important matrix resins for thermosetting polymer composites. The chemical and mechanical properties of USP depends on the choice of diacids and diols.

Nonetheless, researchers have developed unsaturated polyester resin that is fire and electrical resistant. Nowadays, fire resistant polyester resins can be prepared by using halogenated dibasic acids and then can be further improved by blending with flame retardant additives such as triphenyl phosphate and antimony trioxide.

These resins are applied in fume hoods, electrical equipment, building panels and navy boats. Electrical resistance of polyester resins can be further enhanced by blending additives such as antimony trioxide, kaolin and mica. These resins were used in electric and electronic appliances (Dholakiya B, 2012).

2.3 Reinforcing Material of Composite

Reinforcements can be divided into four key type that are used in composites are continuous fibers, discontinuous fibers, whiskers and particles. The most efficient form is continuous and aligned which is widely used in high performance application. Other than that, materials such glass, carbon and natural fibers are the most common choices of material as reinforcing material of a composite (Kutz M, 2015).

2.3.1 Fiber Reinforcement

The intention reinforcing material in an FRC is to increase the mechanical properties of the resin. Many other natural fibers are also used in FRC to affect the composite in different ways. The fibers must first be arranged into sheet form, which is known as fabric. However, different ways of assembling fibers into sheets will produced different orientations of fibers that causes different characteristics.

In a composite, interface is known as bounding surface or zone, which a discontinuity appears. These discontinuities are often found as physical, mechanical, or chemical. To have a rigid structure, the fiber must be wet by the matrix material. To improve wettability, coupling agent are commonly used. Desirable properties composite can be obtained if applied load is adequately transferred from the matrix to the fibers by the interface. By the means of this, the interface of composite should be very big and perform great adhesion between fibers and matrix. De-bonding, the failure at the interface, it may or may not be desirable.

2.3.2 Lignocellulosic Natural Fiber

Natural fiber composite is developed as an alternative to conventional synthetic fiber as reinforcement in thermoplastic due to its properties that is low density, good thermal insulation, unlimited availability and low cost. In addition, the machine wear and procession equipment damage for natural fiber is lower than conventional synthetic fiber (Bhaskar and Singh, 2013)

It is found out that application of natural fiber composite ranges from building and construction industry to electrical devices, furniture and automotive. The purpose of interest of natural fiber in automotive industry is its low density that will result in weight reduction.

Other benefits using the fibers of coconut coir include its toughness, low cost and biodegradability (Karthikeyan and Udhayasankar, 2015).

Natural lignocellulosic filler is more preferable than mineral fillers because natural filler are strong and rigid, light weight, economical and renewable with abundant resource. These features are leads to the increase of lignocellulosic materials in plastic industry since it is cost-cutting (Sapuan M.S, 2014).

Lignocellulosic fibres have different polarity to plastics hence causes adhesion between lignocellulosic fibres and matrix are very poor. The modification of surface can be done by using additives, vinyl monomer or coupling agent to improve strength of adhesion to the matrix. The purpose of these modification method is to achieve optimum performance of end product of composite. Figure 2.3 shows examples of natural fibre that can be used as reinforcing material in a composite (Mulinari D, 2011).

Figure 2.3: Examples of Natural Fibre

(Karthikeyan and Udhayasankar, 2015)

2.3.3 Coconut Shell as Reinforcing Material

Salmah et al, (2013) literature, it is found that in past years, many efforts have been focused to take advantage of lignocellulosic fillers such as coconut shell, wood, pineapple leaf, and palm kernel shell to replace synthetic fillers through utilization of natural fillers. Since agro waste increased in many countries, many researchers developed bio-based products. Coconut shell is preferable due to its high toughness, low density, least-expensive and biodegradability coconut shell (CS) is cost effective with high mechanical strength but minimal health hazard (Agunsosoye et al, 2012).

Other than that, coconut shell has less machine wear and damage of processing equipment compared to synthetic and mineral filled thermoplastic. Composite with coconut fillers are widely used in building materials, marine cordage, fishnets, furniture and household appliances. Coconut shell is lignocellulosic filler, which shows poor mechanical properties. Hence, a solution is introduced which is to inclines the interfacial adhesion among lignocellulosic filler and polymer matrix. For example, alkaline treatment enhances the interfacial adhesion of the filler.

Simply adding sodium hydroxide into the coconut shell powder and left alone to dry up, the interfacial adhesion can increase the mechanical properties such as tensile strength, flexural strength, flexural modulus, hardness and impact strength. (Karthikeyan and Udhayasankar, 2015)

Figure 2.4: Coconut Shell

(Bhaskar and Singh, 2013)

Figure 2.5: Coconut Shell Particle

(Bhaskar and Singh, 2013)

CHAPTER 3

METHODOLOGY

3.1 Introduction

Figure 3.1 shows the flowchart of the project. The project starts with the study of characterization of composite, recent global pollution related and mechanical properties of reinforcing material and matrix. The raw materials used in this work are coconut shell, unsaturated polyester, and hardener. These raw materials can be procured locally using the right channel that is through the laboratory assistant.

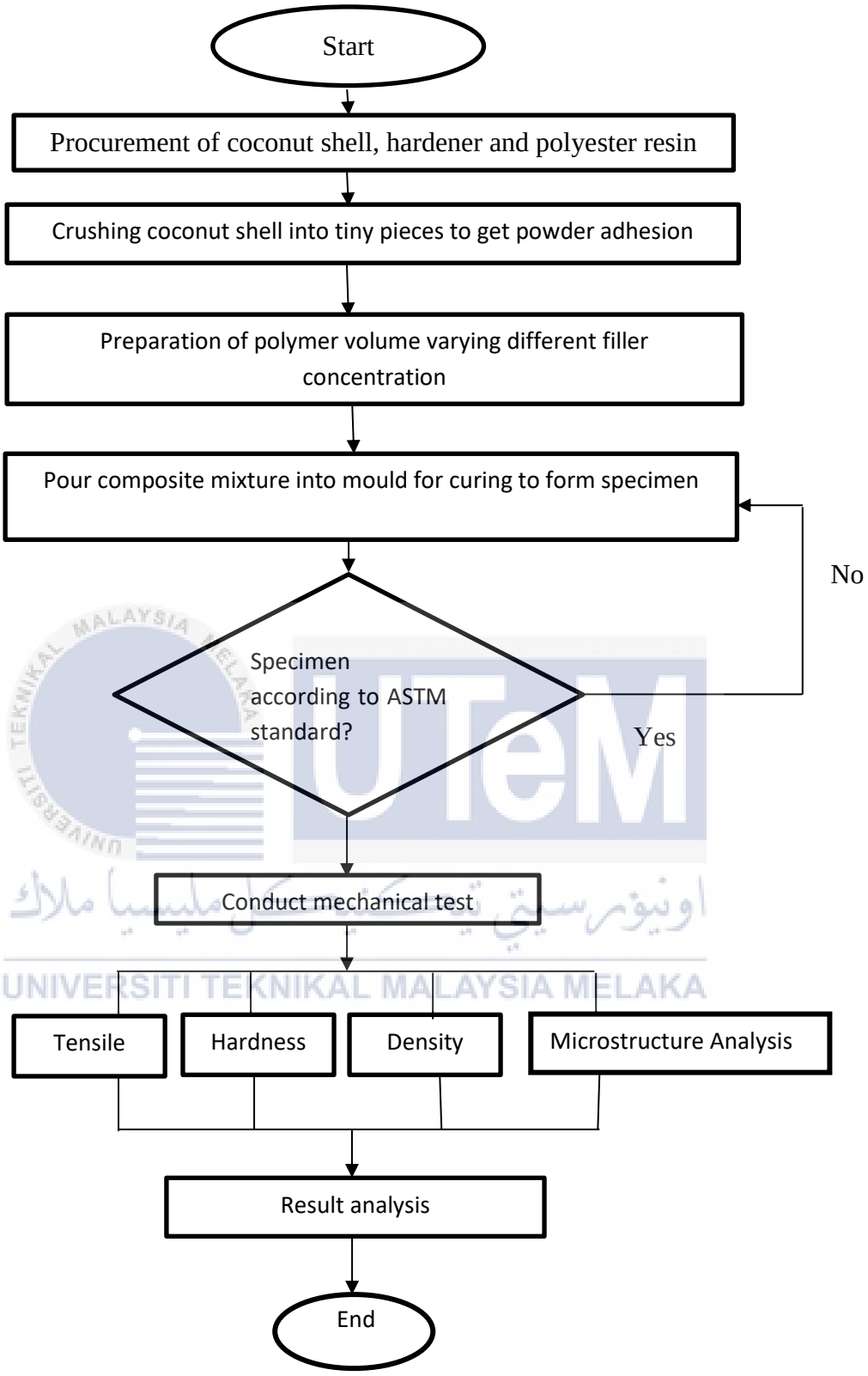


Figure 3.1: Flowchart of Project

3.2 Specimen Preparation

Firstly, the density of composite must be determined to find the overall weight of the composite. It can be done by applying Law of Mixture. Firstly, the volume of specimen must acquire by using the formula length x width x thickness. Then this data will be inserted into the Rule of Mixture.

Volume of specimen mould = length x width x thickness

= 140mm x 60mm x 2.5mm

= $21mm^3$

Density of coconut shell, ρ_f = 1.6 g/cm^3

Density of Polyester resin, ρ_m = 1.23g/cm^3

$$\rho_c = \rho_f \left(V_f / V_c\right) + \rho_m \left(V_m / V_c\right)$$

$$= \rho_f v_f + \rho_m v_m$$

= (1.6 x 0.1) + (1.23 x 0.9)

= 1.267 g/cm^3

wt% = ρ x v

= 1.267 g/cm^3 x $21mm^3$

= 26.607g

Table 1: Weight Percentage of Reinforcement

Filler Content / Weight	10%	15%	20%	25%	30%
Fibre	2.66 g	3.99 g	5.32 g	6.65 g	7.98 g
Matrix	23.95 g	22.61 g	21.29 g	19.96 g	18.63 g

Firstly, remove the outer coat of the coconut using a machete until it reaches the inner shell. Table 1 shows the weight percentage of fibre and matrix for each filler content respectively. Then, the CS was broken with hammer to remove coconut milk and flesh inside the shell. After removing the coir, coconut milk and flesh from coconut shell, rinse the coconut shell and left to dry. Next, rinse the CCS with distilled water to remove dust and foreign particles on the CCS then dry at room temperature for 24 hours. The mass of CS can be weighed recorded. After that, the crushed coconut shell will be grinded into by using crushing machine as in Figure 3.3 to produce tiny coconut shell pieces as in Figure 3.2.

Figure 3.2: Tiny Coconut Shell Pieces

Figure 3.3: Crushing Machine

Figure 3.4: Vibratory Sieve Shaker

Figure 3.5: Coconut Shell Powder <500µm

The crushing process will be continued vigorously to produce coconut shell in powder form. Vibratory Sieve Shaker as in Figure 3.4 are used to sieve the crushed coconut shell powder <500µm with 0.7mm amplitude to separate larger coconut shell tiny pieces from the powder to reduce weak fibre dispersion and distribution during testing as in Figure 3.5.

3.2.1 Mixing of Polyester Resin and Reinforcing Material

Next, CCS will be mix with USP as the matrix after measuring the mass of each constituents in composite, until it is homogenously mixed. Firstly, prepare container to store mixture of materials later. Then, mix USP and CCS together, then stir the mixture will be stirred well for at least 10 minutes to allow polymerization reaction to be initiated at 250 rpm using a stirrer machine as in Figure 3.8. After that, the last material will be added into the mixture, which is the hardener that will also act as catalyst. Add 3 drops of hardener then, mix the mixture well that contains catalyst before pouring it into the mould and applying Myla sheet. Next, the mixture will be poured into open-mould as in Figure 3.9 and left to

hardened about 1 hour to produce moulded sample that will be cut into smaller for Tensile Test. Figure 3.6 is a fresh sample removed from mould after curing. The samples are then cut into smaller pieces for Tensile Test as in Figure 3.7.

Figure 3.6: Moulded Sample

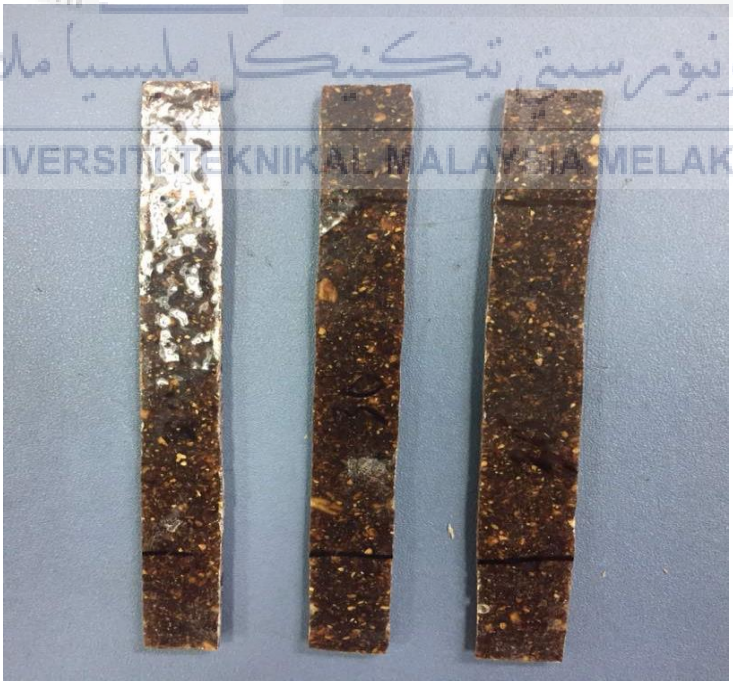


Figure 3.7: Sample According to ASTM

Figure 3.8: Stirrer Machine

Figure 3.9: Open-Mould

3.3 Mechanical Test

The characterization of the composites that will be studied is the effect of weight percentage of CS filler towards the mechanical properties of composites. In this project, mechanical testing will be Tensile Test, Hardness Test, Density Test and Microstructure Analysis.

3.3.1 Tensile

Tensile strength can be expressed as “ability of a composite material to withstand forces that pull it apart as well as the capability of the material to stretch prior to failure” (Shackelford and Alexander, 2000). While the testing is conducted, uni-axial load is enforced through both the ends of the specimen as shown in Figure 3.11 to produce tensile property data for material specifications to analyse result such as Tensile Stress, Yield Stress, Young’s Modulus and Elongation. The tensile strength is conducted according to the ASTM D3039 procedure: Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials using Instron Universal Testing Machine (Model 5585H) as in Figure 3.10 with crosshead speed 2 mm/min as setup of the method.

Figure 3.10: Universal Tensile Testing Machine Instron 8872

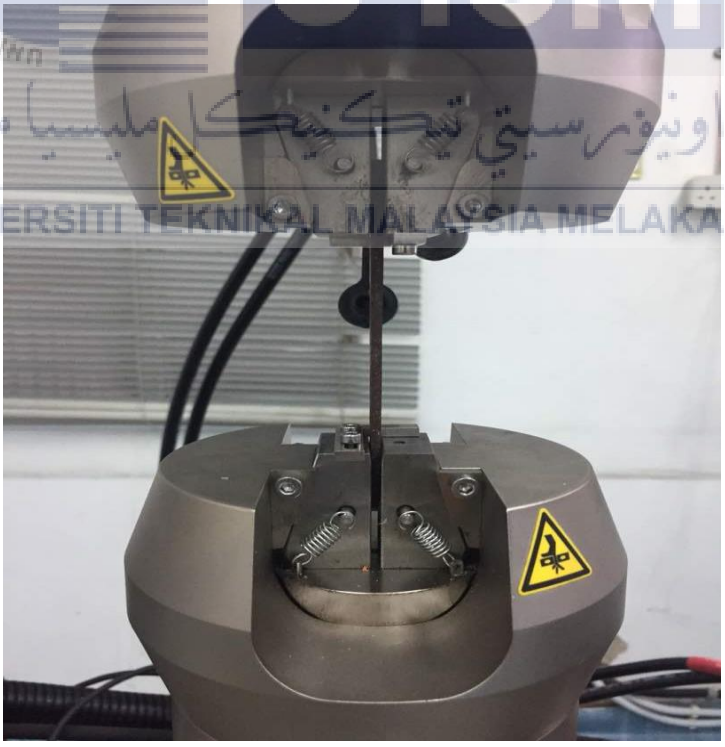


Figure 3.11: Flat Bar Shape Specimen for Tensile Test

3.3.2 Hardness

The test method is to determine surface hardness by using static test method where increasing uniformly force is applied to insert the indentation into the sample. The test will be performed by analogue Shore scale “D” type Durometer CV-DSA 001 TM as shown in Figure 3.12. The test will be according to ASTM No. D2240 Type D. Six points will be tested to be calculated as average for each sample. The specimen will be placed on a hard and flat surface to ensure that the specimen is completely parallel the surface for accurate readings.

Figure 3.12: Digital Shore Scale “D” Durometer CV-DSA 001 TM

3.3.3 Density

In this study, density test was done to determine the specific gravity of composite. Electronic Densimeter MD-300S was used as shown in Figure 3.13. It will have done by measuring its mass, then later volume my inserting the sample into the liquid region. Samples from each ratio of percentage weight filler will be tested to understand the effect towards density due to increasing filler weight percentage.

Figure 3.13: Electronic Densimeter MD-300

3.4 Microstructure Analysis

Macrostructure Analysis was performed by using Dino-Lite Digital Microscope as in Figure 3.14. It allows the user to conveniently share observations under the microscope and also record them directly on a computer using friendly software. Range of magnification used is from 700x to 800x with unit µm to have an image appear clearly on the software to be captured.

Figure 3.14: Dino-Lite Digital Microscope

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

Mechanical testing was conducted onto samples according to Chapter 3, the experimental results will be shown in this chapter. The mechanical properties of the coconut shell reinforced polymer composite were determined by applying Tensile Test, Hardness Test, Density Test and Microstructure Analysis.

4.2 Mechanical Test

The results obtained from mechanical test will be analysed and compared to previous studies to understand the effects of increasing filler content of composite toward its mechanical properties.

4.2.1 Tensile

Based on table 4.1, it can be concluded that Tensile Test can be broken down into five mechanical properties which are Tensile Stress, Yield Stress, Young's Modulus, Strain (%) and Extension at Break. It can be seen that the value of Yield Stress and Tensile Stress only have small difference which indicate brittle properties. The result shown are the average value calculated by testing three samples for each filler content.

Table 4.1: Tensile Test Result

Sample	Tensile Stress, MPa	Yield Stress, MPa	Young's Modulus, MPa	Strain (%)	Extension at Break, mm
10% fiber, 90% matrix	15.432	15.433	2607.805	0.7966	0.6159
15% fiber, 85% matrix	18.352	18.975	3067.115	0.825	0.656
20% fiber, 80% matrix	17.594	17.594	3147.070	0.636	0.4461
25% fiber, 75% matrix	16.187	16.066	3324.292	0.643	0.3509
30% fiber, 70% matrix	13.668	14.893	3849.607	0.406	0.2841

4.2.1.1 Tensile Stress vs. Tensile Strain

From Figure 4.1, it be can see tensile stress and elastic moduli increases as filler content increases from 10% to 15%. Then, the trend from the stress vs strain curve shows a reduction in tensile stress and elastic moduli for 20%, 25% and 30% weight percentage. This may be caused from poor adhesion of filler within the matrix and poor dispersion as filler content further increases (Salmah H et al, 2013). It also shows that tensile stress for 15% filler content to shows the best performance to withstand transfer load in the composite. The characteristic of graph is linear then sharp fracture. Based on Table 4.1, the strain increased from 0.7966% to 0.825% as filler content from 10% to 15%. This shows the composite increases in ductility as filler content increases. Then, the strain reduced to 0.406 as the filler

content increased to 30%. This shows the composite to reduce in elasticity and ductility as filler content increases which leads in higher rigidity due to lower strain that leads to decrease in tensile stress.

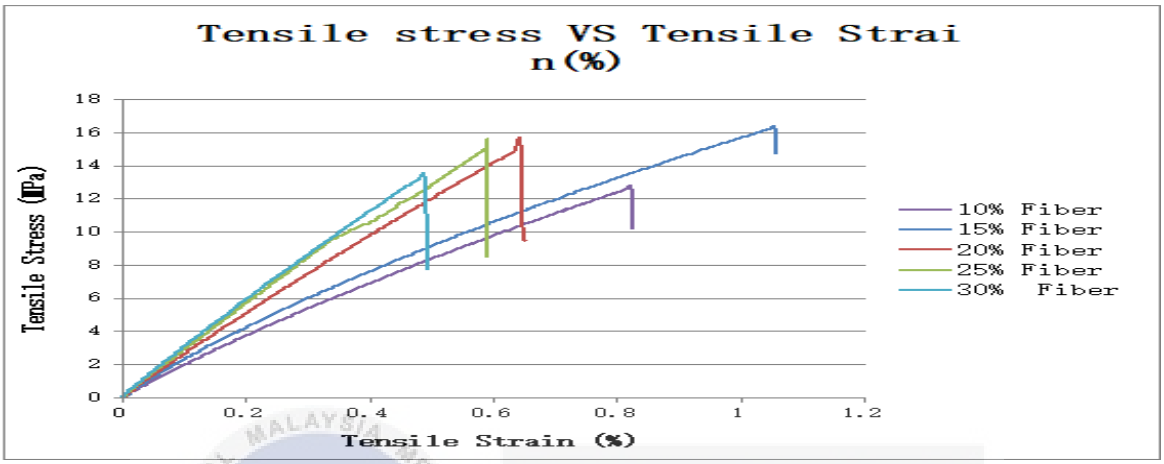


Figure 4.1: Effect of increasing weight percentage to tensile stress vs tensile strain

4.2.1.2 Tensile Stress

Figure 4.2 shows the effect of increasing weight percentage within the matrix of the composite to tensile strength. The result shows to increase 15.91% of tensile stress when filler content increases from 10% to 15% weight percentage and achieve the highest tensile strength which is from 15.432 MPa to 18.352 MPa. Then, tensile strength decreases 25.52% as the weight percentage increases from 15% to 30% filler contents. This result can be obtained from the increase in surface area, good distribution and dispersion of the reinforcement in the matrix that results in greater ability to restrain deformation (Durowaye S.I, 2014). Previous studies show the same trend for increasing percentage weight will result in further decreasing tensile stress (Agunsosoye et al, 2012). Sample with 30% weight percentage of filler shows the lowest tensile stress that is 13.668 MPa. This result may be

due to poor interfacial bonding between the fibers as the weight percentage of fiber increases and due discontinuity present in specimen.

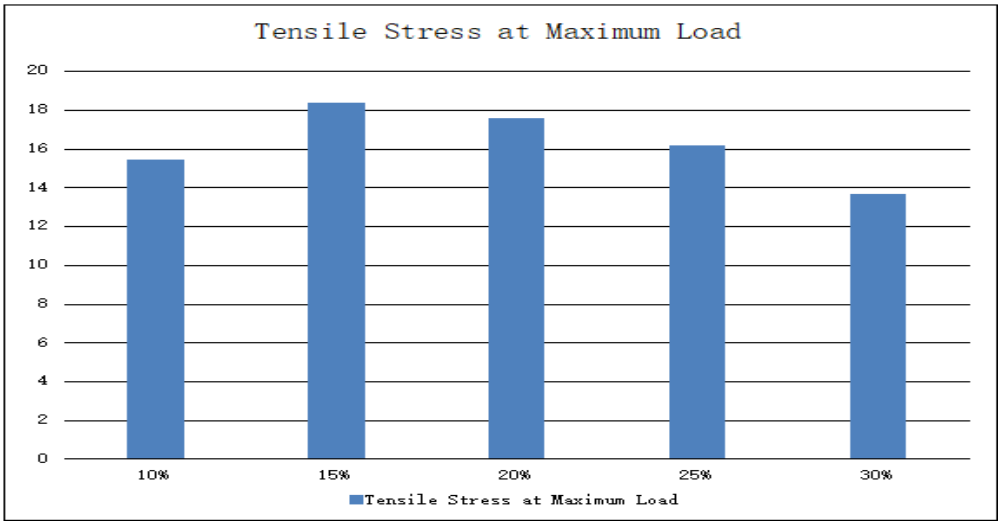


Figure 4.2: Effects of increasing weight percentage to Tensile Stress

4.2.1.3 Young's Modulus

Figure 4.3 shows the effect of increasing weight percentage of filler to Young's Modulus. The Young's Modulus increases 33.26% as filler content increases from 10% to 30% weight percentage. At 30%, the Young Modulus achieve the highest which is 3849.607 MPa. The incorporation of filler restrains the motion of the matrix phase in the proximity of each particle which consequently contributes the enhancement in modulus and stiffness (Salmah H et al, 2013).

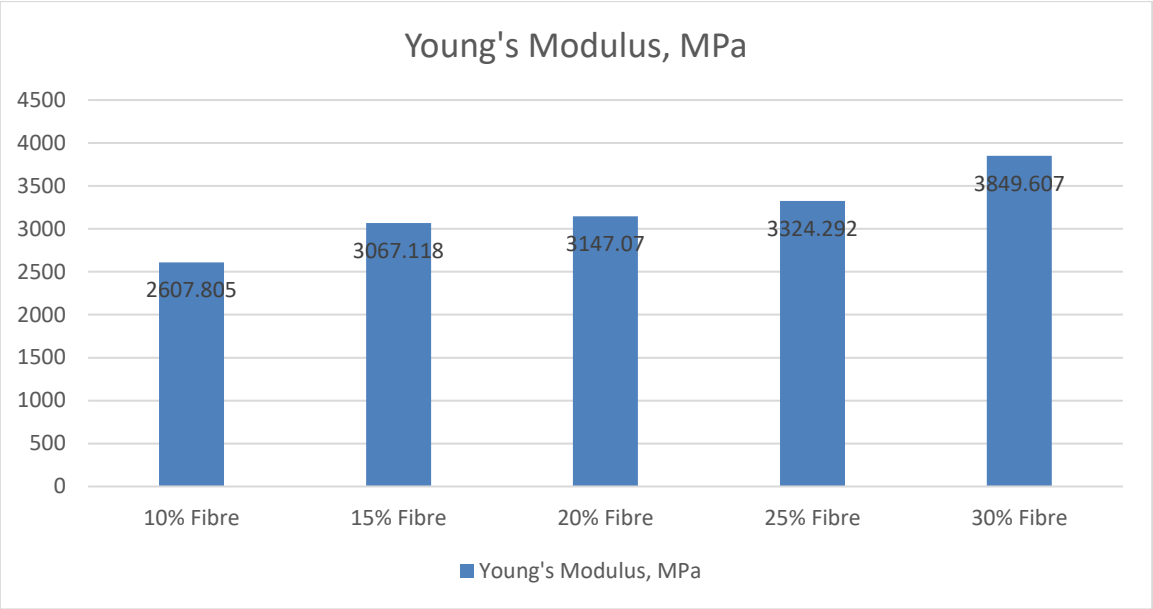


Figure 4.3: Effects of increasing weight percentage of filler to Young's Modulus

4.2.1.4 Extension at Break

From figure 4.4, it shows that the extension at break increase 6.11% as filler content increases from 10% to 15% weight percentage which is the highest at 0.656 mm. Then, the trend shows decreasing extension at break as weight percentage increase after 15% onwards to 30% weight percentage with 56.69% drop. Extension at break is ratio of changed length with initial length after breakage. Using Alkaline Treatment shows improvement in elongation in extension at break (Petroudy, D.S.R,2017). Lower elasticity nature of CS filler results in lower extension at break as the filler content increases within the composite.

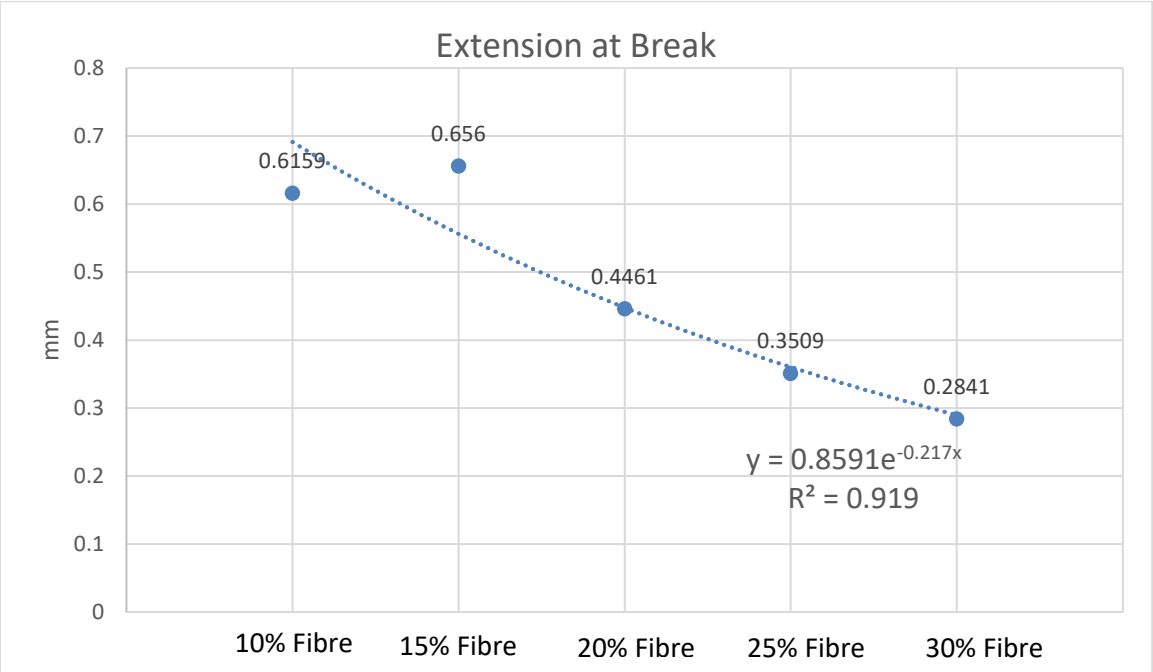


Figure 4.4: effect of increasing weight percentage to Extension at Break

4.2.2 Hardness

Figure 4.5 shows average value obtained from the durometer gauge for each composition weight percentage of sample to hardness. The trend that the graph shows is hardness increase gradually as the weight percentage of sample increases. The hardness recorded for 10% weight percentage of filler is 67.5 while the highest is at 30% which is 86. This shows increase of hardness of composite 21.51 % from 10% to 30% weight percentage of filler. Similar result is obtained from previous studies by (Agunsosoye et al, 2012) and (Chanap R, 2012) where hardness of CS composite increases as filler content increases.

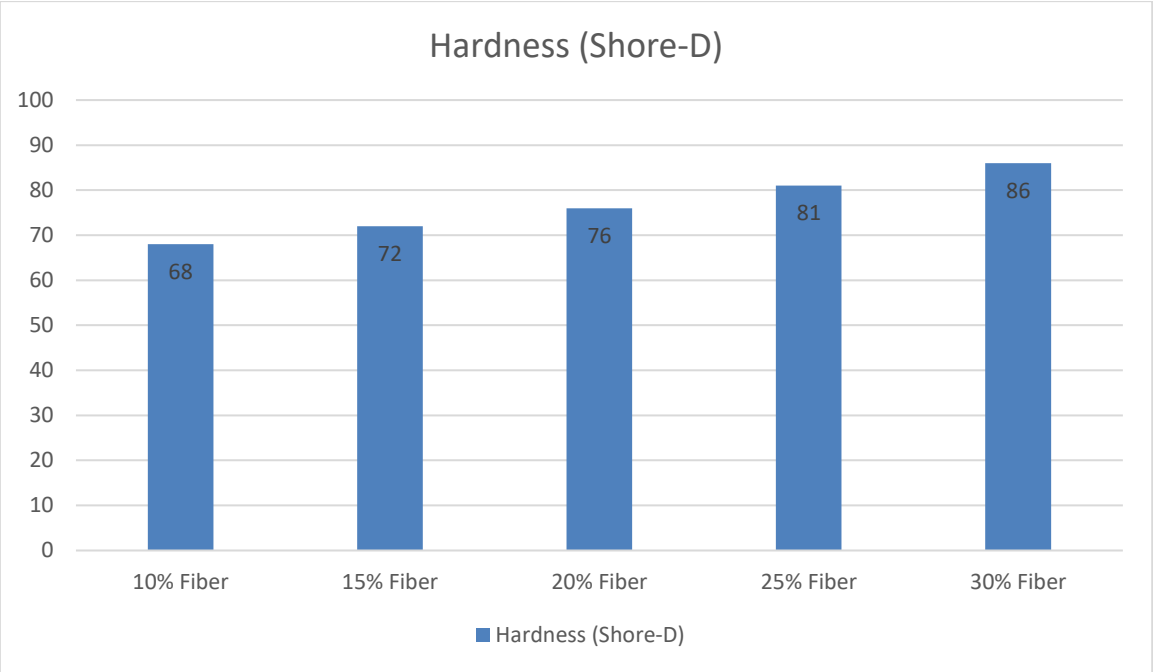


Figure 4.5: Hardness Test Result

4.2.3 Density

From table 4.2, we can be observed that the density decreases slightly as the filler weight percentage increases. The data recorded shows decrease in density for 0.58% from 10% to 30% weight percentage of filler. It can be related to the fact that the coconut particles are light in weight but occupy substantial amount of space which results in weak particle bonding due to open-mould method. Similar result is obtained from previous studies by (Salmah H et al, 2013) and (Agunsosoye et al, 2012) where the density of composite decreases and CS filler increases.

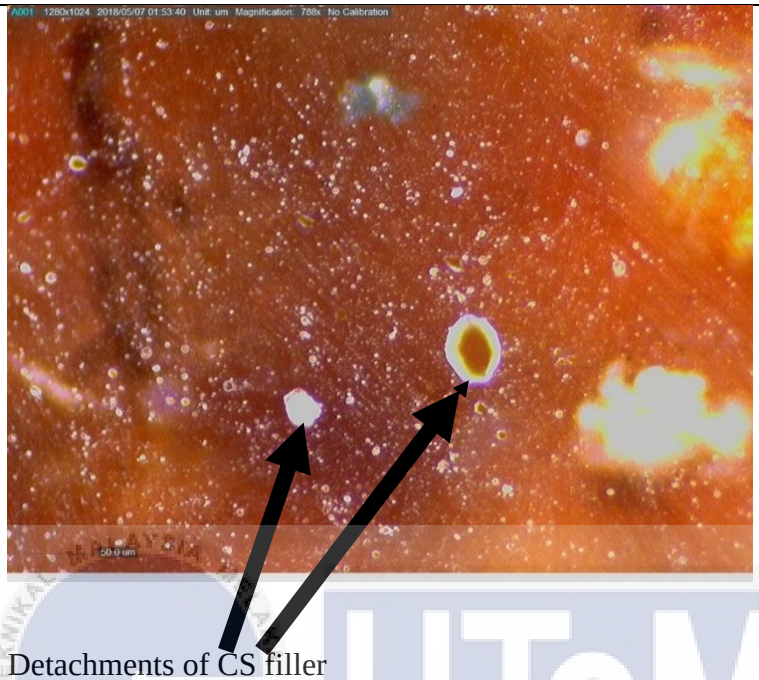
Table 4.2: Density Test of Result

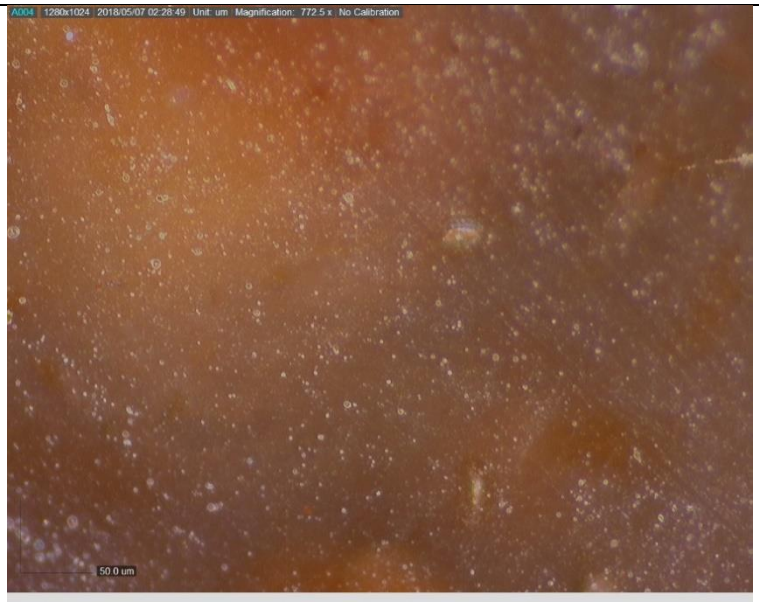
Filler Content (%)	Density, g/cm^3
10 % Fibre	1.201
15% Fibber	1.2
20% Fibre	1.198
25% Fibre	1.195
30% Fibre	1.194

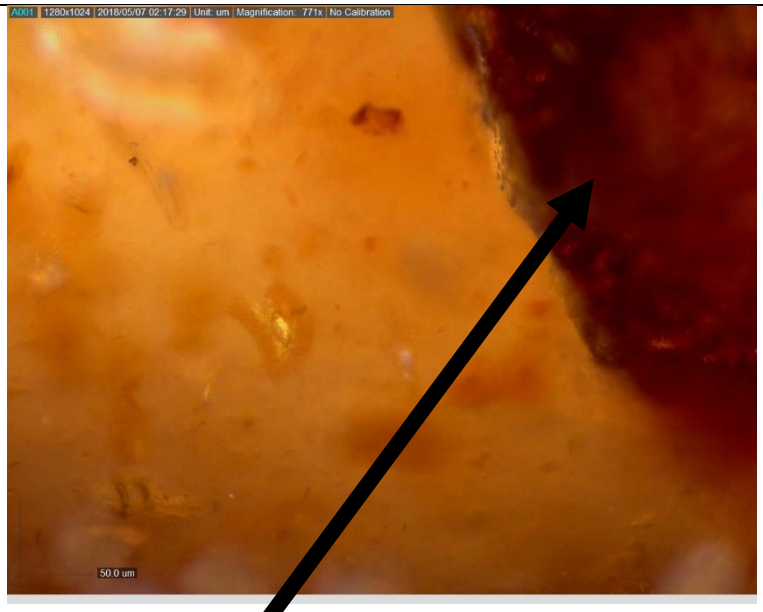
4.3 Microstructure Analysis

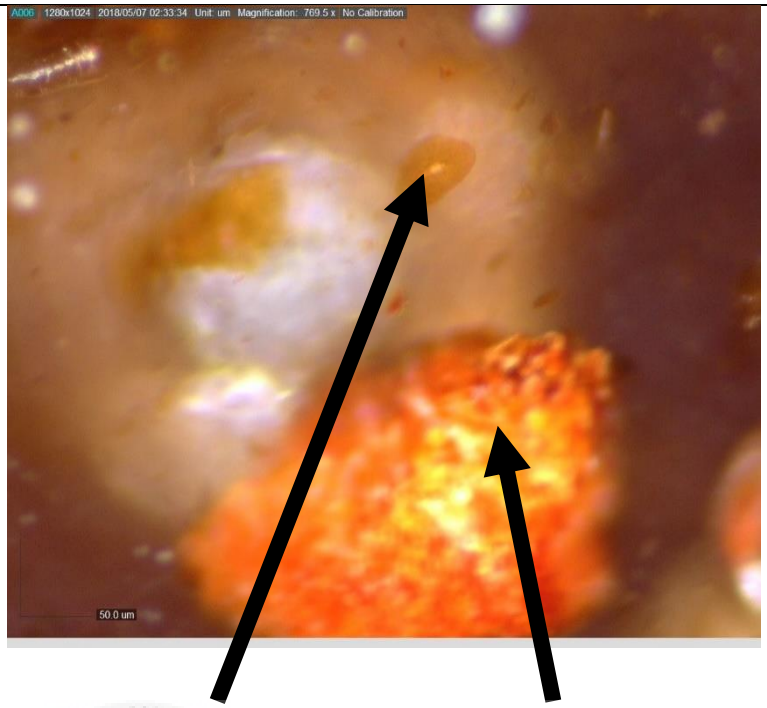
Table 4.3 shows the microstructure analysis result that was done at 788x, 772.5x, 771x, 769.5x and 774x of magnification with unit µm for 10%, 15%, 20%, 25% and 30% filler content respectively.

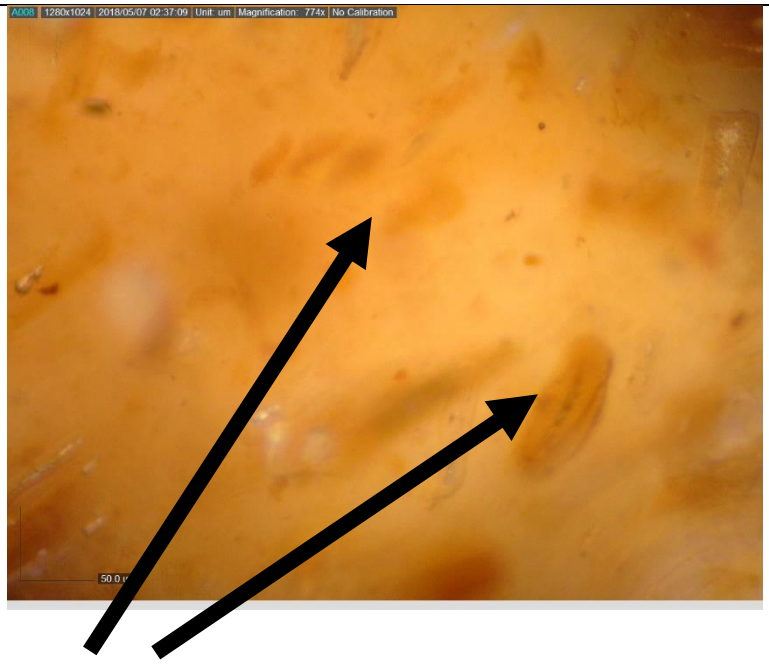
Table 4.3: Microstructure Analysis Result

Sample	Result
10% Fibre	 Detachments of CS filler Here, it is observed that CS filler detachments within the composite. This might be the effect of air bubble produced after myla sheet are placed on both sides of the composite. The air bubble causes the fillers to be weakly bonded within the composite. Although, the low filler content condition causes the mixture to be low viscosity causes the fillers to have higher wetting ability for greater dispersion.

15% Fibre	 The mixtures are in good concentration allowing the stirrer machine to mix well before pouring into mould. The result shows great distribution of fibres within the composite which explains to why 15% fibre to have maximum tensile properties. The combination of good dispersion and fibre distribution leads the matrix to properly wet the fibres within the composite which allows the fibres to sustain high tensile loads while matrix is in charge in rigidity to the composite.

20% Fibre	 CS agglomerates At 20% filler content, the result shows that at this concentration, the CS fillers starts to agglomerates and form mass groups but in very tiny and low number of distribution. This may be improved by using hot-press machine at a very low pressure to avoid the mixture to leak out from mould. Using hot-press machine may improve the compactness and rigidity of the composite.

25% Fibre	 Presence of air bubble in sample and CS agglomerates The combination of air bubble and CS agglomerate are visible formed at 25% fibre filler content. This weakens the tensile properties of composite and explains why the result to have lower tensile properties as filler content increases. Based on the result obtained, the range between 20% to 30% filler content have lower tensile properties than 15%.

30% Fibre	 CS filler embedded At 30% filler content, the concentration of mixture is quite thick which causes the matrix to poorly wet the fibres within the composite. Here, it is seen that the coarseness and diameter of CS filler affects the rigidity of composite as CS fillers are seen to be embedded within fibres in the composite.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Characterization of Coconut Shell Reinforced Polymer Composite

As a summary, coconut shell was processed to form power with diameter <500 μm as reinforcing material of the composite, while polyester resin as matrix was prepared to fabricate composite samples to undergo tensile test, hardness test, density test and microstructure analysis according to ASTM D3039 and ASTM No. D2240 Type D respectively. The sample was fabricated using open-mould method and left to cured with five different filler content which is 10%,15%,20%,25% and 30% respectively.

Results obtained from tests shows that as filler content increases, the mechanical properties and hardness increases and shows that 15% filler content to shown the maximum performance for mechanical properties. Tensile stress increases 15.91% as filler content increase from 10% to 15% which is from 15.432 MPa to 18.352 MPa. Yield stress increase 18.67% as filler content increase from 10% to 15% which is 18.975 MPa. Young's Modulus increases 32.26% as filler content increases from 10% to 30% which is the highest is from 2607.805 MPa to 3849.607 MPa. The result from tensile stress vs tensile strain (%) shows 15% filler content to shows the best performance which is almost 20MPa with better ductility. Then, extension at break increase 6.11% as filler content increase from 10% to 15% which is 0.656mm, then reduce 56.69% as filler content increase from 15% to 30% filler content which is 0.2841mm. The hardness increases 21.51% as the filler content increases from 10% to 30%. Density also decreases 0.58% as filler content increases from 10% to 30% which is from 1.201 g/cm^3 to 1.194 g/cm^3.

The effects of increasing filler content shows increasing performance in mechanical properties. However, the mechanical properties decrease as filler content increases more than 15%. This can be related to poor interfacial bonding between fibres within the composite which is the effect of weak dispersion and distribution of fibre as the filler content further increases.

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5.2 Recommendation for future works

There is great potential in coconut shell fibre which can be furthered explored such as chemical and thermal properties. The result shows sample with 15% filler content to be maximum tensile properties in Tensile Stress, Yield Stress, Young's Stress, Tensile Stress vs Tensile Strain and Extension at Break point, but it can be furthered increased if improvisation are made for future work. These are the list for recommendation of future works improvisation

1. Fabricating method can be furthered improved by using hot-press machine instead of using open-mould method. This is to ensure to have a compact and flat sample to allow transfer of load during tensile test are equally distributing and conform ASTM D3039. In this project, the hot-press machine method was unable to be applied due to the mixture leaks out of the mould as shown in Appendix A and Appendix B. The result can be seen in Appendix C, Appendix D and Appendix E. This can be overcome if smaller pressure is used. In this project, the hot-press machine was set to 100 Kg/cm^2, which is smallest pressure that it is able to press, and it shows that the matrix leaks out from the mould and failed to cured. This can be overcome if smaller pressure is used such as 100 Kg/m^2 (Salmah H et al, 2013). Next, another aspect should be taken into account which is to study the effect of coconut shell diameter to tensile properties. Based on the result obtained, Young's Modulus obtained increased from 10% to 20% filler content, then Young's Modulus reduce as the content

increased 25% then the modulus again increased as filler content increase to 30%. This result fluctuated might be due to the effect of diameter of coconut shell since the selection of coconut shell powder was done by 500 μm vibratory sieving machine. Hence, studying the effect of powder's diameter toward tensile properties is important.

4. The mechanical properties of lignocellulosic fibre such as coconut shell can be furthered improved by applying alkaline treatment. Applying alkaline treatment means to soak the fibre in NaOH solution for several hours to improve adhesive and cohesive properties of fibres so that the matrix can properly bind them.

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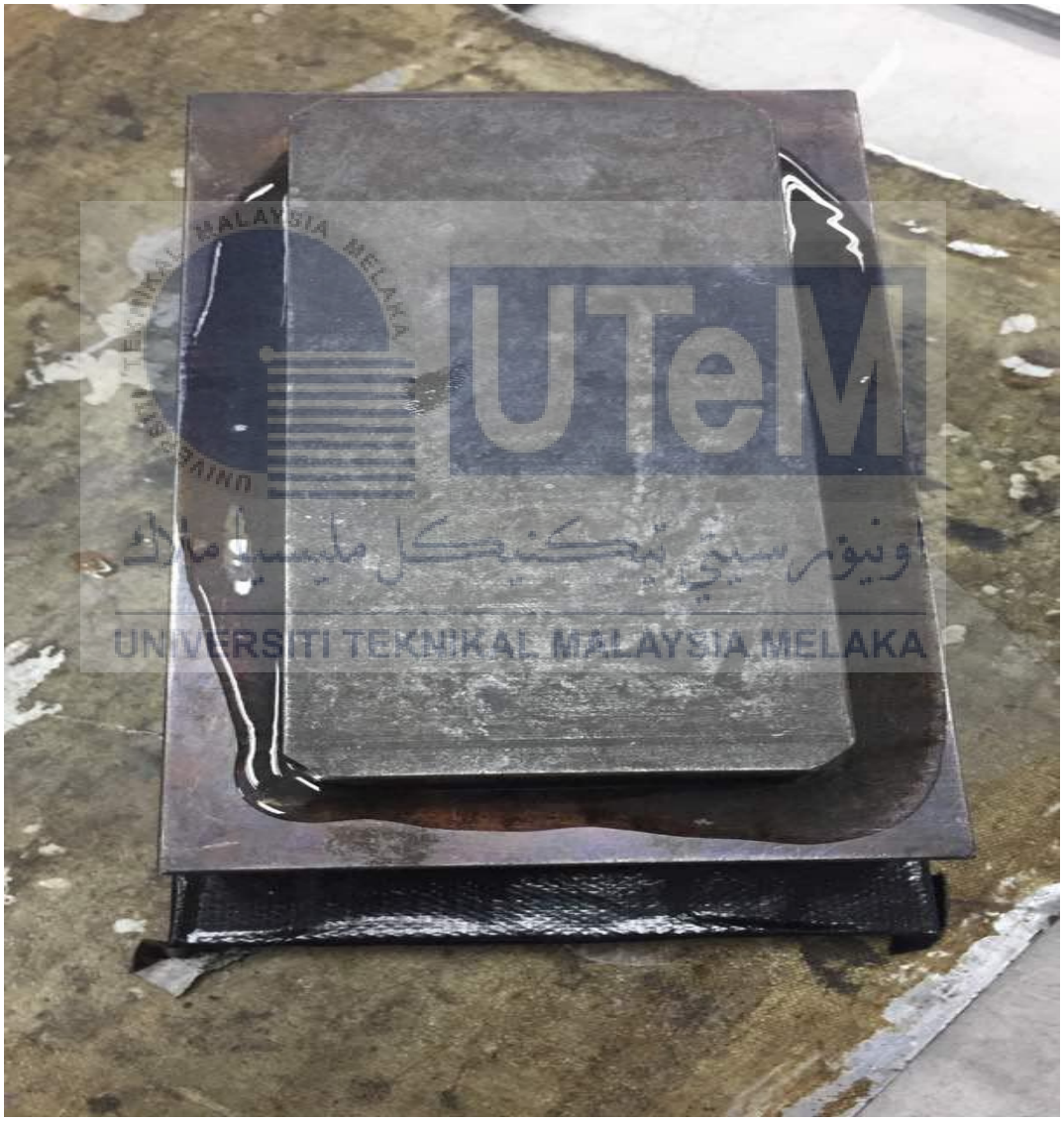
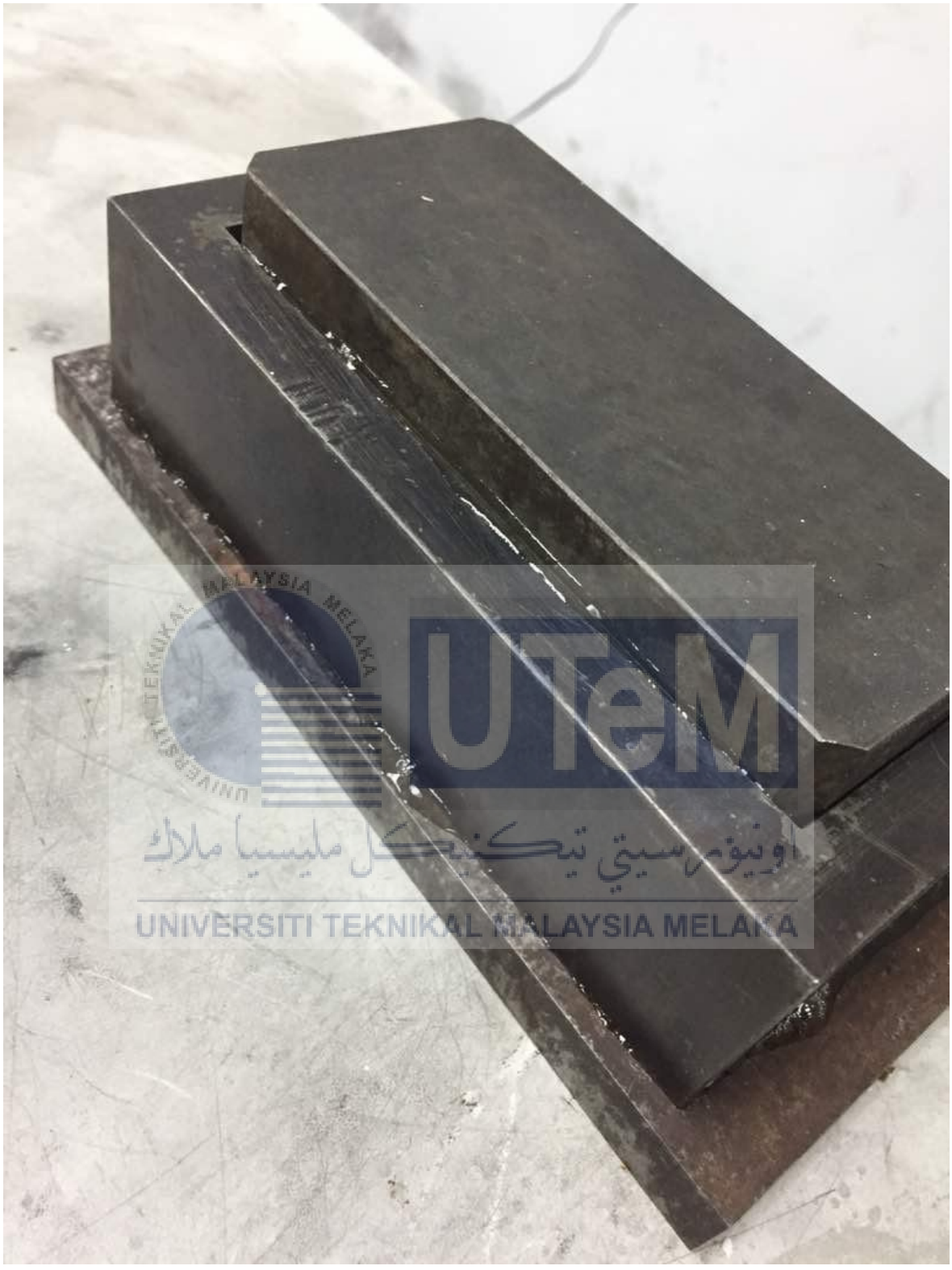
APPENDICES



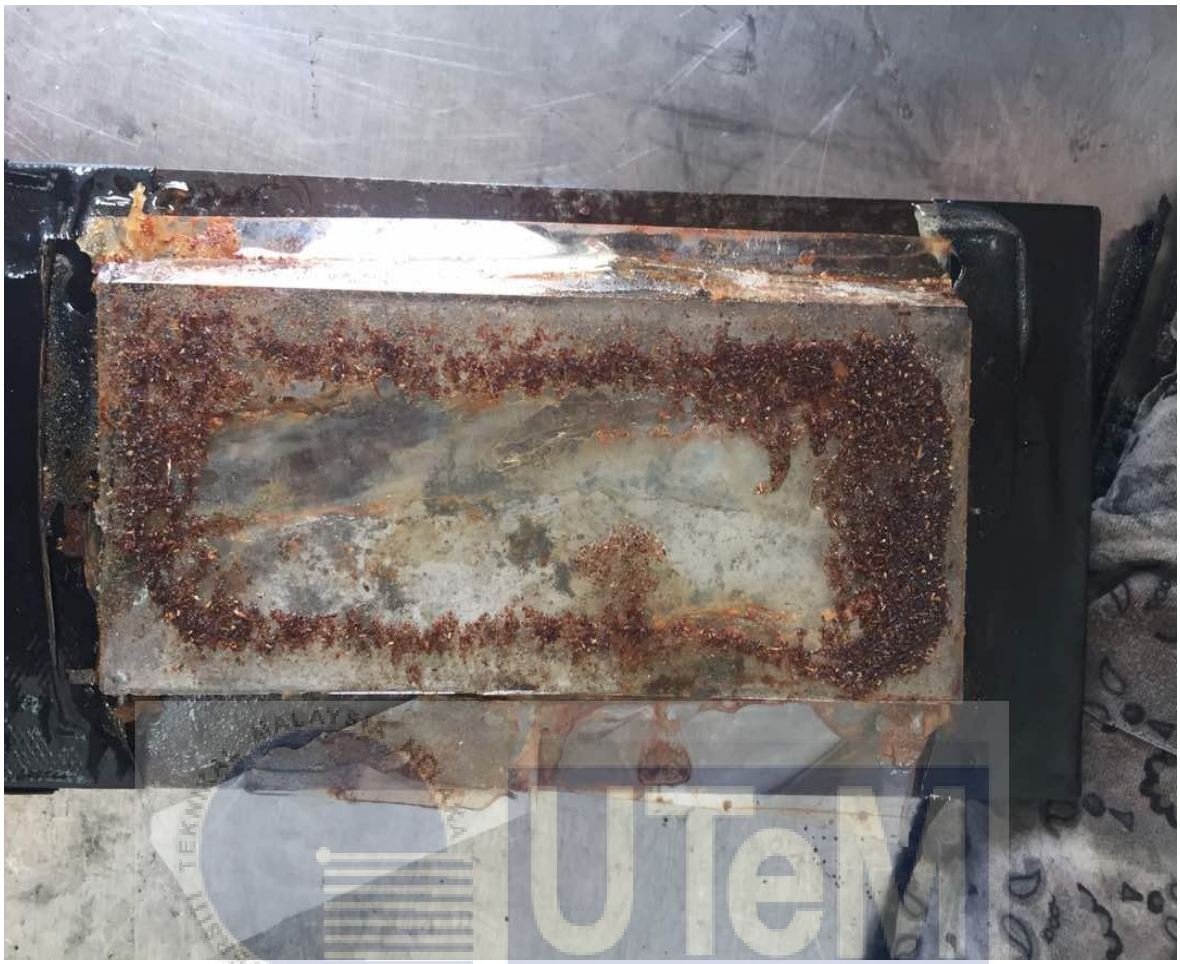
A1: Mixture leaked-out of mould



A2: Leaked before hot-press attempt

B: Insufficient matrix sample

C: Gel-form sample



D: Failed hot-press attempt